Technology campuses and cities

A study on the relation between innovation and the built environment at the urban area level

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Dr.ir. W.A. van Winden, Hogeschool van Amsterdam

To my family, whose geographical distance made our relationship stronger.
Love is the exception to the first law of geography.

Preface

Innovation has become one of the most important and overused words in today's knowledge-based societies. Twelve years ago, when I obtained the title of Architect in Colombia, this word meant nothing special to me compared to creativity, which was the engine of my starting career as a designer. Innovation began to take shape in mind when I changed the context where I used to live and work. In 2008, I started living in Delft, a city in a country that has adopted a knowledge-based system to frame their science, technology and innovation policies. Most importantly, I started studying in a prestigious university of technology where innovation is a process at the core of its mission: educating and advancing research in technology fields. Today, I can relate innovation to creativity through the processes of knowledge creation, diffusion and its further application to develop new and improved technologies because these processes involve people and their ideas. Although there is a clear link between these two terms, innovation has gained more attention than creativity in some socio-economic contexts.

Back then I would not have been able to articulate these thoughts because the context had unconsciously introduced the word innovation. It was only until I was conducting my MSc thesis research in the former Real Estate & Housing department at TU Delft when the word innovation made an explicit link with my career. While learning how to improve the management of university campuses, I became aware of the contemporary context in which these built environments have developed and how innovation has become a central aspect of this context. My view of the built environment expanded beyond excelling creativity to satisfy its end-users towards exploring ways to add value to them. Innovation became then, a way to add value to organisational performance through the built environment. The newly acquired knowledge in real estate management and urban area development thought me that stimulating innovation was a goal pursued not only by universities but also governments and other organisations that are driven by technology and that the built environment has the potential to support such goal. Campuses became interesting subjects to explore the role of the built environment stimulating innovation for two reasons. First, innovation is a buzzword promoting the development of campuses, which often involve many stakeholders and their different perspectives on innovation. Second, campuses are the most popular archetypes to accommodate technology-based research activities leading to innovation in cities and regions of industrialised countries. I called this type of built environment 'Technology campuses'.

As a person who has been studying and working in campuses for twelve years, I asked myself: How do these built environments stimulate innovation? Why do people decide to develop campuses to accommodate research instead of other built environments? How can we explain the link between innovation and the built environment in technology campuses? I knew this relationship would not be easy to explain because it is an assumed relationship. However, this is not just my assumption. Organisations spend resources developing built environments with the expectation to benefit from it and there is an entire research field −called corporate real estate management that investigates this assumption. In the case of developing campuses to stimulating innovation, the costs are more evident than the potential benefits and that is the reason their developments are often questionable. The fact that organisations spend resources replicating a model to accommodate these activities in very different contexts and for different organisations motivated me even more to clarify such relationship.

This thesis examines the development of technology campuses with the aim to gain and provide an understanding of the role of the built environment in stimulating innovation. The research has been conducted to develop more knowledge about the relationship between the built environment and innovation at the area level, which characterises the scale of technology campuses as built environments. This knowledge is targeted to decision-makers influencing the planning, design, and management of technology campuses and similar built environments, and for whom stimulating innovation is a strategic goal. However, the rich descriptions in this thesis can also be interesting for researchers on the built environment, architects, urban designers and those professionals interested in knowledge-based urban development.

I shall admit that clarifying the relationship between innovation and the built environment was not only exciting but also challenging. First, it was a challenge to maintain the physicality of this relationship because the discussion about innovation in the contemporary academic landscape focuses on economic development and its link with the built environment has received little explicit attention. Second, it was hard to stay focused on the given relationship because of the broad scope of the research area and the many links innovation has with other interesting topics that called my attention in this journey. In my attempt to connect theoretical concepts and define technology campuses from its built environment dimension, I learned about evolutionary economic geography, history of technology, knowledge-based development, among other interesting fields. I enjoyed exploring the many alleys I took in my journey even when some of them deviated me from the main path because there was always a knowledge gain and a route to come back to see the relationship from a different perspective. Last but not least, the more I gained knowledge about the relationship at stake, the more I had to avoid focusing on demonstrating the impact of the built environment on innovation as expected in my grounding field. The knowledge I developed during these five years strengthened my position as a researcher in real estate management that delivering understanding is as important as delivering measurable information. Although this thesis delivers both, I devoted my energy to clarify the relationship between innovation and the built environment at a scale level that has been hardly explored before.

In the almost five years that took me developing this knowledge and writing this thesis, I witnessed few developments in the context of the topic investigated that kept me motivated. It was amusing –if not overwhelming- to keep up with the attention given to innovation in the literature and the news. It was already common to read about the development of technology campuses in newspapers and magazines. I must admit that talking to people involved in the development of campuses was the most valuable source of inspiration. I gained a lot of insights from interviewing decision-makers and key informants of the subjects investigated to having informal chats with campus' users and colleagues. These face-to-face conversations, as well as visiting campuses during research trips (and even in my holidays), gave me unexpected insights and the possibility to reflect on these built environments and their link to innovation.

This book mirrors in a good deal its research process. I shall warn the reader that it contains a vast amount of information that is significant to understand the hypothesis of the built environment as a catalyst for innovation and its development process. I hope this book will contribute to enrich the discussion of the added value of real estate in organisational performance, as well as inspire new ways of dealing with the development of technology campuses.

Flavia Curvelo Magdaniel

The Hague, April 2016

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Summary

This thesis examines the development of technology campuses as built environments and their role in stimulating innovation. Technology campuses entail a variety of built environments developed to accommodate technology-driven research activities of multiple organisations. The science park is the most common type of technology campus. Other types include the campuses of universities of technology and corporate R&D parks.

In industrialised countries, the demand for developing technology campuses to stimulate innovation has been growing in line with the attention given to knowledge in global, national and regional policies. There are over 700 technology campuses worldwide occupying hundred thousands of hectares in- and around cities. This type of built environments have emerged and developed during critical periods of technological advancements throughout the 20th century, to support technology-based development in industrialised countries. With the adoption of the knowledge- based economy, governments in many countries have encouraged research as an essential activity in their science, technology and innovation policies. The infrastructure that supports research is also gaining momentum. The number of registered science parks is steadily increasing since the late 1990s. The number of programmes supporting research infrastructure is growing in the European policy agenda. Municipalities are formally engaged with other public and private parties in the development of urban areas targeted to stimulate innovation. Governments, universities and R&D companies are investing billions of euros in developing the infrastructure that will not only support their core processes, but will help them to remain competitive by attracting and retaining the best talent. Part of these investments are targeted to develop new buildings or entire areas that often result in campuses as we know them: a concentration of buildings accommodating organisations, people, and their activities in a (green) field.

The assumption that the concentration of research activities in one location stimulates innovation is promoting the development of technology campuses in many places. However, the capacity of these built environments to support the different processes associated with innovation is not well understood – i.e. Technology campuses are urban areas in the inner city and peripheral locations that have the capacity to support the processes of knowledge creation and diffusion, as well as of attracting and retaining knowledge workers. The existent knowledge about the relationship between the built environment and innovation at the area level is limited. This knowledge gap may lead to inefficient use of the resources employed to develop technology campuses including capital, land, and time. Also, this lack of understanding can have the opposite effect, because technology campuses could easily become problematic areas dealing with vacancy, poor spatial quality, and connectivity issues frustrating the societal goal of attracting and retaining talent in the knowledge economy. A potential way to address these problems is outlining the ways in which the built environment stimulates innovation in technology campuses.

In this context, this research addresses as main question 'How does the built environment stimulate innovation in technology campuses?' This research is grounded in the field of corporate real estate management and its theoretical assumption that the built environment is a resource managed to support the goals of organisations. Research in this field has focused on the practice of real estate management from the end user's view. Campus development is a comprehensive form of this practice, because it deals with activities that vary from developing real estate strategies, developing building projects, up to maintaining and managing the portfolio of an organisation. The relationship between innovation and the built environment has been addressed before in theories of corporate real estate management in a broad sense. Empirically, this has been explored on the supply side at the level of the workplace rather than at the urban scale. Although the contemporary discussion of innovation

in complementary research fields focus on the urban level. Onthe demand side, the involvement of public and private parties in the development of these areas moves forward the organisational scope in corporate real estate management beyond the end-users in large scale built environments.

This research provides an understanding of the relationship between the built environment and innovation at the area level. This research developed knowledge clarifying such relationship in the form of a conceptual model and recommendations for practitioners involved in the practice of campus development. This knowledge developed mainly throughout an inductive approach in two core studies. The first study is an exploratory research that uncovers and positions the link between innovation and the built environment by using inputs from theory (literature review) and empirical evidence (qualitative survey of 39 technology campuses). In this stage, the link between innovation and the built environment is provided in a form of a conceptual framework containing the proposition that the built environment is a catalyst for innovation. The second study is an explanatory research that clarifies the relationship between innovation and the built environment based on empirical evidence in the practice of campus development (theory building from case studies). In this stage, the theoretical constructs of the conceptual framework are applied and revised through the in- depth study of two cases in particular contexts (i.e. High Tech Campus Eindhoven in the Netherlands and the Massachusetts Institute of technology campus in the United States). As a result, the preliminary knowledge from the exploratory research was developed into a conceptual model bearing a hypothesis and five propositions closely linked to empirical evidence.

The answer to the main research question is that the built environment is a catalyst for innovation in technology campuses demonstrated by location decisions and interventions facilitating five interdependent conditions required for innovation. The following propositions explain how the built environment facilitates each of the five conditions for innovation:

1. Location decisions and area development facilitate the long-term concentration of innovative organisations in cities and regions.
2. Interventions enabling the transformation of the built environment at area and building levels facilitate the climate for adaptation along changing technological trajectories over time.
3. Large-scale real estate interventions facilitate the synergy among university, industry and governments.
4. Location decisions and interventions supporting image and accessibility define the innovation area by emphasising its distinct identity, scale and connectivity features.
5. Real estate interventions enabling access to amenities increase the diversity of people & chances for social interaction regardless the distinct geographical settings in which the concentration of innovative activities takes place.

This research acknowledges that the location decisions of some technology-driven organisations have coincidentally determined the concentration of innovative research activities in particular places. Over the years, the accommodation of the research activities of these organisations has co- evolved with particular socio-economic processes in their hosting cities creating unique conditions for innovation. The concentration of innovative organisations can be considered as a primal condition enabling the co-existence of the other four conditions for innovation. Similarly, this research acknowledges the following interventions facilitating conditions for innovation at the area level and depending on the particular location characteristics in which each campus has developed:

- Transforming areas through urban renewal and redevelopment,
- Building, adapting and re-using flexible facilities,
- Implementing the shared use of facilities accommodating different functions and users,
- Developing physical infrastructure enabling access to amenities and connection between functions
- Developing representative facilities and area concepts that support image.

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The empirical evidence supporting the propositions in the model is structured and converted into information available to decision makers involved in the development of technology campuses in the form of tools. The so-called 'campus decision maker toolbox' provides instruments that can guide planners, designers and managers during different stages of campus development. The tool for planners comprises campus models to frame the campus vision during the initiation of the campus based on location characteristics. The tool for designers consists of alternatives to enhance the campus brief during the preparation of the campus. And the tool for managers contains an information map to steer the campus strategy during the use of the campus.

This knowledge contributes to the existing understanding of the relationship between innovation and the built environment in theory and practice. In theory, this research adds to existing theoretical concepts connecting the fields of corporate real estate management, urban studies in the knowledge-based economy and economic geography. The conceptual model proposed a new combination of existing theoretical concepts addressing a new way to look at the relationship between innovation and the built environment. In practice, this understanding is expected to encourage the efficient and effective use of the many resources required to develop technology campuses. Particularly, by providing information that can help decision makers to steer such resources towards strategic decisions and interventions that -under certain conditions- facilitate innovation. The knowledge developed in this research clarifies a relationship between innovation and the built environment at urban area level, in which the built environment facilitates conditions for innovation.

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PART I Background

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1 Introduction

§ 1.1 Research field

This thesis examines the development of technology campuses as built environments and their potential role in stimulating innovation. 'Technology campuses' entail a variety of built environments that have been developed to accommodate technology-based research activities (e.g. science parks, campuses of universities of technology, research and development or R&D parks, etc.). In this research, the built environment is seen as a resource managed to attain organisational performance, while stimulating innovation is seen as a particular organisational goal. Indeed, this goal has become increasingly important for different types of organisations in the knowledge-based economy (e.g. universities, firms, and municipalities). In this view, technology campuses are examined as resources supporting the goal of stimulating innovation in multiple organisations.

Developing knowledge about the relationship between the built environment and innovation is an essential part of this research. This relationship is explored and further developed in two core studies. The first is an exploratory research that uncovers and positions the link between the built environment and innovation in a broad theoretical and empirical context. And the second is an explanatory research that reveals patterns of the built environment as a catalyst for innovation in two technology campuses in their particular contexts.

This introduction chapter describes the rationale of this thesis and the ways in which the research has been conducted. First, it describes the societal and scientific relevance of the research topic as a background to a problem area. Then, it states the problem that leads to the formulation of the main research questions and goals. Later, it describes the research design that explains the approaches and methods used to answer these questions. Finally, this chapter concludes by describing the outline of this dissertation and providing a guide for its readers.

Technology campuses, innovation, and cities in the knowledge economy

In the current economies of many industrialised countries, creating and applying knowledge is the basis of competition. As Porter (1990, p. 73) asserts in his influential work 'a nation's competitiveness depends on the capacity of its industry to innovate'. Today, this capacity seems to depend on the collective effort of three organisational spheres - universities, industry, and governments- also known as the Triple Helix (Etzkowitz, 2008). In order to remain competitive, these organisational spheres pull together several resources (e.g. people, capital, technology, knowledge, infrastructure, etc.) to stimulate innovation as a strategic goal. In this context, the built environment is an important resource supporting the fulfilment of this organisational goal.

Indeed, there is a diversity of built environments accommodating a range of technology-based research activities essential in creating and applying knowledge as basis for competition. These built environments were mostly developed over the 20th century (particularly after the WWII) with the deliberate objective to support technology-based development in industrialised countries across North America, Europe and Asia.

Since the late 1980s, the development of technology campuses to stimulate innovation has gained importance both, in practice and in theory (Carvalho, 2013; Castells, 1985; Castells & Hall, 1994; Huang, 2013; Link & Scott, 2006; Van Winden, 2011) with the so-called knowledge-based economy[1]. In this economy, developing technology campuses has become a milestone resource to stimulate innovation for economic development not only in highly- and new industrialised countries, but also in emerging and developing economies. Universities, firms and governments are spending resources in developing large and costly built environments to support their goals based on spatial models that have a common characteristic: they enable the concentration of people, organisations, and their activities. This approach is being criticised because the actual returns of these investments on innovation are difficult to demonstrate.

Developing campuses to stimulating innovation has become a commonly accepted practice among the three organisational spheres of the Triple Helix in some cities and regions of industrialised countries [See Figure 1.1]. Nowadays, there are many types of technology campuses that has been defined, labelled, and studied in different ways – i.e. Technopoles (Castells & Hall, 1994), Science parks (Link & Scott, 2003, 2006), University campuses (Den Heijer, 2011), Knowledge hot-spots (Van Winden, 2011), High-tech parks (Huang, 2013), Knowledge locations (Carvalho, 2013), among others. Roughly, there is at least one example of this practice in almost every city of an industrialised country.

Figure 1.1 An example of a technology campus developed to stimulate innovation, which construction started in 2014.

1 The knowledge-based economy is a concept discussed in political and economic giving economic significance to knowledge, which meaning is closely associated with science, technology, and innovation. A definition used in this research is given at the end of this chapter. Other definitions are explored in Chapter 2 of this dissertation.

Most of these built environments have been developed in peripheral –and sometimes isolated- locations lacking the liveability of core inner city centres, which is debated in economic geography as the true geography of innovation (Beaudry & Schiffauerova, 2009). Recently, a new urban agenda regarded as 'Innovation districts' (Katz & Wagner, 2014) has emerged criticising the science park and similar models, and calling for new urban development schemes embracing the city as the place for innovation. This metropolitan policy report highlights innovation districts as a means for urban competitiveness and prosperity. As a result, several American cities have launched their 'innovation district strategy' to spur economic growth[2]. Similarly, this type of developments has called the attention of scholars in urban fields who currently debate how to quantify innovation, entrepreneurship, and vitality in cities in an academic context (MIT, 2014).

Certainly, accommodating research as an innovative activity is growing complex with key aspects characterising the knowledge-based economy. For instance, the range of technology-based research activities has increased, both in number and related processes, with the advancements of technologies during the ICT industrial revolution, and the digital and information revolution (Headrick, 2009). Universities are increasingly addressed as the engines of the knowledge-based economy because their primary process lies in research next to educating future researchers (Vorley & Nelles, 2008). Many companies –specially in developed economies- invest on R&D and are increasingly engaged in these activities with universities (World Economic Forum, 2011). Correspondingly, the number of people employed in research is growing steady in many countries (OECD, 2013). With globalization and the changing dynamics of mobility patterns, most of the competitive advantage of countries and organizations relies on their ability of attracting and retaining talented people. As a result, places (regions, cities and areas) have become more important than ever because the new location factors depend on the quality of the knowledge institutions (Faggian & McCann, 2009; Van Den Berg et al., 2005); and the living and working conditions preferred by the highly-educated worker (Florida, 2008). In this dynamic context, the built environment is gaining importance because it is not only a shelter facilitating research activities but it can be a symbol that attract and represent a research community.

In this context, the relationship between technology campuses, innovation and cities in the knowledge economy provides a multidisciplinary research field for this dissertation –i.e. this dissertation builds upon multiple fields of study. On the one hand, this research approach (to study technology campuses as built environments) is based on theoretical assumptions from Corporate Real Estate Management (CREM)[3]. On the other hand, to study the relationship between the built environment and innovation, this research explores theoretical notions from economic geography, regional studies, urban planning, and urban design, because of the scale of these built environments at area level.

2 Examples of these are Detroit, Miami, Chicago, Fremont, Minneapolis, Boston, among other cities. This can be found through online search by using Google News' archives.

3 Corporate real estate management (CREM) is defined as 'the management of a corporation's real estate portfolio by aligning the portfolio and services to the needs of the core business (processes), in order to obtain maximum added value for the business and to contribute optimally to the overall performance of the corporation' (Dewulf et al., 2000). Studies in this field focus on the practice of real estate management (REM) from the end-user's view, which deals with activities that vary from developing real estate strategies and building projects, up to maintaining and managing the built space in the portfolio of a private or public organisation.

§ 1.2 Problem definition

§ 1.2.1 Problem statement

As described above, there is an increasing societal demand to promote the development of technology campuses based on the assumption that the concentration of research activities in one location stimulates innovation. However, the capacity of these built environments to support the different processes associated to innovation is not well understood – i.e. Technology campuses are urban areas in inner city and peripheral locations that have the capacity to support the processes of knowledge creation and diffusion, as well as of attracting and retaining knowledge workers. In fact, there is little knowledge about the relationship between the built environment and innovation at the urban area level.

This knowledge gap may lead to inefficient use of the -sometime scarce- resources employed to develop technology campuses - i.e. their large-scale developments require large amounts of public and private capital, long-term development processes, large pieces of land, the involvement of large groups of stakeholders, and others that are limited specially in periods of economic recession. In addition, this lack of understanding can have the opposite effect because technology campuses can easily become problematic areas dealing with vacancy, poor spatial quality, and connectivity issues frustrating the societal goal of attracting and retaining talent in the knowledge economy. A potential way to address this issue is making evident potential ways in which the built environment stimulates innovation in technology campuses.

§ 1.2.2 Knowledge basis: gaps and opportunities

Studying both, 'the role of the built environment in stimulating innovation' and 'technology campuses' are relatively unfamiliar topics in the literature. Some of these topics have been studied separately in different disciplines. Although these disciplines have shared assumptions, when combined they are overlapping and sometimes redundant, which separately do not offer a coherent whole to explore the campuses' potential supporting innovation as an organisational goal. This research acknowledges the potential to establish some connections between particular concepts in various fields, which are addressed as follows.

On the one hand, stimulating innovation is a topic widely investigated in the fields of management, policy, economic geography and regional studies, because it is critical for maintaining competitive advantage of organisations and nations (Kostoff, 2003). The role of concentration of firms, universities and knowledge institutes as a favourable environment for innovation is widely explored in agglomeration economies when discussing the externalities recognised to play a major role in the process of knowledge creation and diffusion (Beaudry & Schiffauerova, 2009; Glaeser et al., 1992; Porter, 2008). The different views give the concept of geographical proximity an important role in stimulating innovation from a spatial perspective. However, to what extent geographical- and other types of proximity are critical for knowledge networks is still a subject of debate in the evolutionary school of thought of economic geography (Boschma, 2005; Huber, 2012; Lagendijk & Lorentzen, 2007; Torre & Rallet, 2005). Besides, the empirical research that builds upon this academic debate has been done at the scale of the region or the city. Overall, besides location there are very few studies mentioning other aspects of the built environment such as block pattern, density, and image (Florida, 2010; Jacobs, 1961; McCann, 2007) from the extensive amount of research studying innovation in economic geography.

On the other hand, the variety of built environments that technology campuses entail have been studied predominantly in the fields of planning, urban and regional studies and businesses but much less from the built environment perspective [See Figure 1.2]. Only few technology campuses have been studied from a built environment perspective (Den Heijer, 2011; Hoeger & Christiaanse, 2007). For instance, Den Heijer (2011) studies university campuses from the CREM field providing a knowledge basis for this research because of its similar approach.

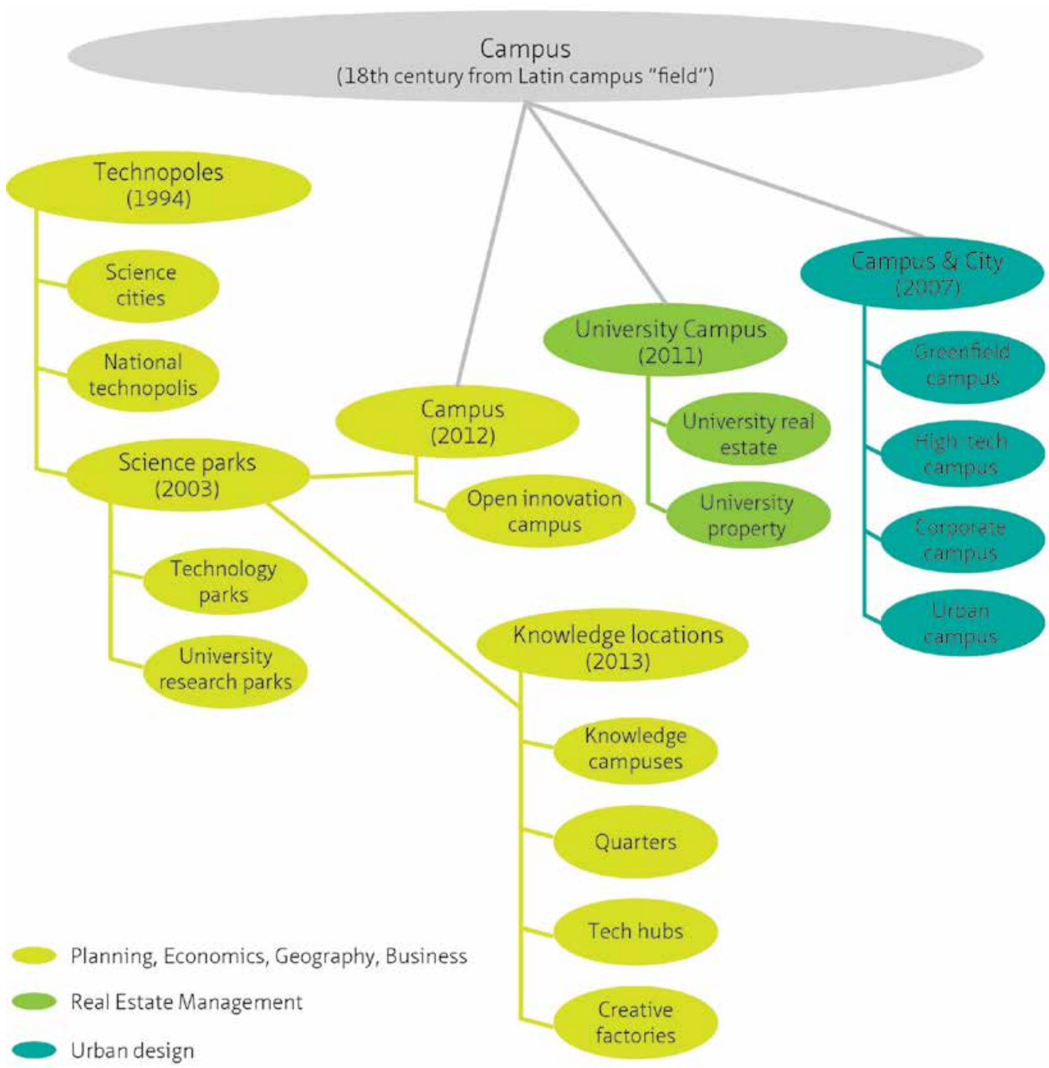

Figure 1.2 Diversity of built environments covered by the definition of technology campuses given in this research. They are distinguished per field of study documenting the concentration of research activities in society.

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In the CREM field, there is a body of knowledge investigating the relationship between the built environment and innovation as one of the many aspects of organisational performance. These studies use the same (or very similar) theoretical assumptions in which the built environment is seen as an organisational resource. However, most of the empirical research outlining the relationship between the built environment and innovation is limited to the scale level of the building and the physical setting of workplace design (Appel-Meulenbroek, 2014; De Vries, 2007). However, the relevance of location and the provision of amenities emphasised in early theories in this field as relevant for innovation (Nourse & Roulac, 1993; O'Mara, 1999a; O'Mara, 1999b) has not been fully explored in empirical research yet. In the urban context, few researches began outlining the importance of phsyical infrastructure resources for cities in the knowledge economy (Florida, 2010; Porter, 2008). However, the scope of these researches is not directly concerned with the built environment.

In this context, studying the role of the built environment in stimulating innovation deserves attention for two main reasons. In academy, studying the development technology campuses will provide with understanding of the relationship between the built environment and innovation at the scale levels of the area, which has not been sufficiently explored in the CREM field even though there is a good knowledge basis to explore it. Besides, the patterns that may be observed from these developments can add to the current debate about geographical proximity and innovation in the field of economic geography. Together, it will help setting the grounds for more empirical research investigating this topic, which is gaining societal relevance.

In practice, knowing more about the relationship between the built environment and innovation can lead to more efficient -and perhaps effective- use of the resources required to develop these built environments as mentioned before. Besides, it can raise awareness about the potential positive or negative effects of these developments in their hosting cities. Finally, it can stimulate new ways of thinking that can facilitate the tasks of campus decision-makers (i.e. planners, designers, and managers) when dealing with the current challenges of accommodating tech-based research activities in the near future.

§ 1.3 Research aim and questions

This research examines the development of technology campuses with the aim to gain and provide understanding about the role of the built environment in stimulating innovation. Therefore, this study seeks to develop more knowledge about the relationship between the built environment and innovation at area level, which characterises the scale of technology campuses as built environments. This knowledge is targeted to decision-makers influencing the planning, design, and management of technology campuses and similar built environments, and for whom stimulating innovation is a strategic goal. To shed light on this problem, this research asks ***How does the built environment stimulate innovation in technology campuses?***

The following guiding questions developed throughout this thesis to derive understanding and knowledge that can answer the main research question.

§ 1.3.1 Exploratory questions

- What is the role of the built environment in innovation in theory?
- What are the distinct characteristics of technology campuses from the built environment perspective?
- How can we study the development of technology campuses and simultaneously provide understanding about the role of the built environment in innovation? By using which concepts from theory and cases from practice?

§ 1.3.2 Explanatory-descriptive questions

- What campus' interventions have facilitated the conditions leading to innovation in particular technology campuses and their hosting cities, and how?
- What are the common and distinctive development patterns between these technology campuses? And what is the nature of similarities and differences in their built environments facilitating innovation?
- What can be concluded on the role of the built environment in innovation from the observed patterns in the cases studied? How can we use this knowledge to improve future outcomes and challenges in the practice of developing technology campuses and similar built environments?

§ 1.4 Research design

§ 1.4.1 Research approach

Studying the development of technology campuses is aimed to provide significant insights on the relationship between the built environment and innovation both, in theory and practice. Because of the limited precedent for this study, its outset is exploratory and mostly inductive but its ending is explanatory and uses both deductive and inductive approaches. – i.e. this research follows a bottom-up approach that moves from observations to hypothesis development. It goes back and forward between theoretical constructs that emerge from patterns observed in empirical data at different stages.

Two important stages of theory development are distinguished throughout two core studies. The first is an exploratory research that uncovers and positions the link between the built environment and innovation in a broad theoretical and empirical context. And the second is an explanatory research that develops understanding of this potential link from empirical evidence in particular contexts. These two core studies are the second and the third of the four sequential parts in which this thesis is framed: I) Background; II) Exploratory research; III) Explanatory research; and IV) Conclusions [See Figure 1.3].

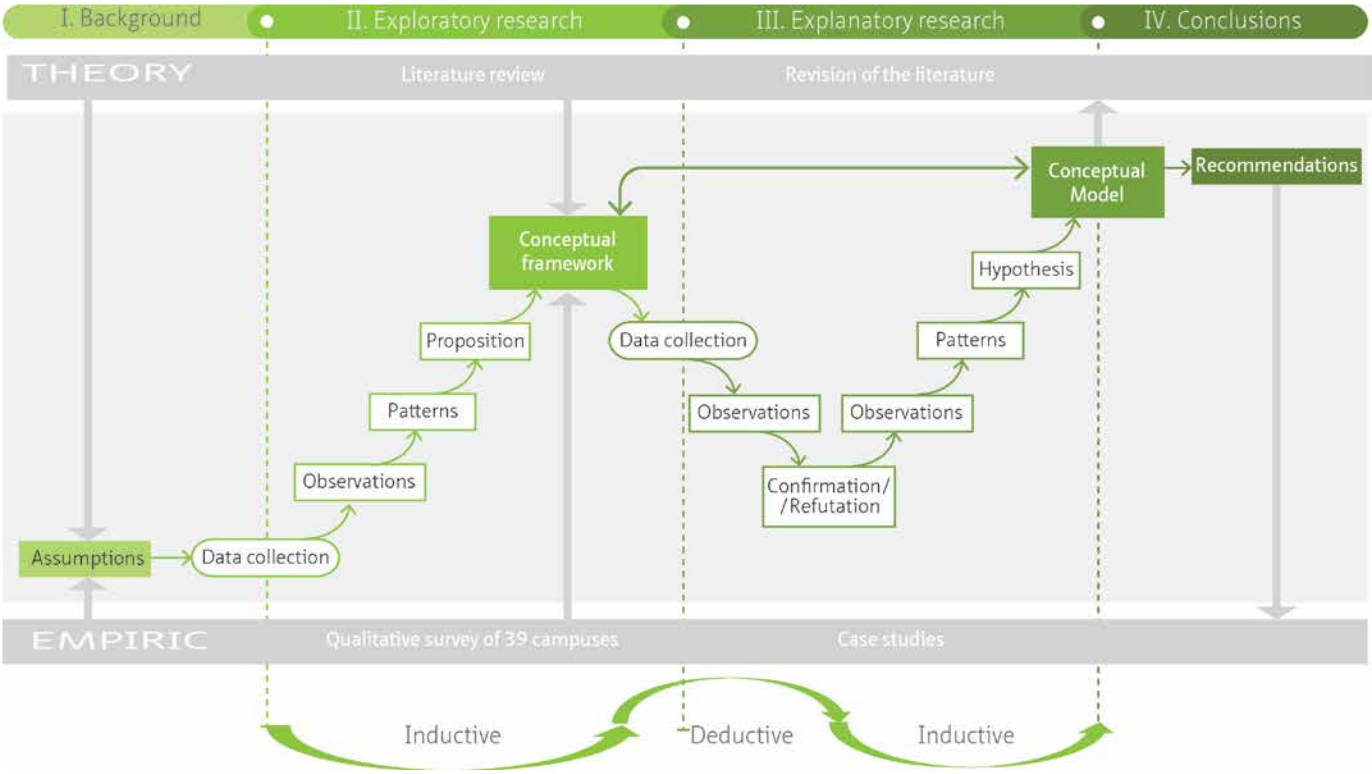


Figure 1.3 Research approach

Each of the two core studies uses particular strategies and methods of data collection and analysis because each of them had a different purpose within the overall research. The reasoning behind this choice and the various methods used are described in brief in the next paragraphs for each of the core studies. Also, detailed information regarding methodology is found through the dissertation when required.

§ 1.4.2 Strategies and methods

Exploratory research

This part of the research uses two main strategies: literature review and a qualitative survey of technology campuses and their hosting cities. The design of the exploratory study has its starting point in two knowledge gaps. The first is a theoretical one about the object of study 'the role of the built environment stimulating innovation in the knowledge economy', which is gaining momentum in research from various complementary fields but it remains broad and unfamiliar because it is treated as unconnected subjects. To integrate the existing knowledge, this research conducted a literature review that lied at the intersection of three primary disciplines (i.e. corporate real estate management, economic geography and urban studies in the knowledge economy), which define a research area that connects also with urban planning, architecture, science and technology and regional policy in a broad sense. The details about data collection and analysis procedures of this strategy are further described in Chapter 2 – i.e. applied concepts and theories.

The second knowledge gap to be addressed in this exploratory research is an empirical one about the subject of study 'the development of technology campuses as built environments'. Technology campuses have been extensively studied in the fields of business, economic geography, and regional studies but much less from the built environment sciences. This research conducted a 'qualitative survey' with the purpose of describing and gaining familiarity with the subject of study. This method is rather unfamiliar in social research methods compared with the well-known statistical survey (Jansen, 2010). Accordingly, it studies the diversity (not the distribution) of a population with the purpose of description. Through this method, the variety of built environments referred as technology campuses can be explored, described, and compared. Since campuses are the subjects under examination, this qualitative survey uses documentation analysis rather than questionnaires for data collection. The details about data collection procedures of this strategy are further described in Chapter 3 – i.e. Technology Campuses: emergence and development.

Both strategies developed in parallel with the purpose to gain familiarity with the object and subject of study while narrowing down the research area and the focus of further empirical study. The research design of the exploratory research is illustrated below [See Figure 1.4].

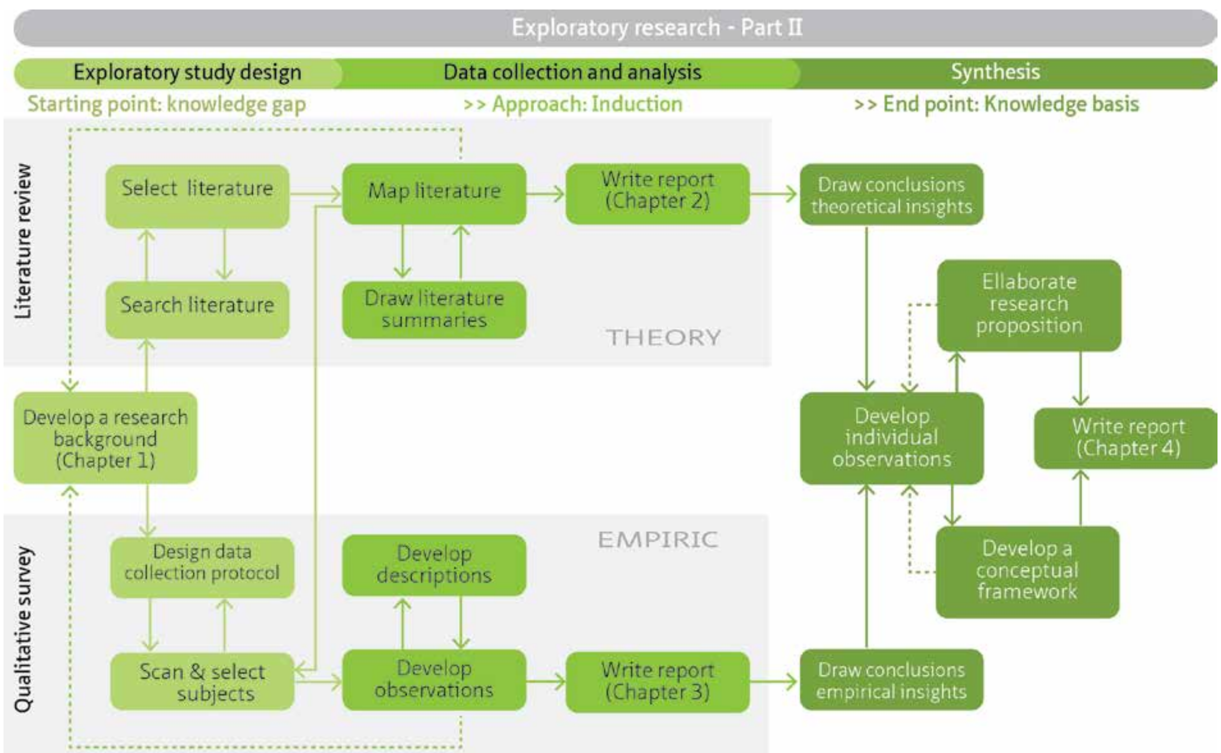


Figure 1.4 Exploratory research: design and methods

The combined insights from these two strategies are synthesised in a conceptual framework, which contains a proposition to be verified in the second core study. Therefore, this framework informed the research design of the explanatory research. The concepts and the relationships embedded in this framework are the main outcome of the exploratory research and constitute the preliminary knowledge basis required to further answer the main research question.

TOC

Explanatory research

This part of the research uses 'theory building from case study research' (Eisenhardt, 1989) as main strategy to provide better understanding of the relationship between the built environment and innovation based on empirical evidence in the practice of campus development. A preliminary arrangement of concepts (i.e. the conceptual framework developed at the end of the exploratory research) is applied, verified, and revised through the study of two cases in particular contexts. Accordingly, this research combines both, deductive and inductive approaches through a continuous iterative process that concludes with a conceptual model supporting this research thesis.

The two cases studied in this research were selected from the sample of 39 technology campuses described in the qualitative survey. Their selection was based in their suitability to clarify the relationships established in the conceptual framework and their likelihood to offer theoretical insights. Thus, this research selected two cases based on the criteria of exemplarity explaining the research proposition and practicality allowing in-depth analysis and comparison in a restricted time. The research design of the explanatory research is illustrated below [See Figure 1.5].

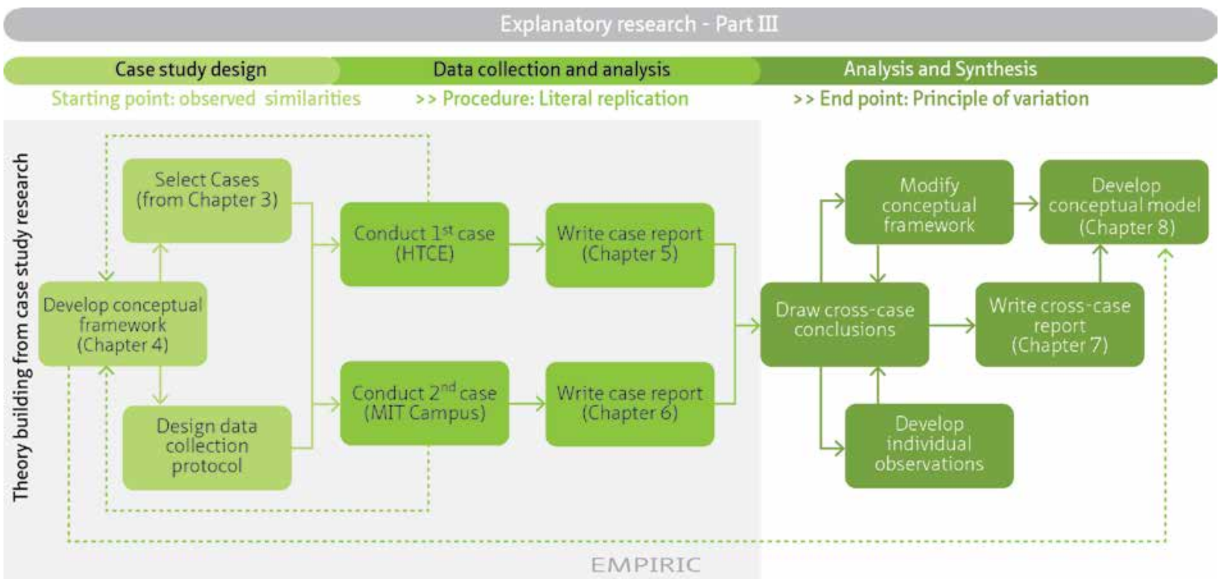


Figure 1.5 Explanatory research: design and methods

This research uses a 'differentiating comparative analysis' (Pickvance, 2001), in which the starting point is the observed similarities in the cases or their exemplarity in explaining the research proposition. However, the end-point is to explain the research proposition in terms of the variation given by the contexts in which these campuses develop. Similarly, it uses literal replication as main procedure for analysis (Yin, 2013), allowing a systematically examination of similarities and differences in two international contexts. The conceptual framework serves as instrument for this analysis facilitating the comparison. The way in which the conceptual framework informed the strategy used in the explanatory research, the case selection and its analysis process is described at the end of Chapter 4 – i.e. The built environment as a catalyst for innovation: a conceptual framework. The details about the data collection sources and procedures are further described per case study in Chapters 5 and 6.

The insights from the case comparison are synthesised in a conceptual model, which is the main outcome of the case study research, and constitute the knowledge developed to answer the main research question.

§ 1.4.3 Assumptions

Four assumptions are made on this study based on the researchers' experience and background as user, designer, and researcher in the management of university campuses.

First, technology campuses have the capacity to stimulate innovation because that is the primary goal of its end-users. This assumption is based on the premise that built environments are first, designed to shelter the activities of end-users (e.g. individuals, organisations and society) and second, they are managed to satisfy their demands. This premise holds on theoretical approaches in the CREM field, and in the practice of architectural design.

Second, the area is a suitable scale level to examine the relationship between the built environment and innovation. This assumption is guided by the fact that technology campuses are the result of the concentration of innovative activities carried out by people and organisations in one location. This condition – spatial concentration- is investigated in theories of economic geography, which insights can be used to guide the exploration of this relationship at the mentioned scale.

Third, the local contexts in which these built environments locate influence their potential role in innovation. This assumption is based on the premise that built environments cannot be seen as isolated objects but rather as part of an integral context named the city or the region. For instance, built environments develop and evolved in line with particular transformations in society (e.g. technological, economic, institutional, and cultural). In the case of technology campuses, the societal attention given to innovation in cities and regions in the knowledge economy gives significance to the context.

Last, more knowledge about the development of technology campuses can stimulate built environments that conduct effectively to stimulate innovation as pursued by different organisations in the knowledge economy. This assumption is based on the notion of bounded rationality that characterise decision-making in planning, designing, and managing built environments – i.e. decision makers often rely on limited information, time constrains and other pressures. Building a stock of knowledge based on empirical experiences can avoid the negative effect of using resources inefficiently when developing technology campuses as described before.

Based on the above, this research can be categorised as naturalistic system of enquiry – also referred as a qualitative and interpretative/constructivist enquiry (Groat & Wang, 2002).

§ 1.5 Research outline

§ 1.5.1 Dissertation structure

The structure of this thesis follows the way in which the research is conducted in four parts [See Figure 1.6]. Part I of this dissertation (Background) consist of Chapter 1. This chapter has introduced the research by providing background information that describes the purpose of this research and how this is going to be achieved.

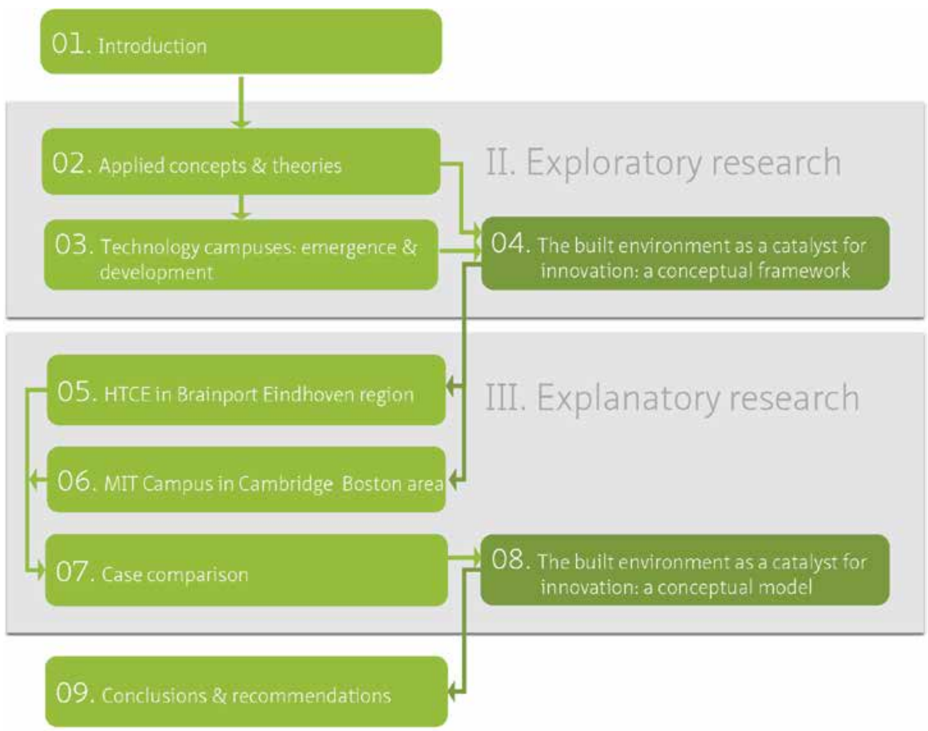


Figure 1.6 Dissertation structure

Part II (Exploratory research) consists of three chapters. It begins with Chapter 2, which objective is to uncover and to position the role of the built environment in stimulating innovation in a scientific context. Chapter 3 describe the general patterns in the demand for- and the supply of technology campuses in an international context. Chapter 4 proposes a conceptual framework with the aim to help uncovering the role of the built environment in stimulating innovation.

Part III (Explanatory research) consists of four chapters. It begins with evaluating the two selected cases according to the proposed conceptual framework. Chapter 5 and 6 present each an in-depth study of a technology campus, with the aim to uncover patterns of the built environment facilitating innovation in their particular contexts. Chapter 7 presents the comparison between two case studies, with the aim to uncover common and distinct patterns of the built environment facilitating innovation. Chapter 8 presents a conceptual model or the main outcome of this research, with the aim to explain its proposition of the built environment as a catalyst for innovation based on the empirical findings.

Last, Part IV (Conclusions) consists of Chapter 9. This chapter aims to answer the main research question by outlining the main conclusions of this thesis and its contribution to science and practice.

§ 1.5.2 Readers' guide

This dissertation provides an abstract as a cover page at the beginning of each chapter. This abstract describes in a concise way (both in text, and graphic), the position of the chapter within the whole dissertation, and the content presented in the chapter in relation to other chapters. Each chapter's abstract includes the research question addressed in the respective chapter, the main objective, and the chapter outline. An example of the cover page for each chapter is illustrated below [See Figure 1.7]. The relationship between the chapters is also summarised in Table 1.1 that can be used as reference.

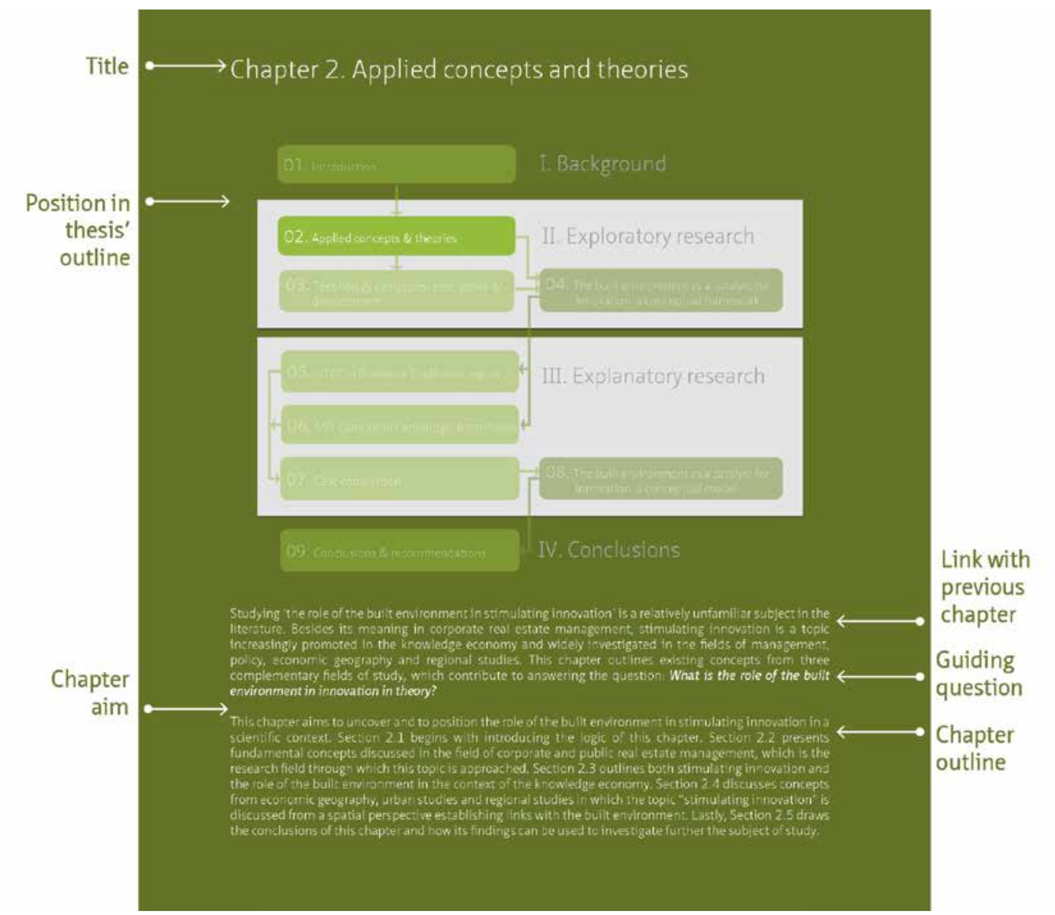


Figure 1.7 Example of chapters' abstract page

	RESEARCH QUESTIONS IN RELATION TO CHAPTERS AND RESEARCH APPROACH		
	Research questions	Chapters	Aims
I. Background	What is the main purpose of this study and which approaches and methods suit best achieving this purpose?	Chapter 1. Introduction	This chapter aims to provide a clear context for understanding this thesis.
II. Exploratory research	What is the role of the built environment in innovation in theory?	Chapter 2. Applied concepts and theories	This chapter aims to uncover and to position the role of the built environment in stimulating innovation in a scientific context.
	What are the distinct characteristics of technology campuses from the built environment perspective?	Chapter 3. Technology Campuses: emergence & development	This chapter aims to describe the general patterns in the demand for- and the supply of technology campuses in an international context.
	How can we study the development of technology campuses and simultaneously provide understanding about the role of the built environment in innovation? By using which concepts from theory and cases from practice?	Chapter 4. The built environment as a catalyst for innovation: a conceptual framework	This chapter proposes a conceptual framework with the aim to help uncovering the role of the built environment in stimulating innovation
III. Explanatory research	What campus' interventions have facilitated the conditions leading to innovation in HTCE, and in Brainport-Eindhoven region, and how?	Chapter 5. HTCE in Brainport-Eindhoven region.	This chapter presents an in-depth study of HTCE's development, with the aim to uncover patterns of the built environment as a catalyst for innovation in Brainport-Eindhoven region.
	What campus' interventions have facilitated the conditions leading to innovation in MIT, and in Cambridge-Boston area, and how?	Chapter 6. The MIT Campus in Cambridge – Boston area	This chapter presents an in-depth study of MIT campus' development, with the aim to uncover patterns of the built environment as catalyst for innovation in Cambridge-Boston area.
	What are the common and distinctive development patterns between HTCE and MIT campus? And what is the nature of similarities and differences in their built environments facilitating innovation?	Chapter 7. Case comparison	This chapter presents the comparison between two case studies: HTCE and MIT campus, with the aim to uncover common and distinct patterns of the built environment as a catalyst for innovation.
	What can be concluded on the built environment as a catalyst for innovation from the observed patterns in the two case studies? How can we use this knowledge to improve future outcomes and challenges in the practice of developing technology campuses and similar built environments?	Chapter 8. The built environment as a catalyst for innovation: a conceptual model	This chapter presents the main outcome of this research, with the aim to explain its proposition of the built environment as a catalyst for innovation based on empirical findings.
IV. Conclusions	**How does the built environment stimulate innovation in technology campuses?**	Chapter 9. Conclusions and recommendations	This chapter aims to answer the main research question by outlining the main conclusions of this thesis and its contribution to science and practice.

TABLE 1.1 Relationship between research questions and chapters through the dissertation

Overall, this dissertation uses rich and extensive descriptions, tables, maps and figures, which were central in the generation of insights during the research process. This information is predominantly qualitative and derives mainly from the empirical data analysed. This is more evident in the empirical chapters addressing the in-depth case studies (Chapters 5 and 6). The inclusion of this information in the dissertation is essential enhancing the consistency of this research. Those chapters rich in descriptions contain relevant information for those readers interested in gaining knowledge of the particular cases studied in this research.

§ 1.5.3 Definitions

This research uses key terms that need explanations for the reader of this dissertation because they entail particular meanings. The following definitions deserve special attention in this research. Other definitions are addressed in particular chapters when required.

Built environment. As described in architecture theories, built environments consist of built forms created by humans, to shelter, define and protect activity. In this research, the term built environment is used as a synonym of 'real estate', which according to theories in the management of the built environment is seen as an enabler of the activities performed by individuals, organisations and the society. This research distinguishes three scales of the built environment: building, portfolio and urban areas. This research recognises Technology campuses as built environments at the scale of the urban area.

Knowledge-based economy. Although there are many definitions addressing this term, this research adopts an existing view on this term from regional development studies, which distinguishes that this economy had emerged in the 1950s focusing on the composition of the labour force and has developed by adding structural aspects such as technological trajectories and institutional frameworks (Cooke & Leydesdorff, 2006). Accordingly, the knowledge economy is seen as a system perspective used by governments to frame their perspectives for developing science, technology and innovation policies.

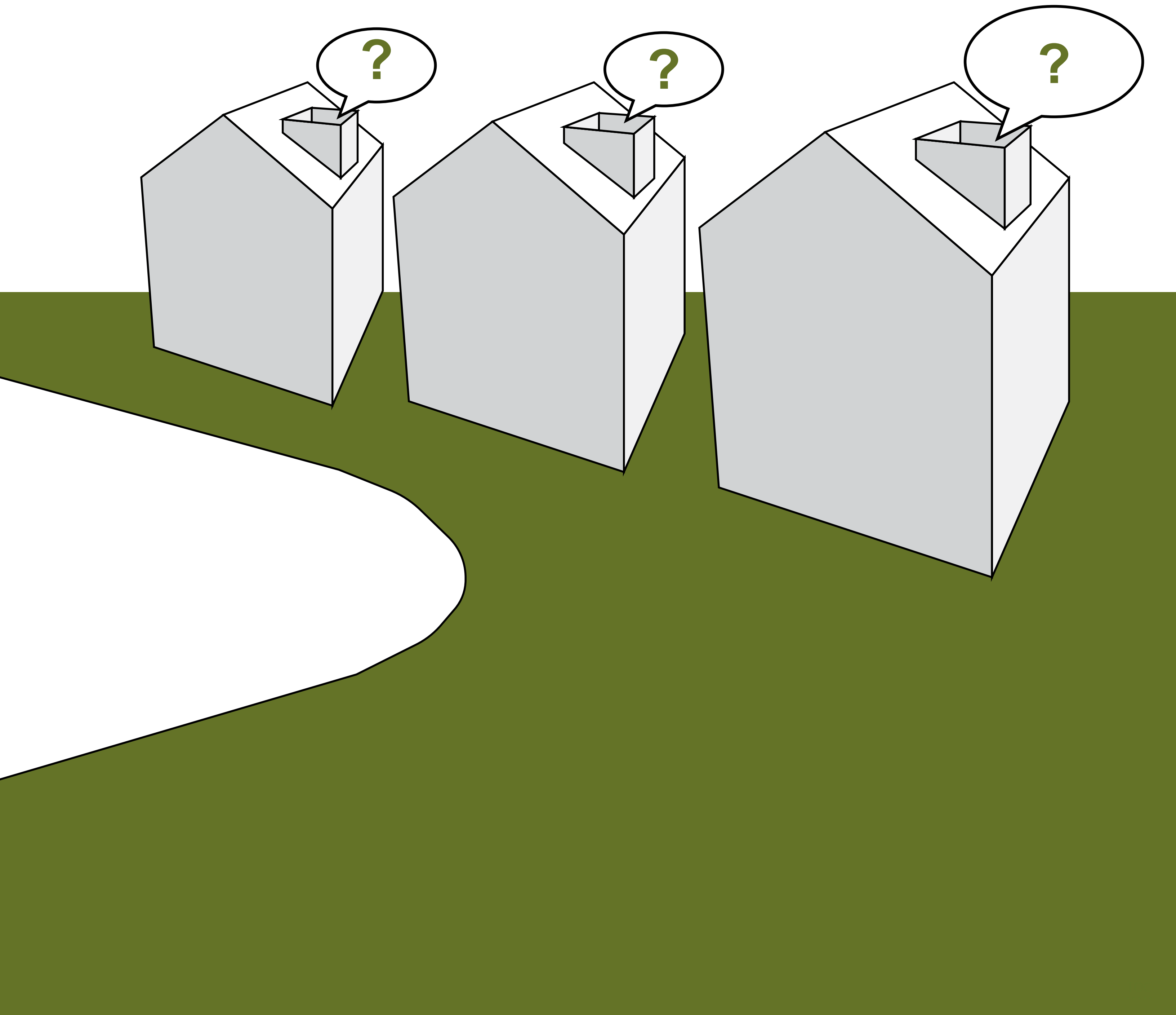
Innovation. Innovation has multiple views. In this research, innovation is regarded as the processes of knowledge creation, diffusion and its further application in the development of new and improved technologies. The human dimension is inherent to these processes because they involved tacit knowledge (i.e. knowledge embedded in people). The process of knowledge diffusion is key in this context because it enriches knowledge creation and its application (e.g. knowing what other researchers do and connecting this knowledge to their own work might drive knowledge further and also enhance possibilities for collaboration to create more knowledge or to apply this knowledge). In this view, this research refers to innovation also as a learning process addressing the human dimension interrelating these processes. These processes are seen as essential for the competitive advantage of multiple organisations in industrialised economies. Stimulating innovation is, therefore, a common goal of many organisations.

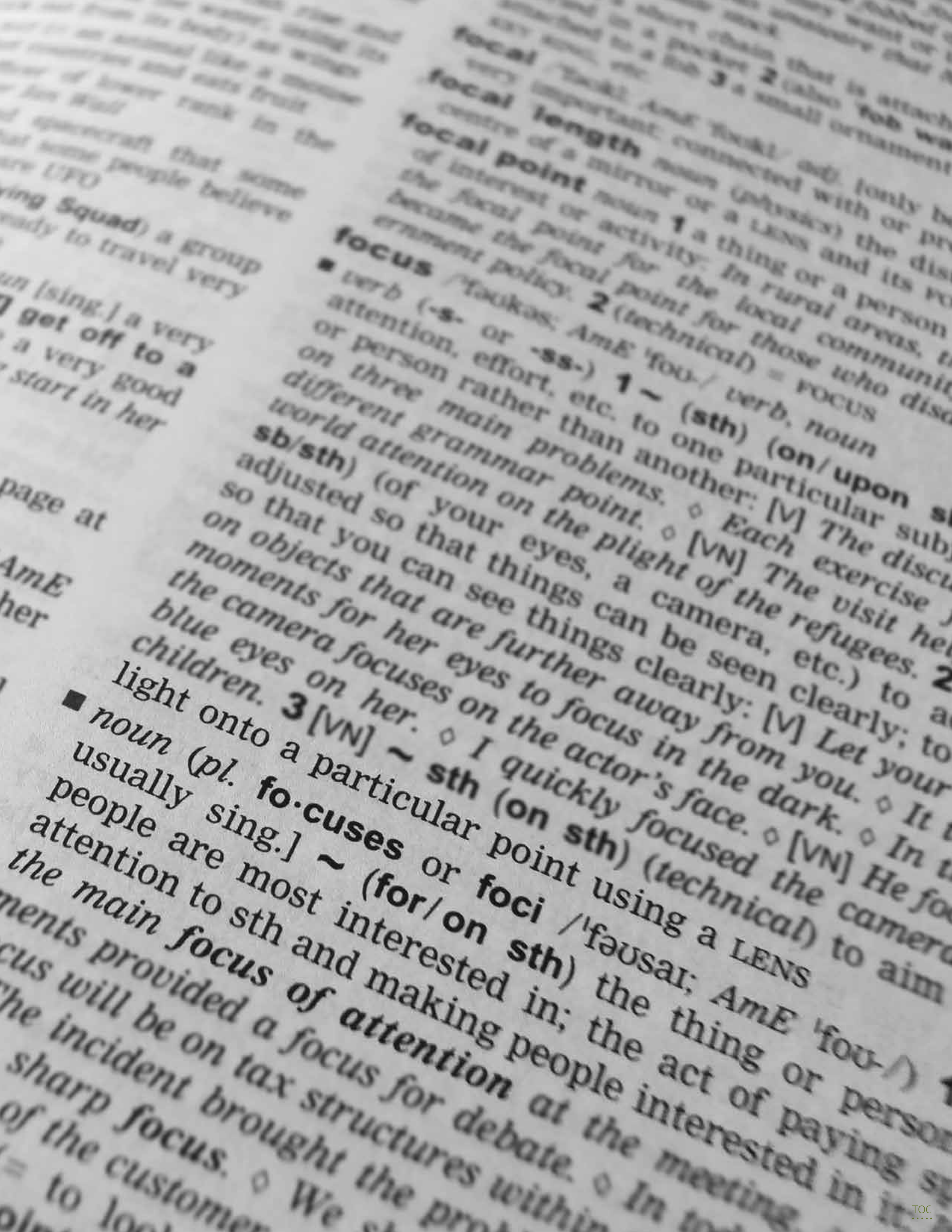
Technology-based research. This term refers in this research to both, (1) fundamental or basic research and (2) research and development activities, which have a focus on the advancement of technologies in various fields. Essentially, technology-based research entails the processes linked to innovation as seen in this research.

Organisations. Organisations are systematically arranged frameworks relating resources (e.g. people, knowledge, capital, technologies, etc.) in a design intended to achieve specific goals. This definition is adapted from management theories (Clegg et al., 2008). This research has chosen to use the term technology-based research organisations to refer to a specific type of knowledge-intensive organisations such as: research universities or institutes in technology fields and R&D companies in high technologies.

Stakeholders. Stakeholders are individuals, organisations, or institutions, whose interests are involved or affected by a course of action. For instance, any decision on the built environment counts as a course of action. Thus, there are several stakeholders involved in the development of technology campuses whose interests can affect and be affected by such developments.

PART II Exploratory research




focal /ˈfəʊkl; AmE ˈfoʊkl/ adj. [only before noun]
very important; connected with or
focal length noun (physics) the distance from the
centre of a mirror or a LENS and its
focal point noun 1 a thing or a person
of interest or activity: In rural areas,
the focal point for the local communit
became the focal point for those who
ernment policy. 2 (technical) = FOCUS
focus /ˈfəʊkəs; AmE ˈfoʊ-/ verb, noun
■ verb (-s- or -ss-) 1 ~ (sth) (on/upon sb/sth)
attention, effort, etc. to one particular sub
or person rather than another: [V] The discu
on three main problems. ◇ Each exercise
different grammar point. ◇ [VN] The visit he
world attention on the plight of the refugees. 2
sb/sth) (of your eyes, a camera, etc.) to a
adjusted so that things can be seen clearly; to
so that you can see things clearly: [V] Let your
on objects that are further away from you. ◇ It t
moments for her eyes to focus in the dark. ◇ In t
the camera focuses on the actor's face. ◇ [VN] He fo
blue eyes on her. ◇ I quickly focused the camer
children. 3 [VN] ~ sth (on sth) (technical) to aim
light onto a particular point using a LENS
■ noun (pl. fo·cuses or foci /ˈfəʊsaɪ; AmE ˈfoʊ-/)
usually sing.] ~ (for/on sth) the thing or person
people are most interested in; the act of paying
attention to sth and making people interested in it
the main focus of attention at the meeting
ments provided a focus for debate. ◇ In
focus will be on tax structures within
the incident brought the pro
sharp focus.
of the customer
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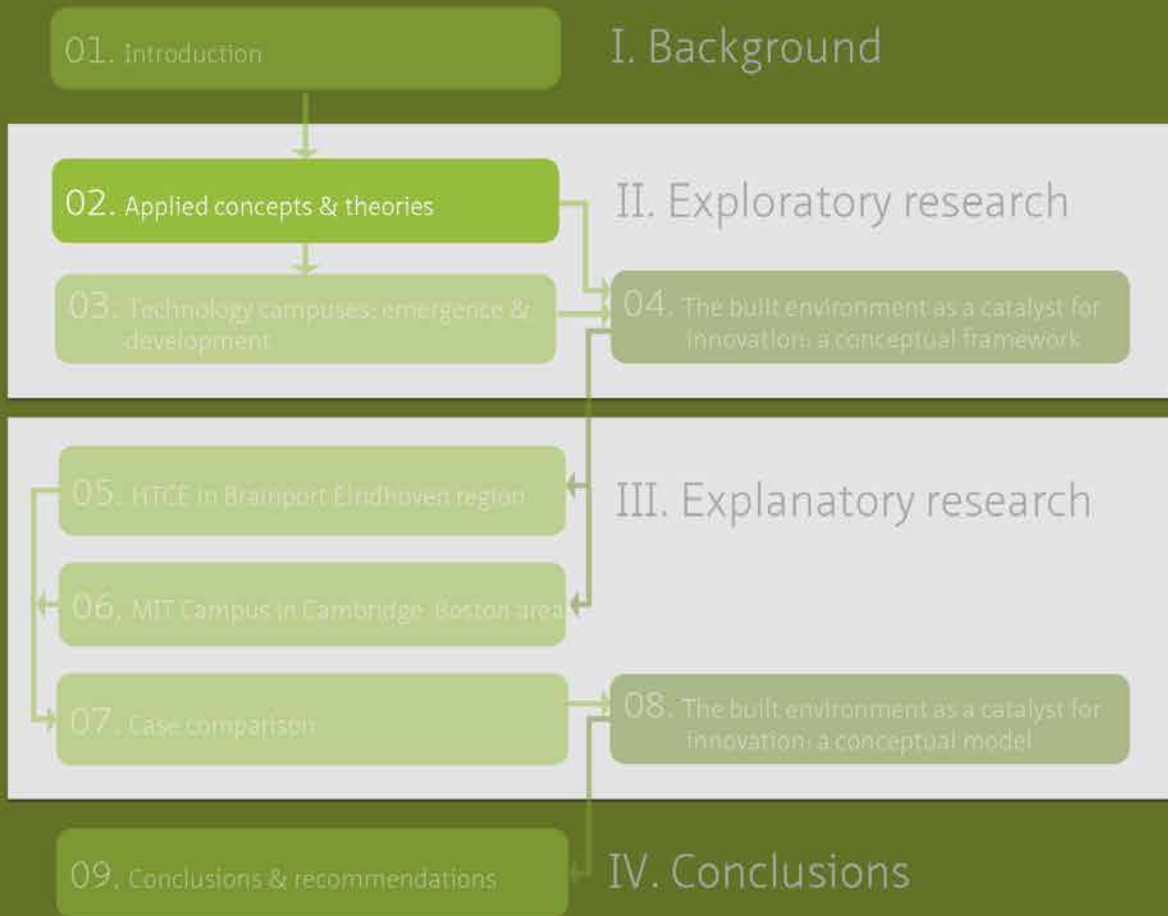
Chapter 2. Applied concepts and theories



Studying 'the role of the built environment in stimulating innovation' is a relatively unfamiliar subject in the literature. Besides its meaning in corporate real estate management, stimulating innovation is a topic increasingly promoted in the knowledge economy and widely investigated in the fields of management, policy, economic geography and regional studies. This chapter outlines existing concepts from three complementary fields of study, which contribute to answering the question: ***What is the role of the built environment in innovation in theory?***

This chapter aims to uncover and to position the role of the built environment in stimulating innovation in a scientific context. Section 2.1 begins with introducing the logic of this chapter. Section 2.2 presents fundamental concepts discussed in the field of corporate and public real estate management, which is the research field through which this topic is approached. Section 2.3 outlines both stimulating innovation and the role of the built environment in the context of the knowledge economy. Section 2.4 discusses concepts from economic geography, urban studies and regional studies in which the topic "stimulating innovation" is discussed from a spatial perspective establishing links with the built environment. Lastly, Section 2.5 draws the conclusions of this chapter and how its findings can be used to investigate further the subject of study.

2 Applied concepts and theories

§ 2.1 Introduction

§ 2.1.1 Chapter aim and questions

This chapter aims to uncover and to position the role of the built environment in stimulating innovation in a scientific context. Its main objective is to gather existing knowledge that provides a theoretical basis for this research. The expected theoretical insights will be used to develop a conceptual framework or analytical tool to further conduct the next research phase (Exploratory research or Part III of this dissertation).

This chapter addresses as main question: **What is the role of the built environment in innovation in theory?** Next to it, the following set of sub-questions guided this theoretical exploration:

- What is known about the role of the built environment in stimulating innovation in the literature?
- What are the key sources and theories related to this topic?
- What are the major issues and debates that have been raised up to date?
- Which concepts can be used as theoretical grounds to address this topic?

§ 2.1.2 Methods

This chapter is the result of a literature review, which is one of the parallel strategies used in the exploratory research. The review of the literature is used to fill a theoretical knowledge gap about the object of study 'the role of the built environment stimulating innovation in the knowledge economy' [See Figure 2.1]. This topic is gaining momentum in research from various complementary fields but it remains broad and unfamiliar because 'built environment' and 'innovation' have been treated as unconnected subjects.

Thus, the review of the literature about the built environment and innovation in the context of the knowledge economy integrates existing knowledge at the intersection of three primary disciplines (i.e. corporate real estate management, economic geography and urban studies in the knowledge economy). These disciplines provided theoretical notions, which can be applied at area level to study the development of technology campuses. These theoretical insights defined a research area that connects also urban planning, architecture, science and technology and regional policy in a broad sense.

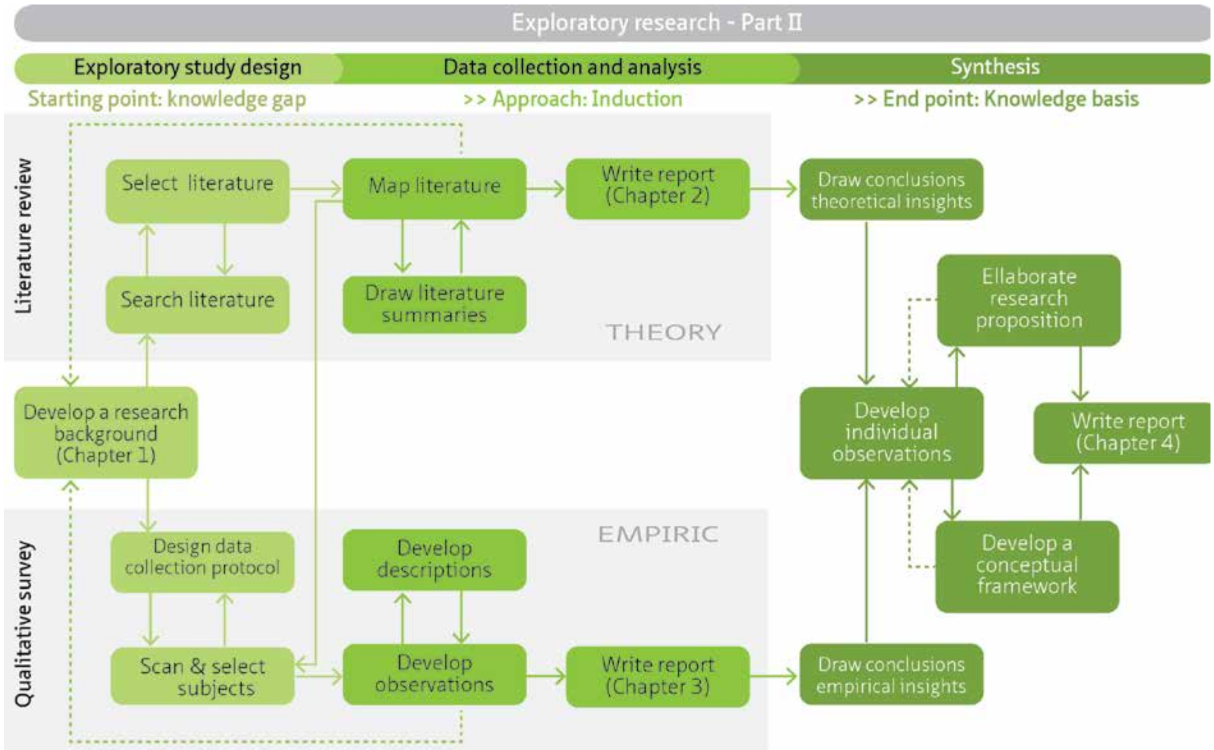


Figure 2.1 Exploratory study methods and phases. This chapter is the output of the 'theory box' outlining literature review as main method of data collection and analysis.

The insights of this chapter, in combination with the empirical insights from the qualitative survey, will form the synthesis of the exploratory research and constitute the knowledge basis required to answer further this research main question.

Data collection and analysis

As shown in Figure 2.1, the literature review comprised five main activities used to locate and summarise the object of study within existing theories and/or scientific research.

First, it gathers material through literature search focusing on the knowledge economy as a relevant context to investigate the subject. This activity used computer databases (e.g. Scopus, Google Scholar, etc.) and physical libraries of universities to easily access the relevant and available literature.

Second, it selects preliminary materials that have content on the built environment in stimulating innovation. At this point, a revision of the recommended bibliography on this selection leads to a new round of search and selection of the literature.

Third, it draws a literature map based on the selected materials helping to connect the different themes and fields of study. Similar, the mapping of the literature triggers a back loop in the process of developing the research background.

Fourth, it summarises the most relevant articles or books that were used in writing the review. The relevance was determined by (1) the match between the content of the body of information and the keywords used to specify the search, and (2) the quality of the source indicated by the number of citations and standing in the built environment sciences.

For instance, conceptualising and coding are used as techniques to go back and forth between the themes of the literature map and the summaries. The major themes and more important concepts addressed in the summaries are used to give structure to the literature review suggesting a particular research area to further add to this study.

Last, it reports the findings in this chapter that provide a preliminary theoretical frame for this research. Overall, these activities were carried out in the sequence described above. Nevertheless, some of the activities overlapped because the review process demanded simultaneous steps back and forward. Also, the literature has been revised in the last stage of the study to avoid missing important viewpoints.

The following paragraphs discuss the relevant body of information that will uncover and position the role of the built environment in stimulating innovation in a scientific context, and why this is important in the contemporary context of the knowledge economy. Thus, this review is organised in three main parts that provide a theoretical framework that integrates different fields [See Figure 2.2]. Section 2.2 outlines the scientific approach of this research from the field of corporate real estate management. Section 2.3 outlines the contemporary scientific context outlining both stimulating innovation and the role of the built environment in urban studies in the knowledge economy. Last, section 2.4 elaborates on concepts from economic geography and regional studies in which 'innovation' is discussed from a spatial perspective.

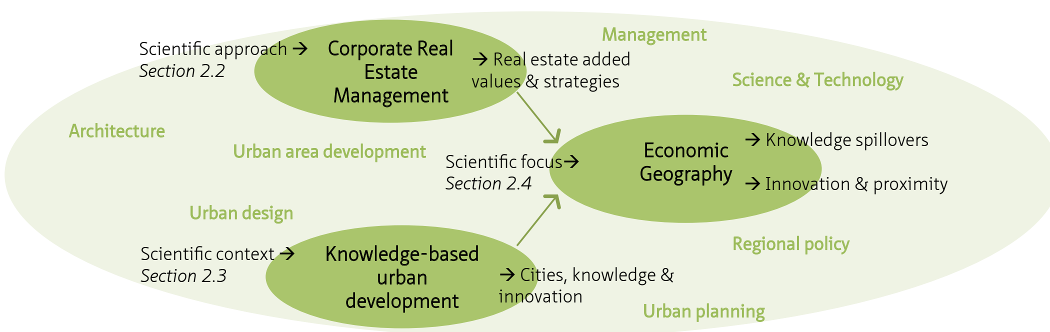


Figure 2.2 Research areas and fields explored in the literature review providing a theoretical framework for this research.

§ 2.2 The role of the built environment in stimulating innovation

Definition

Management *is the process of steering resources (e.g. people, knowledge, capital, technologies, etc.) in the pursuit of organisational objectives, while handling relationships with stakeholders and other resources, both within as well as between organisations.*

Adapted from (Clegg et al., 2008)

This section outlines the scientific approach of this research that derives from a specific field of study. This literature review begins with the researchers' assumption that *the built environment is* a *resource supporting the goals of organisations* as discussed in theories of corporate and public real estate management (CREM/PREM), which is the research field providing background to this study.

Scholars define CREM/PREM as the management of a real estate portfolio by aligning the portfolio and services to the objectives of an organisation and the needs of its end-users and other stakeholders. (De Jonge et al., 2009) The main distinction between corporate and public real estate is that the first refers to the portfolio of private companies (e.g. banks, firms, multinational corporations, etc.) while the second refers to the portfolio of public organisations (e.g. governments, governmental agencies, and/or non-for-profit institutions like universities). This field is widely known as CREM.

In research, CREM is defined as 'the management of a corporation's real estate portfolio by aligning the portfolio and services to the needs of the core business (processes), in order to obtain maximum added value for the business and to contribute optimally to the overall performance of the corporation' (G. P. R. M. Dewulf et al., 2000). Existing studies in this field, focused on the practice of Real Estate Management (REM) from the end-user's view, which deals with activities that vary from developing real estate strategies, developing building projects, up to maintaining and managing the built space in the portfolio of an organisation. Accordingly, this research considers the development of technology campuses as an exemplar practice of REM because it involves most of these activities.

Empirical research on REM has focused on one or the combination of these activities (e.g. strategic management, project management, facility management, etc.), and on a specific application area (e.g. office, higher education, health care, etc.). Some others have developed concepts that can be applied on a more generic way to different areas. Although this is relatively young research field, there is relevant knowledge developed mostly from the corporate practice, which has been adapted to the real estate management of organisations in the public sector.

In this context, this section outlines first two important concepts from the review of the literature of CREM in order to make sense of the role of the built environment in stimulating innovation, especially for those readers who are not familiarised with knowledge in this research field. Last, it focuses on 'stimulating innovation' from the CREM perspective.

§ 2.2.1 Real estate as an organisational resource

Technology campuses are resources of universities, firms and governments engaged in the accommodation of tech-based research activities. The knowledge economy is the dynamic environment in which these organisations operate, which is affecting their values and the management of their built environments. Universities and R&D companies as well as other research institutions have become major actors in this context because their core processes deal with research activities leading to the development of new technologies, services and products. These advancements determine the competitive advantage of cities and regions in todays' knowledge society[4]. Evidently, municipal, regional and national governments are actively encouraging (and sometimes directly involved in) the accommodation of research activities leading to these outputs. Most technology campuses have emerged and developed along the 20th century, specifically since the early 1950s, throuought different periods of technological advancements in industrialised countries. However, the ways in which these and other built environments began to be seen as organisational resources have developed in management theories since the early 1990s.

Certainly, one of the most influential concepts in the field of CREM/PREM is the one coining corporate real estate as 'the fifth resource' (Joroff et al., 1993). Accordingly, real estate is outlined as a facilitator of the primary processes of an organisation next to capital, human resources, information and technology. This approach established corporate real estate as a management field, whose changing role was described in five evolutionary stages that moves from a technical towards a strategic focus. In this approach, the 'alignment' between corporate and real estate strategies is central as well as the dynamic environment in which organisations operate.

Simultaneously, Nourse and Roulac (1993) worked in a corresponding strategic approach of corporate real estate management outlining the relevance of real estate decisions contributing to the realisation of the overall business objectives on an enterprise. Accordingly, the 'articulation' between real estate strategy and corporate business strategy is a precondition to make effective real estate decisions favouring an enterprise's business[5]. This work pointed out that in obtaining such results managers must explicitly address how real estate strategies support corporate strategies. Furthermore, this study outlines that the driving force(s) of a company (in terms of products/markets, capabilities, and results) determines the business direction of a company, which changes over time with changes in specific environments.

Accordingly, these two studies positioned the dynamic environment in which organisations operate as an influential context for alignment between corporate and real estate strategy. Indeed, this context and the particular culture and value of the organisations determine the appropriate real estate strategy or strategies that effectively support the broad business objectives of such organisations. From the CREM perspective, technology campuses are hybrids subjects of study in the sense that their developments involve the objectives of different organisations.

Table 2.1 illustrates how these organisations might have similar driving forces (i.e. the creation of new knowledge and its application to develop new technologies) but different values and culture (i.e. the traditional mission of universities is to educate people and advance research for society, while R&D

4 Details about measures of innovation (inputs and outputs) are discussed in Section 2.3 of this chapter

5 Although some authors refer to this approach in a different way, this study will refer to it as alignment.

companies advance technologies targeted to yield return or profit). Demonstrating how technology campuses can act as organisational resources considering their hybrid corporate real estate status increases the relevance and complexity of this research considering that the driving forces of the involved organisations have changed with the knowledge economy.

ORGANISATIONS	Potential role(s) in campus development	Organisational objectives	Competitive driving force in the Knowledge economy
Universities and research institutions in technology	End-user Owner / Tenant Developer	Educate students and advance knowledge and research for the benefit of the society	Science & Technology
R&D and high-tech companies	End-user Owner / Tenant Developer	Support research and to apply new knowledge to develop new products and services for the profit of the company's business	Technology & Return/profit
Municipalities and regions	Developer Promoter	Support research for economic and societal development	Technology and Growth

TABLE 2.1 Organisations involved in the development of technology campuses. Note: competitive advantage is seen as dependent upon the exploitation of an organisation's internal resources and capabilities.

Another important aspect of managing a corporation's real estate portfolio is maintaining a balance between conflicting interests inside the organisation. According to Nourse and Roulac (1993) the implementation of real estate decisions involves negotiations between multiple parties, which have 'diverse objectives, resources, requirements and constrains'. These authors also outline that in these negotiations it is crucial for all the parties to identify their real interests in order to reach agreements when an explicit strategy is defined. Correspondingly, G. Dewulf et al. (2000) outline that balancing the conflicting interest inside an organisation requires different skills and activities.

This view is linked to a previous study that positions corporate real estate as a management field that deals with four domains or fields of focus within the organisation, connecting the demand and supply at both, strategic and operational levels (De Jonge, 1997). Further research linked these perspectives to specific stakeholders involved in real estate decision – i.e. policy makers, controllers, users, and technical managers (Den Heijer, 2006). These CREM models have been used as conceptual frameworks that facilitate the identification of the conflicting interest among the parties involved in the delineation and implementation of real estate strategies. A recent research on the management of university campuses (Den Heijer, 2011) expanded the application scope of these models by positioning in these four perspectives other relevant stakeholders outside the organisation and connecting organisational and physical scales [See Figure 2.3, Figure 2.4, and Figure 2.5].

Correspondingly, an important question has been posed in previous research in the CREM field: 'How can we measure the effectiveness of real estate strategy on corporate strategy?' In studying technology campuses as organisational resources, the focus must be placed on some specific aspects of real estate decision stimulating innovation as an organisational goal. In the early 1990s, geography and interpersonal interaction between workers were considered two basic issues with implications for the business strategy of specific organisations. For example, the demand for physical proximity (or not) in real estate decisions such as location and workplace settings were critical for generic strategies in which competitive advantage -as described in cluster theories- determined the driving force of many organisations (Nourse & Roulac, 1993, pp. 478, 479). Today, competition is still shaping the driving forces of universities of technology, R&D firms and governments involved in the development of technology campuses. However, the dynamic context of the knowledge economy is making the role of physical proximity in competition increasingly complex and important.

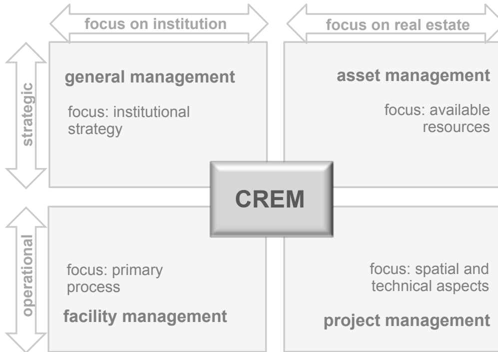


Figure 2.3 CREM domains model (De Jonge, 1997)

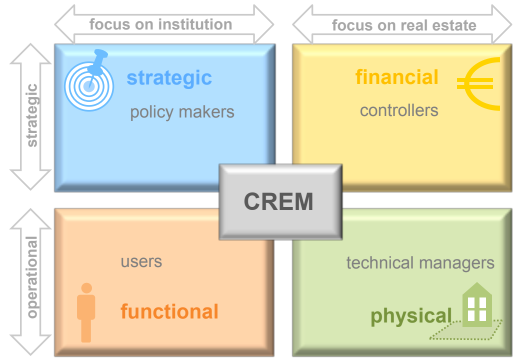


Figure 2.4 Stakeholders model linked to the four CREM perspectives (Den Heijer, 2006)

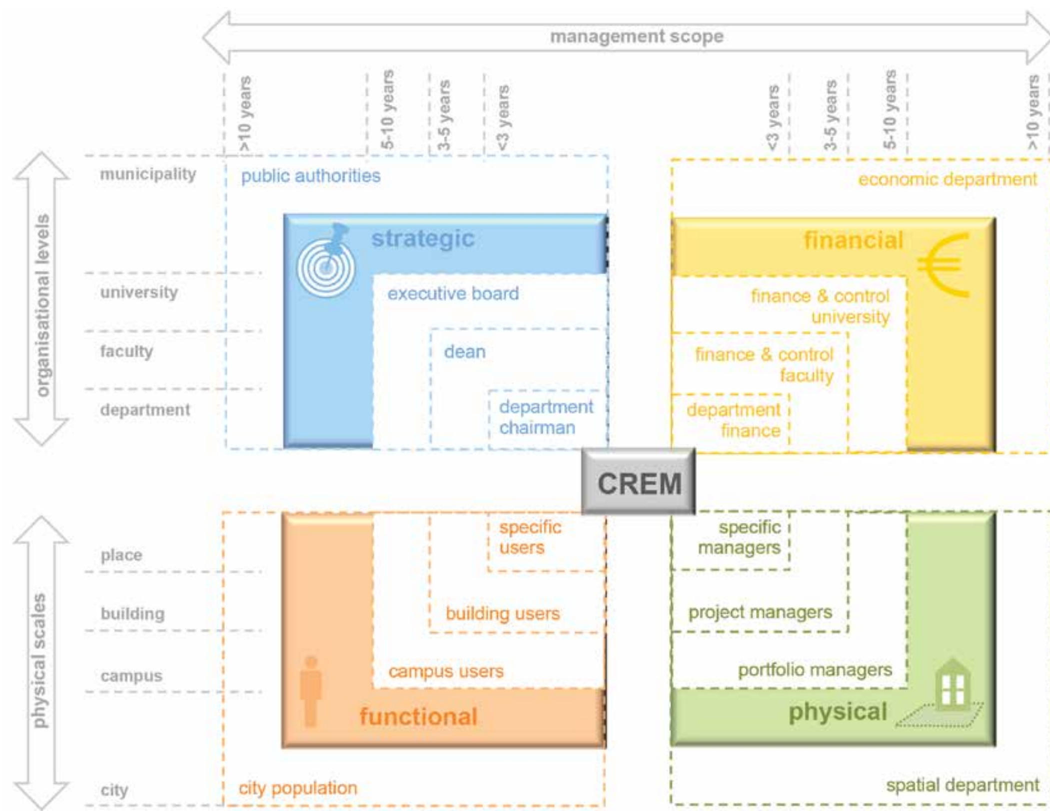


Figure 2.5 Multiple layers of stakeholders involved in campus management (Den Heijer, 2011)

This example reinforces the position that managing real estate has become managing the many uncertainties companies deal with when adapting to changes in their contexts. For instance, (1) the economy, (2) the user focus, (3) the dynamic between the functional, technical and economic lives of buildings, (4) the information technology, and (4) the environment are addressed as critical issues influencing the ways in which real estate should be managed (G. Dewulf et al., 2000). These -among other- aspects have been influencing the business environment of organisations, and therefore the ways of measuring the effectiveness of real estate strategy on corporate strategy.

In this theoretical context, the following four aspects determine the view of technology campuses as strategic organisational resources in stimulating innovation:

The first is the hybrid corporate real estate status of the subject of study due to the different organisational objectives and values impacting decisions in technology campuses – i.e. Technology campuses are strategic resources that suggest alignment between real estate and multiple organisations at area level.

The second is the dynamic context of the knowledge economy changing the competitive driving forces of the organisations involved in the development of technology campuses. For instance, an area to further explore in this literature is identifying the fundamental transformations of the knowledge economy affecting these organisations and the role of real estate in this context.

The third is the need for balancing the conflicting interests among internal and external stakeholders involved in the development of technology campuses. Campuses are large scale built environments that are an integral part of large physical and organisational contexts (e.g. cities and regions).

And the fourth is the ways of measuring the effectiveness of real estate strategies on organisations' strategies. This last aspect has been extensively addressed in the CREM literature, which has developed from eight types of real estate strategies to twelve added values of real estate. The following paragraphs elaborate on this last aspect and how it will be used in this research.

§ 2.2.2 The added value of real estate on organisational performance

Definition

Organisational performance *is the fulfilment of organisational goals according to the judgement of various stakeholders and their perspectives on their available resources including real estate.*

Adapted from De Vries et al. (2008).

The added value of real estate is based on the presumed impact of real estate on organisational performance. Added values can be seen as multiple courses of action on real estate that attempt to fulfil organisational goals. Indeed, studies that built knowledge upon this notion directly address to it either as real estate strategies (Lindholm et al., 2006; Nourse & Roulac, 1993), or as real estate added values (De Jonge, 1996; De Vries, 2007; Den Heijer, 2011). This concept and its contribution to organisational goals have been explored and categorised by many (Appel-Meulenbroek, 2014; De Vries, 2007; De Vries et al., 2008; Den Heijer, 2011; Jensen et al., 2012; Krumm, 1999; Lindholm et al., 2006; Lindholm & Leväinen, 2006; Scheffer et al., 2006; Van Der Zwart, 2014). Early studies used a generic approach to develop knowledge on the newly established field of CREM. Recent studies have applied the concept of added value when studying the practice of real estate management in different areas such as office, higher education, and health care.

Overall, these studies are connected and built upon each other generating new knowledge on the concept of added value of real estate in organisational performance. Figure 2.6 gives an overview of the relevant sources examined in this review of the CREM literature. Generally, this review has not attempted to cover and describe the entire world of added value in the CREM literature but the sources in this field that are meaningful for this study.

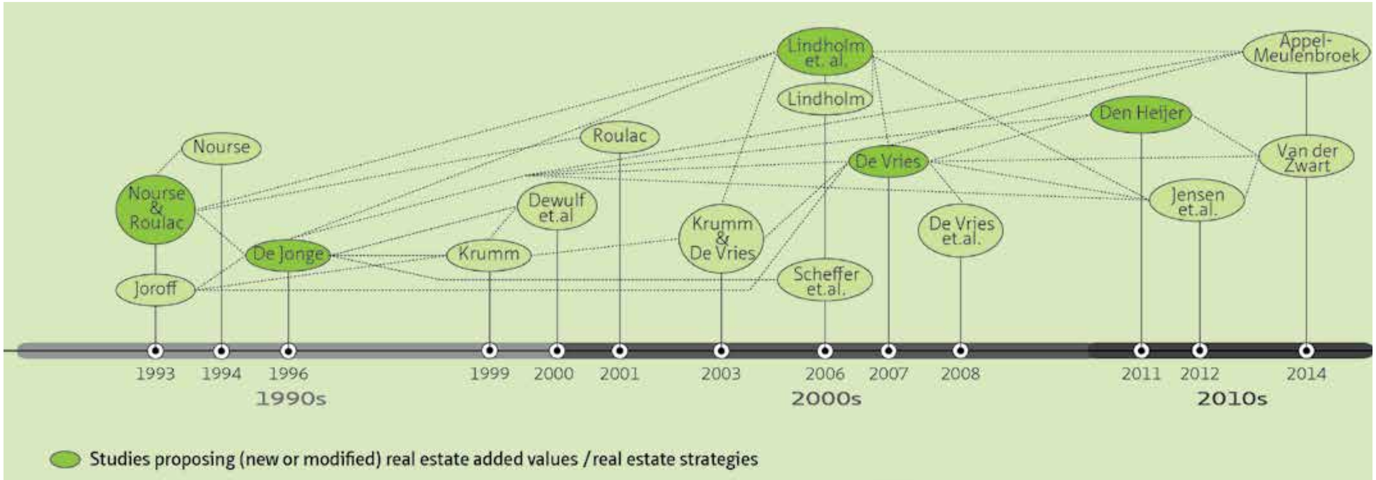


Figure 2.6 Map of relevant and interconnected sources building knowledge on the impact of real estate on organisational performance over the last two decades

Recently, Van Der Zwart (2014) reviewed the literature on the concept of added value of real estate listing a number of studies that have addressed this concept over the last two decades. This study served to identify five key sources that have contributed to expand the current knowledge of added value in the CREM field (These are highlighted in Figure 2.6). The review of these five studies uncovers ten aspects of organisational performance linked to real estate strategies or added values [See Table 2.2].

Accordingly, these studies used empirical data to outline different ways in which real estate is considered to contribute in attaining organisational goals. These ways, which are presented as real estate strategies, added values, and/or real estate goals and objectives, constitute the existing body of knowledge on the added value of real estate on organisational performance. Indeed, most of the added values relate to one another across studies because they focus on a specific aspect of organisational performance. These aspects are 1) costs; 2) real estate value; 3) risk control; 4) flexibility; 5) productivity; 6) users' satisfaction; 7) image; 8) innovation; 9) culture; and 10) sustainability. From this list, costs, real estate value, flexibility, productivity, and image are the most persistent aspects addressed across the studies, followed by users' satisfaction and innovation. Regardless the minor differences in their approaches, these studies outline similar attributes in the concept of real estate added value that deserve attention in this research and will be addressed as follows.

	KEY SOURCES ON THE ADDED VALUE OF REAL ESTATE FROM THE CREM LITERATURE				
ASPECTS OF ORGANISATIONAL PERFORMANCE	Nourse & Roulac (1993) *8 Real estate estrategies*	De Jonge (1996) *7 Elements of added value of real estate*	Lindholm et al. (2006) *7 Real estate (alternative) strategies*	De Vries (2007) *10 Real estate added values*	Den Heijer (2011) *12 Added values of real estate*
Costs	Occupancy cost minimisation	Cost reduction	Reduce costs	Reducing costs	Decreasing costs
Real estate value	Capturing real estate value creation	Increase of value	Increase value of assets	Expanding funding possibilities	Increase real estate value
Risk control		Risk control		Controlling risks	Controlling risks
Flexibility	Flexibility	Increase of flexibility	Increase flexibility	Enhancing flexibility	Increase flexibility
Productivity	Facilitating and control production, operations and service delivery	Increasing productivity	Increase productivity	Increase productivity	Supporting user activities
Users' satisfaction	Promoting human resource objectives		Increase employee satisfaction	Increasing satisfaction	Increasing (user) satisfaction
					Improving quality of place
Image	Promote marketing message	PR & Marketing	Promote marketing and sale	Supporting image	Supporting image
	Promote marketing message				
Innovation	Facilitating managerial process and knowledge work		Increase innovations	Stimulating innovation	Stimulating innovation
				Synergy or Improving collaboration	Stimulating collaboration
Culture		Changing the culture		Improving culture	Supporting culture
Sustainability					Reducing footprint

TABLE 2.2 Key sources on the added value of real estate from the CREM literature linking real estate strategies or added values to ten aspects of organisational performance. Adapted from Van der Zwart (2014)

Real estate added value is versatile

The added value of real estate on organisational performance is understood as the contribution of multiple real estate strategies in attaining different organisational goals. A central point of discussion in the literature is how to measure the actual contribution of real estate to organisational performance. This complex process involves understanding organisational driving forces while balancing individual's perspectives.

An early viewpoint (Nourse & Roulac, 1993) suggested that the link between real estate strategy and corporate strategy is determined by the driving force(s) of the company, which may change over time. In this study, they use nine possible strategic driving sources based on Tregoe and Zimmerman (1980), who considered all nine forces important to a business but only one as the primary force determining the strategy of the business [See Table 2.3]. These strategic forces where used to identify priorities of the eight real estate strategies proposed in their research.

Accordingly, Nourse and Roulac (1993) concluded that there is no single but multiple real estate strategies and priorities required to support a range of organisational goals. For example, companies driven primarily by 'technology' might place emphasis on specific real estate strategies compared to companies driven by 'return and profit'. Also, it can be that forces such as 'technology' or 'market needs' currently drive companies, which in the past were driven by 'production capabilities'. Overall, they suggested the proper combination of real estate strategies varies depending on the corporation's strategic position within the market.

	CATEGORIES		
	Products/ Markets	Capabilities	Results
9 Strategic driving forces of an organisation	1. Products offered	3. Technology	8. Size/Growth
	2. Market needs	4. Production capability	9. Return/Profit
		5. Method of sale	
		6. Method of distribution	
		7. Natural resources	

TABLE 2.3 Strategic driving forces of an organisation determining the business strategy according to Tregoe and Zimmerman (1980). Adapted from Nourse and Roulac (1993).

This view is supported by Lindholm and Leväinen (2006), for whom firms are structured and focused in different ways wanting different results from their real estate. Thus, there is no one indicator of good performance by real estate because real estate is expected to serve multiple roles within an organisation (Lindholm et al., 2006).

A complementary viewpoint (De Jonge, 1996) outlined a focus of CREM on the interests of corporate stakeholders rather than only problem solving. Accordingly, his seven elements of added value contribute to the evolution of real estate as a strategic resource of an organisation. This viewpoint grew in interest among researchers on the CREM field. Recent studies outline that adding value is determined by the stakeholders' perception of attaining the organisational goals (De Vries, 2007; De Vries et al., 2008; Den Heijer, 2011; Jensen et al., 2012; Lindholm et al., 2006). Thus, the balance of the different perspective of stakeholders is also determined by the priority given to the stakeholders' perspectives within the overall corporate strategy.

According to Lindholm et al. (2006), the supporting role of CREM is defined by seven strategies developed to maximise the wealth of shareholders in firms. This is based on the consideration that firms increase economic value by means of revenue growth and productivity. Their seven real estate strategies are categorised in these two performance criteria, which can be seen as the driving forces aimed to increase shareholder value – i.e. the financial perspective is priority within the overall corporate strategy. Therefore, CRE performance can be measured not only through space efficiency, cost reduction, and capital minimisation, but also through increased revenues.

Further studies have built upon this approach adding more performance criteria through the study of added values in different organisations. For instance, De Vries (2007) outlines that organisational objectives differ and can be categorised into productivity, profitability, and comparative advantage or distinctiveness. Thus, her ten real estate added values are also classified into these categories. More recently, Den Heijer (2011) distinguishes four main performance criteria in organisations: competitive advantage, profitability, productivity, and sustainable development. These criteria are based on the study of campus management in universities but they are not exclusive for university and can be applied to other organisations. However, organisations give different priorities to a specific performance criteria – e.g. in the case of universities, competitive advantage is a priority. Thus, her twelve added values are categorised into these four performance criteria, which are linked to four stakeholders' perspectives. Overall, these two last approaches reinforce that performance refers to more than financial results and goals. Table 2.4 shows an overview of the additive categorisations of real estate added values per performance criteria covering the four CREM perspectives and domains.

		Sustainable development	Physical – Project management
	Distinctiveness	Competitive advantage	Strategic – General management
Productivity	Productivity	Productivity	Functional – Facility Management
Revenue growth	Profitability	Profitability	Financial – Asset Management
Lindholm et.al., 2006	De Vries, 2007	Den Heijer, 2011	CREM perspective - domain

TABLE 2.4 Performance criteria in which added values have been categorised in research linked to CREM perspectives and domains.

All in all, these studies also outlined the lack of proper measurements or performance indicators making difficult to demonstrate the effect of real estate on performance[6]. That is because the relationship between real estate and organisational performance is complex. Companies are different; they have multiple goals based on the perspective of different stakeholders, they formulate their organisational objectives in different ways according to their core values and businesses, and to changes in the context in which they operate. Thus, the same real estate strategy might contribute to organisational performance in multiple ways by the judgement of different stakeholders.

Accordingly, Table 2.5 shows how the ten aspects of organisational performance identified in this literature review are linked to single or multiple performance criteria depending on the study. Some of these aspects are seen differently from the perspective of the stakeholders.

CREM perspectives	**Strategic**	**Functional**	**Financial**	**Physical**
CREM domains	*General management*	*Facility management*	*Asset Management*	*Project management*
Stakeholders	*Policy makers*	*Users*	*Controllers*	*Technical managers*
Performance criteria Aspect	*Distinctiveness* *Competitive advantage*	*Productivity*	*Profitability*	*Sustainable development* *Adaptability*[1]
Cost			YES	
Real estate value			YES	
Risk control			YES	
Flexibility	YES		YES	YES[1]
Productivity	YES	YES	YES	
Users' satisfaction		YES	YES	
Image	YES		YES	
Innovation	YES	YES	YES	
Culture	YES			
Sustainability				YES

[1] Added values or strategies referring to 'flexibility' are not explicitly categorised from a physical perspective. However, several studies repeatedly addressed the need for functional, financial, and physical flexibility of real estate because of the changing and competitive environment in which organisations operate. Thus, the review of the literature in this study suggests 'adaptability' as an implicit performance criterion for this added value linked to the physical perspective.

TABLE 2.5 Performance criteria in which added values have been categorised in research linked to CREM perspectives and domains.

6 According to De Vries et al. (2008) input indicators are not sufficient to measure the performance of real estate portfolios because they focus on the efficiency but not the effectiveness of strategic decisions.

When looking at these aspects from the categorisations made by some researchers one can observe there are some added values whose contribution to organisational performance is perceived differently by the stakeholders, and that is pretty much determined by the core business of the organisation. Accordingly, flexibility, productivity and innovation are good examples of aspects linked to multiple performance criteria covering most CREM perspectives and domains.

This overview illustrates the complexity of this research, which seeks to investigate stimulating innovation as an organisational goal and in different types of organisations. Certainly, it is clear that depending on the organisation innovation is perceived differently and the impact of real estate on performance is measured accordingly. In this sense, the identification of common performance criteria in different organisations facilitates the focus of this research – e.g. in the further selection of subjects of study.

Real estate added value is interdependent

The added value of real estate on organisational performance is understood as the combined effect of interdependent real estate strategies. As described before, organisational performance is measured in terms of difference performance criteria and by the judgement of different stakeholders. According to De Vries (2007), it is difficult to isolate the effect of real estate on performance because there is a relation between added values within and also across categories – e.g. increasing flexibility can lead to reducing cost, but also to stimulate innovation.

This relationship between real estate strategies was addressed by Nourse and Roulac (1993) in an early research. Furthermore, they outlined the relationship of real estate strategies with other functional strategies within the firm such as promoting human resources or marketing objectives. However, this relationship is not always a reinforcing one. For instance, some added values may reinforce but also neutralise each other's effect. In the worst-case scenario, they can have a combined negative effect frustrating the goals of stakeholders (De Vries, 2007). This view is also shared in further research. According to Den Heijer (2011), isolating the positive effect of real estate on organisational performance can be more difficult than outlining its negative effect.

Real estate added value is intermediary

The added value of real estate on organisational performance is understood as strategic courses of actions guiding real estate operational decisions. This attribute is key for corporate real estate managers -and other decision makers of the built environment- because it clarifies paths to attain organisational goals through real estate.

Early, Nourse and Roulac (1993) outlined that 'real estate strategies encompass real estate decisions but in a strategic context within the broad aims of the firm'. This view differentiates two levels linking real estate decisions to corporate strategy. The first level links business strategy to real estate strategy and the second links real estate strategies and real estate operating decisions. Indeed, they distinguish fourteen types of real estate operating decisions that must be addressed in each real estate strategy[7]. In this context, a particular real estate strategy is the instrument to set objectives and guide real estate decisions.

7 These are 1) location, 2) quantity (amount of space), 3) tenancy duration, 4) identity/signage, 5) building size/character, 6) building amenities, 7) exterior quality, 8) company space (work environment), 9) mechanical systems, 10) information/communication systems, 11) ownership rights, 12) financing, 13) control, and 14) risk management.

This view is supported in further studies that attempted to simplify the relationships between real estate and organisational performance through conceptual models. According to Lindholm et al. (2006) real estate strategies guide operating decisions. Their model illustrates how corporate real estate directly and indirectly adds value to the core business and the wealth of the firm (e.g. Performance, productivity, usability and functionality results from real estate decisions). In this view, real estate strategy derives from the business strategy, which derives from the vision and mission of the company. Lindholm et al. (2006) adressed that 'real estate decisions affect financial outcomes through causal pathways involving two or three intermediate stages' (i.e. real estate strategies, tactical decisions, and actions). However, while making optimal decisions real estate managers must balance the perspectives of different stakeholder. Indeed, according to Lindholm et al. (2006) the four CREM domains outlined early by De Jonge (1996) are the vehicles to implement real estate strategies.

Likewise, De Vries (2007) asserts that added values can be used to pinpoint different objectives of real estate interventions. In her descriptive model, the process of adding value is demonstrated in terms of input-process-output (i.e. real estate interventions – business processes - performance criteria). In a further research, De Vries et al. (2008) studied five potential real estate interventions connected to organisational performance in higher education institutions: maintenance, functional adjustment, reshuffling, renovation, and new building. The study concluded that the relationship between real estate interventions and organisational performance is a complex one but interventions can be connected to performance criteria such as competitive advantage, profitability and productivity. Thus, there is an opportunity in further research to 'broaden the range of potential real estate interventions and to study different types of interventions more in-depth' (De Vries et al., 2008). In this context, interventions can be seen as the implemented choices of real estate decisions.

Recently, Den Heijer (2011) took forward the instrumental role of real estate added values. In her study of managing university campuses, the concept of added value is used to define campus projects (ex-ante) and evaluate past campus decisions (ex-post). In her descriptive model, the process of adding value is demonstrated in terms of input – throughput - output (i.e. real estate decisions - real estate goals - performance criteria). Accordingly, her improved model of adding value is seen as a tool that can be used either way, 'before taking a real estate decision to make a business case, or after implementing a real estate decision to make a post-occupancy evaluation'. In this context, every real estate intervention and decision should be justified by its positive effect on specific performance criteria relevant to different organisations.

Although there are differences in the meanings of each theoretical model, this research acknowledges the positioning of real estate interventions and decisions as input resources in different processes and leading to different outcomes in organisations.

This review distinguishes, then, two main levels of adding value through real estate (i.e. strategic and operational). Positioning real estate strategies, decisions, and interventions illustrate the paths that determine the relationship between real estate and organisational performance [See Figure 2.7]. Accordingly, the indirect relationship between corporate strategy and real estate intervention accounts for the complexity of measuring the impact of real estate on organisational performance. This is especially important because the entire shift of corporate real estate management is based on the presumed effect that such operational interventions and decisions may have at strategic level within an organisation.

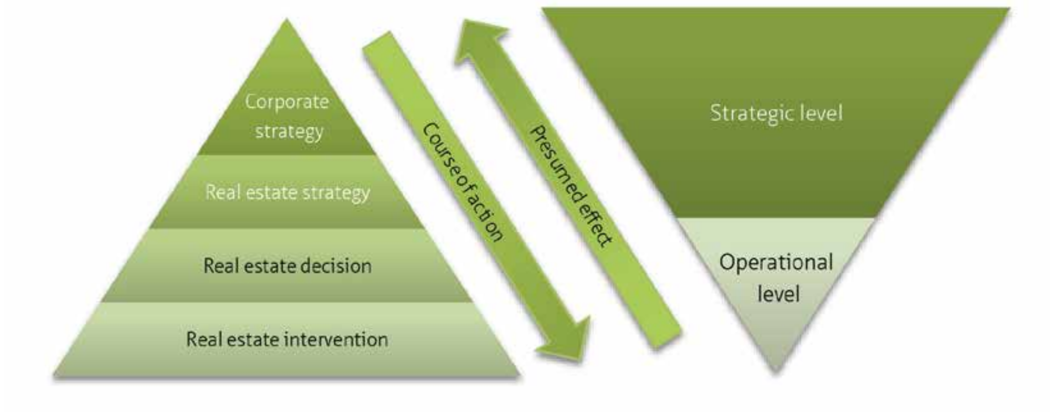


Figure 2.7 Levels of adding value to organisational performance through real estate based on an interpretation of the CREM literature

Largely, managing real estate is a challenging task that requires both knowledge and skills to be able to choose and implement real estate strategies that are versatile, interdependent, and intermediary in supporting organisational goals. Researchers in the CREM field require awareness of this complexity, which is at the core of the existing body of knowledge of added value. Studying the role of the built environment in stimulating innovation from the CREM perspective requires the specific review of 'innovation' as an aspect of organisational performance. The following section discusses 'stimulating innovation' as an added value – i.e. its versatility in matching specific performance criteria judged by different stakeholders, its interdependence with other added values, and its intermediate role in guiding and justifying specific real estate decisions and interventions.

§ 2.2.3 Stimulating innovation: organisational goal, real estate strategy, and added value.

As seen in the CREM literature, many studies have addressed innovation as an aspect of organisational performance. Indeed, stimulating innovation (also referred to as increasing innovation) is one of the real estate strategies and added values proposed by most of these authors. Besides, it is one of the most versatile added values studied in the CREM field [See Table 2.6]. Depending on the study and the application area, innovation contributes to organisational performance by means of competitive advantage in firms driven by technology capabilities (Nourse & Roulac, 1993); revenue growth in firms across different industries (Lindholm et al., 2006); productivity in higher education institutions (De Vries, 2007); and competitive advantage in universities (Den Heijer, 2011).

	Performance criteria		
Application field	*Competitive advantage*	*Productivity*	*Revenue growth*
Firms (for-profit organisations)	Facilitating managerial process and knowledge work (Nourse & Roulac, 1993)		Increase innovations (Lindholm et.al., 2006)
Higher education institutions (non-for-profit organisations)	Stimulating Innovation; Stimulating collaboration (Den Heijer, 2011)	Stimulating innovation; Enhancing synergy and collaboration (De Vries, 2007)	

TABLE 2.6 Key studies addressing strategies related to innovation as an aspect of organisational performance.

A recent study on the added value of CRE and building design (Appel-Meulenbroek, 2014) distinguishes 'increasing innovation' as an added 'use' value rather than an added 'exchange' value[8] - i.e. this added value is strongly related to other functions within the organisation having an indirect effect on the people who occupy the CRE. Accordingly, the strategies 'increase productivity', 'increase employee satisfaction', and 'support marketing and sales' fall also into this category, and are addressed by the author as difficult to separate. Similarly, other studies have outlined the interdependence of stimulating innovation with other added values or real estate strategies. Correspondingly, such relationships are also determined by the way in which these added values or real estate strategies are categorised by different authors. Table 2.7 illustrates how innovation is related to other six aspects of organisational performance as seen in different studies. According to most of the studies reviewed, innovation and user's satisfaction (and in some degree image) are mutually dependant aspects of organisational performance regardless the priority given to specific performance criteria in different organisations.

	Performance criteria				
	Competitive advantage		*Productivity*		*Revenue growth*
Key source Aspect	*Nourse & Roulac (1993)**	*Den Heijer (2011)*	*De Vries (2007)*	*Appel-Meulenbroek (2014)^*	*Lindholm et.al. (2006)*
Innovation	Facilitating managerial process and knowledge work	Stimulating Innovation	Stimulating innovation	Increase innovation	Increase innovations
		Stimulating collaboration	Enhancing synergy and collaboration		
Users' satisfaction	Promoting human resource objectives	Improving quality of place	Increasing satisfaction	Increase employee satisfaction	Increase employee satisfaction
Image		Supporting image		Support marketing and sale	Promote marketing and sale
Productivity				Increase productivity	
Culture		Supporting culture			
Flexibility	Flexibility				
Real estate value					Increase value of assets

*They categorise these three real estate strategies because of their priority in firms driven by technology capabilities as a competitive driving force.
^ The author categorises these four strategies as use value strategies, which have an indirect effect on people as the most important production factor.

TABLE 2.7 Interdependence among real estate strategies or added values defined by categories in performance criteria according to different studies.

In the case of universities of technology, research institutes, R&D companies, local governments and other organisations interested in the development of technology campuses, stimulating innovation is a goal whose contribution to organisational performance differs among these organisations. For instance, competitive advantage and productivity are suitable performance criteria for all these organisations when stimulating innovation because they are driven by technology as competitive force,

8 According to Appel-Meulenbroek (2014), corporate real estate management can add value to the organisations in multiple ways. First, through 1) reducing costs, 2) increasing the values of the assets, and 3) increasing flexibility, which are distinguished as added exchange value. Second, through 4) promoting marketing and sales, 5) increasing innovation, 6) increasing employee satisfaction, and 7) increasing productivity, which are distinguished as added use value. The first distinction lies within the expertise field of the corporate real estate manager while the second is in tune with other business functions such as human resources, R&D, and marketing & sales.

and knowledge capabilities (embedded in people) as a crucial production factor. Nevertheless, R&D companies -in contrast to universities- may give priority to profitability as performance criteria because they are also driven by financial return and profit. Likewise, municipalities and regions are increasingly giving priority to economic growth as performance criteria since both, technology and people define the wealth of cities and regions in today's knowledge economy.

In this context, the versatility and interdependence of innovation as an aspect of organisational performance can be used to position the different organisations, for which stimulating innovation is a goal in the development of technology campuses [See Table 2.8]. Accordingly, stimulating innovation can be studied as a real estate strategy aimed to support three different performance criteria, but also interconnected to two other aspects of organisational performance. This illustrates that in the case of technology campuses; competitive advantage and productivity can be seen as common performance criteria for all these different organisations. In the knowledge economy, competitive advantage is a crucial performance criterion for organisations whose core business is technology-based research, which may lead to productivity, profitability or distinctiveness. This research considers stimulating innovation as *one of the ways in which the built environment has an effect on the competitive advantage of organisations involved in the development of technology campuses*.

		Versatility		
	Performance criteria Aspect	*Competitive advantage*	*Productivity*	*Profitability / Economic growth*
Interdependence	Innovation			
	Users' satisfaction	Universities and research institutes in technology fields		R&D and high-tech companies Municipalities & Regions
	Image			

TABLE 2.8 Positioning the organisations involved in the development of technology campuses according to the versatility and interdependence of innovation as an aspect f organisational performance.

Innovation-related real estate decisions and interventions

Measuring the added value of real estate is a critical part in the CREM literature since early researches. For instance, Nourse (1994) addressed the need for better real estate performance measures to reflect how real estate is being used in the business. According to Lindholm et al. (2006) the lack of indicators and financial outcomes make difficult the comparison of alternative CREM strategies. This view is shared by De Vries et al. (2008) who addressed measuring the added value of real estate is uneasy because of the lack of outcome indicators for some of the added values. For instance, according to Lindholm et al. (2006), key performance indicators can 'be used to quantitatively assess whether real estate decisions are having the desired effect on the financial success of the firm', and 'will allow managers to adjust real estate strategies and operations accordingly'. However, can this be done for all added values? For instance, what sort of performance indicators would organisations use to quantitatively assess if real estate decisions or interventions will stimulate innovation? This section tries to give an answer on these questions.

An early viewpoint (Nourse & Roulac, 1993), suggests that strategic-specific approach rather than generalised approaches is recommended in linking real estate to corporate strategy – i.e. Corporate strategy is defined by a specific driving force. Correspondingly, some real estate strategies are priorities to specific organisations depending on their driving forces. Ultimately, some real estate operating decisions are more relevant than others depending of the specific real estate strategies. For instance, they consider three specific strategies as priorities for firms driven by technology such as universities and R&D companies[9]. First, 'Flexibility' because of real estate must be capable to adapt to the short life cycles of their products and services, which tend to change rapidly. Second, 'Promote human resource objectives' because they need to attract and retain technical or highly educated personnel. And third, 'Facilitate managerial process and knowledge work' because they need to promote learning and creativity inside the organisation.

Accordingly, company space (i.e. the design and functionality of the working environments) is a priority real estate decision for all the three strategies mentioned above. Next to it, location, building amenities, and control over space are other relevant decisions for these three strategies. Indeed, the third real estate strategy (i.e. facilitating managerial processes and knowledge work) appeals for the design of physical workspace for knowledge work or the type of work characterising senior management functions in organisations. For instance, concepts of space facilitating meeting is outlined as crucial[10]. In further research, Roulac (2001) extended this knowledge by outlining that 'the values and identity of a place can stimulate, reinforce or obstruct managerial process, by providing significant stimulus to creativity or encouraging inward focus'.

In this study, he addresses 'stimulate innovation and learning' as one of the seven contributions of real estate strategies to the competitive advantage of the organisation. Accordingly, locations and facilities are considered as corporate real estate decisions that can enhance innovation and learning. In this view, the ambience of places where facilities locate, the access to learning resources, and the stimulus of the spaces in which organisations operate are interdependent aspects of real estate impacting innovation and learning. For instance, real estate locations within markets of creativity are crucial, influenced by the idea that creativity is one of the most important capabilities to achieve growth within organisations.

In this context, this early study suggested that in the future there would be more demand for properties, goods and services in creative markets. Indeed, this observation is close to the reality of today's knowledge economy in which the advancements in technologies have influenced the trajectory of several companies increasingly driven by R&D in technology fields and dependant on the creativity of highly educated people. Such demand, has positioned specific features of real estate as key sources of competitive advantage. That is because companies must ensure their workplaces and locations appeal to the creative staff they employ and want to attract. Thus, 'attracting and retaining outstanding people' is addressed as another important contribution of real estate strategy to the competitive advantage to an organisation linked to real estate strategy 'promoting human resources objectives' (Roulac, 2001).

A recent study applying CREM theories (Den Heijer, 2011) aligns with Roulac's view by addressing human resource as the most important assets of universities. Aligning individual needs to organisational goals is an important aspect of CREM in this type of organisations. In today's competitive environment for talent, keeping satisfied the users, who will become the knowledge workers of the cities and regions where universities locate, has become an essential organisational goal that can be supported by

9 According to Nourse and Roulac (1993) technology is a driving force in organisations that 'defines the business by attempting to provide products, services, and markets derived from its technological expertise. The search is for applications of its technology. Its capabilities support research in its field of knowledge and in finding applications for this knowledge in new products.'

10 The implementation of workplace facilitating communication and the transfer of knowledge was addressed by De Jonge (1996) as a real estate intervention linked to culture -rather than innovation- as an aspect of organisational performance. However, further research linked culture to innovation in specific organisations such as higher education institutions (De Vries, 2007). Accordingly, the atmosphere creating opportunities for interaction and stimulating collaboration is addressed as determinant for real estate operating decisions in these organisations (i.e. they expect that by stimulating collaboration they improve their culture and thus, increase the probability of innovation).

corporate real estate. Hence, the organisational perspective of managing university campuses is broad since it extends beyond the universities' goals. In this view, this study also outlines the focus on the quality of the working environment that supports the activities of main universities' users (student and academic staff) in real estate decisions. These working environments are not limited to academic or office space but also other functions in which working take places such as restaurant, cafes, bars, and other campus amenities.

Although the direct impact of these strategies on organisational performance is difficult to measure, attracting and retaining outstanding people can be the means to achieve competitive advantage through productivity, profitability and distinctiveness. For instance, a study targeting higher education institutions (De Vries, 2007) suggests that innovation and users' satisfaction are addressed as strategies from which an organisation distinguishes from its competitors and is able to make profit. Likewise, Lindholm et al. (2006) add to this thinking by addressing that the contribution of real estate to increased revenues 'is particularly important in knowledge-based businesses whose values lies mainly in their intangible assets'. It does so, because 'these firms are more likely than manufacturers and retailers to view real estate not as a physical factor of production, but as a facilitator that creates an inviting and supportive workspace that enables employees to provide high quality services'. According to this study, knowledge-based firms operate in competitive environment where innovation is essential to survival. The real estate strategy 'increase innovations' considers developing workplace solutions with an emphasis on knowledge work settings and the design of facilities that allow innovative processes. Furthermore, these authors suggest allowing users to participate in the design phase when implementing real estate decisions.

Largely, innovation as an aspect of organisational performance relates to users and users-related processes such as learning or knowledge sharing. These critical dimensions are not easy to measure with financial or quantitative indicators, as expected with other aspects of performance in the CREM field. Indeed, research has shown that in the practice of real estate management 'innovation' and 'users' satisfaction' are aspects less frequently perceived as an explicit added value either in public and private firms (Lindholm et al., 2006) or in higher education institutions (De Vries, 2007). The empirical findings of the later study challenge the early theoretical viewpoint that specific real estate strategies such as supporting knowledge work and promoting human resource are priority in organisations driven by technology such as higher education institutions. In most cases, workplace solutions are addressed as real estate operating decisions generating opportunities for innovation. In this line, a similar research (Lindholm & Leväinen, 2006) suggested two potential measures for this strategy: number of teamwork settings and number of workstations per employee. The measurements for this strategy are scarce compared with other strategies, which have more than ten potential measurements. These empirical findings corroborate that innovation is an unfamiliar real estate strategy used in practice. This subject area can be study in diverse organisations driven similar processes, but considering their differences.

Recently, Appel-Meulenbroek (2014) studied the specific added value of stimulating innovation in the office workspaces of a research organisation. She focused on developing and testing a list of suitable quantitative metrics that can prove through which mechanisms CREM adds value to the knowledge sharing behaviour between employees within an organisation. This study focused on generating information that explains cause-effects relationships between characteristics of physical settings (layout in this case) and measures of innovation processes (e.g. knowledge sharing meetings). The findings of this research have found no strong association between these two measures. However, it addresses accessibility through visibility and proximity as two important mechanisms to be explored for consistency of their importance in knowledge sharing behaviour. Overall, the author concludes that with the examination of 'soft' CRE strategies as 'stimulating innovation' researchers in this field can illustrate how CREM can help to outline the role of the real estate as a strategic resource that 'can do more than just aim for efficiency'. Specifically, she recommends future research in the same theme (added value of CRE for innovation) to map in more detail the context influencing the outcome. These recommendations are considered in this research.

In this line, a recent empirical study investigating the actual impact of workspace design on the performance of innovative companies (Waber et al., 2014) collected data that suggest the design of the space can improve different performance outputs such as productivity and increased innovation. This study begins outlining the increasing attention of tech-firms like Google, Samsung, Apple, and Facebook – among others - to designing spaces aimed to maximizing employees' encounter in their corporate campuses. However, they also address that in measuring the efficiency of these interventions, CRE managers still use metrics that focus on efficiency - e.g. Cost/m2. In response, these researchers were able to generate other type performance data by using smart tools that captured interaction, communication, and location information. This data proves that 'creating collisions -chances of encounter and unplanned interactions between knowledge workers, both inside and outside the organization- improves performance' (Waber et al., 2014).

An important contribution of this empirical study, is noting that the type of organisation and their objectives are central to activate the role of workplace design on performance. In contrast with the general approach that interaction and collaboration is relevant for innovation, this research go deeper in distinguishing different degrees of interactions required in firms – e.g. for a company that tries to innovate and change, interactions with people outside their social group might be more relevant than interacting with people in their on department. In this sense, the space required for employees' interaction varies according to the degree of interaction appropriate for the firm. For example, coffee corners within buildings, corridors or lobbies, and even the public space are spaces facilitating this type of interaction between employees in different departments.

In this view, stimulating innovation through real estate strategies is not as simple as deciding on one intervention but the ones adding value to organisational goals. As a result, this study proposes several aspects to consider before changing the built environment. In office design, two important factors -relative openness of the office and flexible setting- may lead to different outcomes (individual productivity, group efficiency, rapid prototyping, and cross-pollination). The trade-off is for design of workplaces that promotes collisions facilitating either organisational or individual performance[11]. Concepts that are important to explore here are density, diversity and proximity of people, both at the workplace level and in urban instances. Next to it, the observation of organic users' patterns is suggested since popular settings such as co-working was not invented by designers but explored by users.

Overall, this study reveals a variety of strategic real estate interventions for stimulating innovation such as, re-engineering space for interactions over efficiency; merging digital communication patterns with physical space; and highly networked, shared, and multi-purpose spaces within the urban fabric. They also address this type of interventions required time and the engagement of stakeholders outside the organisations.

This view aligns with the idea that stimulating innovation is not an exclusive goal of organisations engaged in R&D research activities. For instance, Den Heijer (2011) provides key performance indicators for 12 added values to measure the impact of real estate on performance at both organisational and urban levels. Surprisingly, the indicators concerning the goal of stimulating innovation at organisational

11 Data in this research has shown that in some case a drop in personal productivity might have a positive outcome on group performance (Waber et al., 2014).

level are vague compared to those at urban level. For instance, the number of start-ups, GPD per capita and distance between universities'- and firms' locations are addressed as indicators that can be used by urban authorities to measure the impact of real estate on competitive advantage at urban level. This study outlines with examples how universities try to stimulate innovation. For instance, (1) making room for incubators and similar formats in which students explore ideas that can be converted into business plans for start-ups and (2) inviting R&D companies with whom universities share research ambitions to establish on campus. These examples emphasize one of the conclusions of this research on the multiple real estate levels of campus management (city, campus, building) affecting many stakeholders inside and outside the university and their performance criteria. Clearly, stimulating innovation is a real estate strategy, goal, or added value that deserves attention in the context of the knowledge economy.

Summing up, most of the existing research addressing 'stimulating innovation' as a real estate strategy gives an important and deserved position to workplace solutions as a real estate decision supporting users' creative processes. Undoubtedly, these processes are very relevant for organisations whose competitive advantage and other sources of performance depend upon it. On the contrary, less attention has been given to location decisions, which are important organisations' decisions in today's knowledge economy. Existing research has addresses how companies are more tied than ever to locations with an existing pool of talented people who can be potential employees to carry out their innovative processes (Van Den Berg et al., 2005). The crucial role of accessibility is no longer exclusive for companies driven by production or marketing factors. Organisations driven by technology and creativity require access to environments where the knowledge workers live and want to live. Attracting and retaining knowledge workers has become an organisational goal, which can be supported by making right location decisions. This review identified some studies tackling this angle in the CREM field.

Nourse and Roulac (1993) addressed physical proximity as critical for some real estate strategies. For instance, both geography and interpersonal interaction between workers played an important role in the business of particular organisations. In fact, there was a distinction investigating such issues for specific companies – i.e. geographic considerations and physical proximity within a region were more important for businesses driven by production factors rather than for those delivering intangible products. Indeed, for the latter business physical proximity was addressed as important in terms of face-to-face interaction and the easy access to liveable places for highly talented employees. In the case or R&D companies, this is ambiguous because although the core processes in these organisations required high skilled employees, R&D functions have been clustered outside cities for other reasons such as intellectual property protection and access to infrastructure that easy the transport of equipment.

A more detailed perspective to this consideration is addressed by O'Mara (1999). In this study, she uses empirical data from IT companies in the USA to investigate the strategic drivers of location decisions in this type of organisations[12]. For instance, focusing on the priorities of this companies and how they might affect future real estate development trends. As a result, this study suggested that the quality of the workforce in a location –i.e. high skilled workers- is more influential for these companies than economic incentives. Next to it, quality of life factors such as housing quality (affordable and attractive), ease of commuting, transportation, and the presence of educational institutions that train potential employees and serve the needs of current employees' families are crucial attributes are most influential in site selection processes. Accordingly, this behaviour in location decisions ratified the importance of integrating real estate management decisions with other functions or organisational objectives such as human resource, and information technology. This aligns with Nourse and Roulac's view of linking

12 In this study, O'Mara (1999) so-called these type of organisations 'information-age companies' referring to 'companies for whom information is a product of component of production' in contrast to manufacturing firms.

'Promote human resource objectives' and 'Facilitate managerial process and knowledge work' as priority real estate strategies for companies driven by technology. In both views, people and technology are essential aspects to consider when addressing innovation as an aspect of organisational performance.

Overall, O'Mara's research revealed important trends that are part of today's landscape, in which tech-firms operate and make real estate decisions such as location and workplace design. Examples of these trends are (1) labour pool of skilled knowledge workers and their preferences driving geographical clusters, (2) urban location becoming competitive due to their ability to provide ready-to-use and shared facilities and amenities for companies that prioritise to focus on their core business functions, and (3) the changing but relative importance of facilities stimulating face-to-face interaction with changes in information technologies impacting communication.

In this broad spectrum, Table 9 provides an overview of the real estate decisions addressed in the literature as key to support innovation as an aspect of organisational performance. Accordingly, the existing empirical research focuses on organisations driven by technology and creativity, in which decisions targeting workplace design are dominant. Likewise, this has been explored mostly in office environments excluding other types of activities such as research and development happening in different workplace settings such as laboratories. In turn, these are rather inflexible facilities because they accommodate specific equipment and machinery that are less likely to accommodate the changing demand that characterises R&D work (Gillen, 2008). Although flexibility is not addressed as a separate real estate decision, it is implicit in the design of real estate facilities as a required spatial characteristic. Overall, these real estate decisions focus mostly on perceived spatial quality judge by the users. Thus, the study of this added value considers the use of a qualitatively rather than a quantitative approach in measuring the effect of real estate on performance.

	KEY SOURCES LINKING REAL ESTATE DECISIONS TO INNOVATION RELATED-STRATEGIES						
FOCUS OF REAL ESTATE DECISION	*Nourse & Roulac (1993)*	*O'Mara (1999)*	*Roulac (2001)*	*Den Heijer (2011)*	*Lindholm et al. (2006)*	*Appel-Meleunbroek (2014)*	*Waber et al. (2014)*
Workplace (design/use)	YES		YES	YES	YES	YES	YES
Location (accessibility)	YES	YES	YES	YES			YES
Amenities (functional diversity)	YES	YES	YES	YES			YES
Facilities (design/use)	YES	YES	YES		YES		YES
Space control	YES						
Participatory design (organic use)					YES		YES

TABLE 2.9 Overview of real estate decision linked to innovation as an aspect of organisational performance in the CREM literature.

A remaining consideration for this research is that some real estate decisions such us location, and amenities, cover a larger range of organisational performance because of the multiple organisations involved in the development of technology campuses, for whom stimulating innovation is a crucial goal in the knowledge economy. The next section provides insights on the role of the built environment stimulating innovation in such context.

§ 2.3 Stimulating innovation in the knowledge economy

This section outlines the societal relevance of both stimulating innovation and the role of the built environment in the context of the knowledge economy. As mentioned before, the knowledge economy is assumed as the relevant contemporary context influencing the strategic goals of the organisations involved in the development of technology campuses. Therefore, the reader of this review must take into account that the development of technology campuses is studied as a built environment phenomenon involving public and private organisations interested on stimulating innovation in the knowledge economy. The knowledge economy is often used as a concept in different fields of study. This review focuses on those theoretical notions used in urban studies that can help to uncovering the relationship between innovation and the built environment in this context.

Knowledge, innovation and the built environment

The meaning of knowledge has increased in complexity since today's economy is being referred to as the knowledge-based economy. Related definitions of the knowledge-based economy have been elaborated in different fields from the second half of the 20th century up to date. The idea of knowledge as an economic factor is attributed to Schumpeter, who addressed the economic relevance of knowledge for innovation and entrepreneurship in 'The theory of economic development', first published 1912. This idea has gained importance in the 1990s.

A prominent business study (Porter, 1990) positioned the creation and assimilation of knowledge as basis of competition. In his study, Porter asserts that 'a nation's competitiveness depends on the capacity of its industry to innovate' (p. 73). This study gave to knowledge and innovation an economic significance at national level.

Similarly, an earlier viewpoint on knowledge as an economic resource comes from a management study addressing its importance for a so-called 'post-capitalist society' (Drucker, 1993). Accordingly, in this society –also called the knowledge society- the application of knowledge to work creates value through productivity and innovation. In his study, Drucker coined the term knowledge workers as to the leading social group of the knowledge society. In this context, knowledge as an essential societal resource puts the educated person in the centre of the system. Correspondingly, the importance of knowledge and innovation for the economy was sustained by a well-known study in social sciences, in which society is referred to as the network society (Castells, 1996).

Soon, knowledge was put forward as the new source of competitive advantage in industrialised countries. According to Cooke and Leydesdorff (2006), the term knowledge-based economy has emerged as a required system perspective used by governments for developing science, technology and innovation policies. In policy, one of first definitions was addressed in an economic development report as 'the economies which are directly based on the production, distribution and use of knowledge and information' (OECD, 1996). In this document, knowledge is 'recognised as the driver of productivity and economic growth, leading to a new focus on the role of information, technology and learning in economic performance'. Likewise, other development organisations manifested their interest on knowledge as central for society. For example, the World Bank released 'Knowledge for Development' in 1998 followed by the European Commission, which launched 'Innovation Policy in a knowledge-based economy' in 2000.

At regional level, some industrialised countries began focusing their attention on this matter. For example, the Department of Trade and Industry of the UK declared its position in a white paper by defining the knowledge economy as 'a new economy in which the generation and exploitation of knowledge has come to play a predominant part in the creation of wealth. It is not simply about pushing the frontiers of knowledge; it is about the most effective use and exploitation of all types of knowledge in all manner of economic activity' (DTI, 1998). In practice, few regions in Europe have already adopted knowledge-based policies and strategies. For example, the city of Delft has a deliberate knowledge-based strategy since the beginning of 1990 (Van Der Geest & Heuts, 2005).

Certainly, the focus of global policy on *knowledge* since 1996 has been calling the attention of many scholars in the urban domain since knowledge is mainly produced and exploited in cities. In academia, there has been an interest to outline the relevance of cities and regions shaping the dynamic of the knowledge economy. For instance, scholars in the field of economic geography (Bryson et al., 2000) focused on explaining the nexus between knowledge, space, and economy. They brought together the interdisciplinary work of scientists from a range of social sciences to emphasize the meaning of knowledge from a spatial perspective as a research agenda. Likewise, this study also recognises the need for continuous innovation and the importance of knowledge for competitive advantage in capitalist societies. Nevertheless, it brought a new perspective to explore the spatiality of the knowledge economy explaining agglomeration or clustering as a knowledge-based phenomenon, which contested the idea of globalisation diminishing the importance of geography in business.

Many of these and more notions were summarised in a well-known urban study outlining the role of cities in the knowledge economy (Van Den Berg et al., 2005). These researchers list a number of characteristics of the knowledge economy found in the literature, which are relevant to investigate its urban dimension. For instance, they argued that knowledge economy applies to all capitalist economies that depend on knowledge as crucial input. Furthermore, they emphasize the distinction made in previous researches between the various types of knowledge (tacit and codified), data (unstructured facts), and information (structured data). In this discussion, the individual 'knowledge worker' plays a central role embodying tacit knowledge, and using data and information in problem setting/solving. Indeed, knowledge and information are recognised as the main inputs and outputs in the knowledge economy since the knowledge worker is continuously transforming these two into new knowledge and information. In the knowledge economy, innovation and entrepreneurship are major points of attention as source of competition because knowledge and information can be transformed into new and competitive businesses relevant for economic development. Likewise, the knowledge economy is recognised as a network economy because both, knowledge and information are difficult to appropriate due to globalisation and ICT advancements, which have increased their diffusion speed. Thus, networks enable people, companies, or cities to share complementary knowledge resources in a fast changing environment. Last, these researchers discuss a socio-cultural dimension of this economy pinpointing the differences among countries in their transition path to a knowledge-based economy. This dimension raised question about the role played by culture and social equality in the efficiency of the entire system.

As seen in this academic viewpoints, there are multiple and interdisciplinary approaches and notions that can be used to refer to a knowledge-based economy, which is increasingly complex to define. More detailed stands has grown over the last two decades referred to as 'knowledge-based urban development' (KBUD), which focuses on the so-called 'knowledge city' or 'knowledge/learning region' as subject of analysis.

Overall, both knowledge-based policies and urban studies have positioned universities and other higher education institutions as key players in this context because they educate the future knowledge worker.

These institutions increasingly compete to attract a growing number of students in tertiary education. Several university rankings have been created as instruments to compare the quality of knowledge in a global scale. Cities and regions increasingly use those as means of competitiveness. In the current economic context, the physical presence of universities and other higher education institutions are crucial to strengthen regional economies, especially in those regions that focus their economies on clusters development.

All in all, there is a co-evolving path outlining the importance of knowledge in studies, policies, and practices that positions innovation as main driver of competitiveness. However, when listing existing built environments that have emerged to accommodate the creation and application of knowledge this study observed that (1) a large number of them have emerged earlier than the so-called knowledge economy, and (2) their popularity has increased in the last decades. Indeed, these developments are related to earlier periods of technology developments since the late 1940s, which have also influenced the complex meaning of knowledge as addressed in the literature[13] [See Figure 2.8].

The following paragraphs aim to outline the deserved importance of the built environment in innovation in the context of the knowledge economy. First, it draws the attention towards cities as local context of technology campuses. Second, it outlines the roles and meanings of the built environment for the stakeholders involved in campus development in this context. This section concludes with directions for reviewing concepts in specific fields of study, which can be used to explore the relationship between innovation and the built environment at area and portfolio levels.

13 These conclusions emerged from a parallel empirical study of this exploratory research (See Chapter 3)

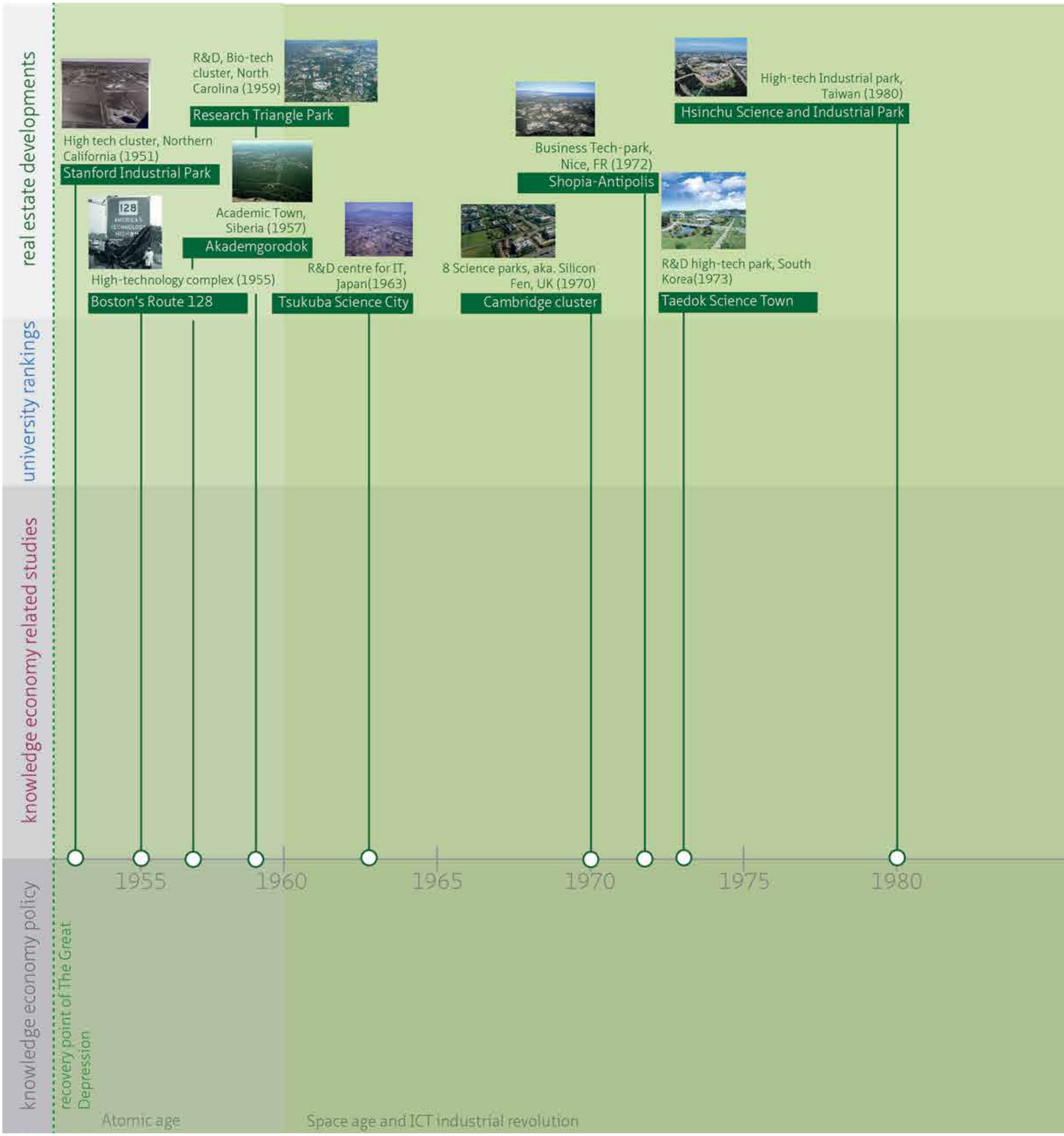
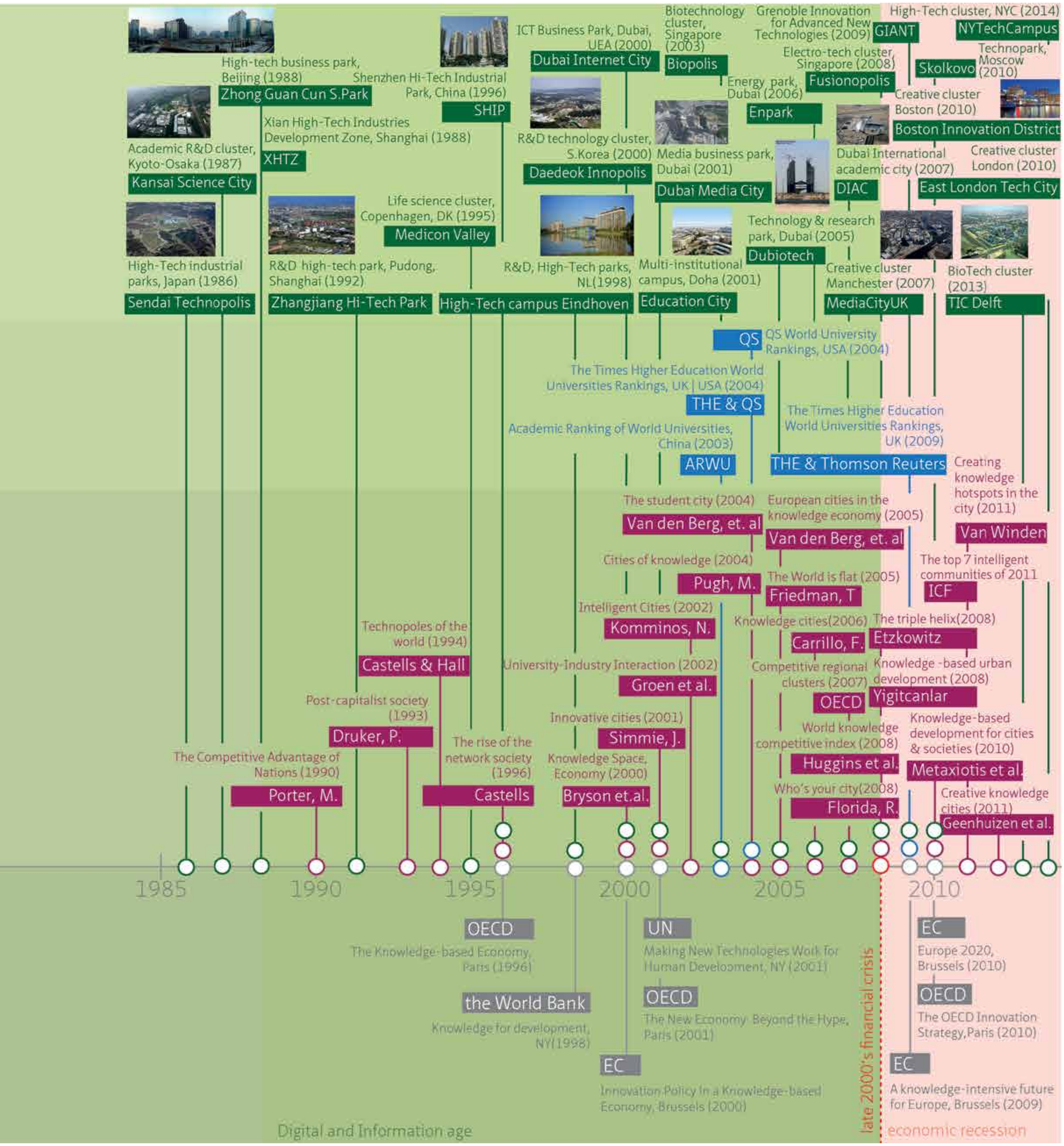


Figure 2.8 Overview of the different layers considered in this review of the literature as relevant for the development of technology campuses.


High-tech business park, Beijing (1988)
Zhong Guan Cun S.Park
Shenzhen Hi-Tech Industrial Park, China (1996)
SHIP
ICT Business Park, Dubai, UEA (2000)
Dubai Internet City
Biotechnology cluster, Singapore (2003)
Biopolis
Grenoble Innovation for Advanced New Technologies (2009)
GIANT
High-Tech cluster, NYC (2014)
NYTechCampus
Technopark, Moscow (2010)
Skolkovo
Electro-tech cluster, Singapore (2008)
Fusionopolis
Energy park, Dubai (2006)
Enpark
Creative cluster Boston (2010)
Boston Innovation District
Academic R&D cluster, Kyoto-Osaka (1987)
Kansai Science City
Xian High-Tech Industries Development Zone, Shanghai (1988)
XHTZ
R&D technology cluster, S.Korea (2000)
Daedeok Innopolis
Media business park, Dubai (2001)
Dubai Media City
Dubai International academic city (2007)
DIAC
Creative cluster London (2010)
East London Tech City
Life science cluster, Copenhagen, DK (1995)
Medicon Valley
Technology & research park, Dubai (2005)
Dubiotech
High-Tech industrial parks, Japan (1986)
Sendai Technopolis
R&D high-tech park, Pudong, Shanghai (1992)
Zhangjiang Hi-Tech Park
R&D, High-Tech parks, NL(1998)
High-Tech campus Eindhoven
Multi-institutional campus, Doha (2001)
Education City
Creative cluster Manchester (2007)
MediaCityUK
BioTech cluster (2013)
TIC Delft
QS
QS World University Rankings, USA (2004)
The Times Higher Education World Universities Rankings, UK | USA (2004)
THE & QS
Academic Ranking of World Universities, China (2003)
ARWU
The Times Higher Education World Universities Rankings, UK (2009)
THE & Thomson Reuters
Creating knowledge hotspots in the city (2011)
Van Winden
The student city (2004)
Van den Berg, et. al
European cities in the knowledge economy (2005)
Van den Berg, et. al
Cities of knowledge (2004)
Pugh, M.
The World is flat (2005)
Friedman, T
The top 7 intelligent communities of 2011
ICF
Intelligent Cities (2002)
Komminos, N.
Knowledge cities(2006)
Carrillo, F.
The triple helix(2008)
Etzkowitz
Technopoles of the world (1994)
Castells & Hall
University-Industry Interaction (2002)
Groen et al.
Competitive regional clusters (2007)
OECD
Knowledge -based urban development (2008)
Yigitcanlar
Post-capitalist society (1993)
Druker, P.
Innovative cities (2001)
Simmie, J.
World knowledge competitive index (2008)
Huggins et al.
Knowledge-based development for cities & societies (2010)
Metaxiotis et al.
The Competitive Advantage of Nations (1990)
Porter, M.
The rise of the network society (1996)
Castells
Knowledge Space, Economy (2000)
Bryson et.al.
Who's your city(2008)
Florida, R.
Creative knowledge cities (2011)
Geenhuizen et al.
1985
1990
1995
2000
2005
2010
OECD
The Knowledge-based Economy, Paris (1996)
UN
Making New Technologies Work for Human Development, NY (2001)
EC
Europe 2020, Brussels (2010)
the World Bank
Knowledge for development, NY(1998)
OECD
The New Economy: Beyond the Hype, Paris (2001)
OECD
The OECD Innovation Strategy, Paris (2010)
EC
Innovation Policy in a Knowledge-based Economy, Brussels (2000)
EC
A knowledge-intensive future for Europe, Brussels (2009)
late 2000's financial crisis
Digital and Information age
economic recession

§ 2.3.1 Cities and the built environment in the knowledge economy

Definition

Urban competitiveness *is 'the ability of a city to exploit or create comparative advantage, and thereby to generate high and sustainable economic growth relative to its competitors'*

(D'arcy & Keogh, 1999).

Knowledge is a source of urban competitiveness in the current economy. Cities and regions compete with each other to attracting and retaining high-skilled people. The ideal city in the knowledge economy is an 'attractive city' which is characterised by the concentration of human capital and the organisation of this capacity into productive outcomes. Accordingly, the following paragraphs highlight the most important features of cities in the knowledge economy as relevant for this research.

The knowledge city

The review of the literature has shown that the topic so-called 'knowledge city' is emergent and based in empirical approaches, which theoretical frameworks are interdisciplinary. In fact, its relations with theories of Economic Growth, Knowledge Management, Urban Studies, Planning, Geography and other social disciplines make 'the knowledge city' a complex topic, and therefore difficult to define especially in terms of scale. Indeed, this intrinsic link between city and economic growth and development -outlined by several researchers investigating the knowledge-based economy- has blurred its geographic scale. Several studies refer to the knowledge city as geographic areas where knowledge-based activities are taking place and influencing local economies in different ways. Accordingly, the scales of these areas range from knowledge hot spots (Van Winden, 2011) and knowledge precincts (Yigitcanlar et al., 2008) up to knowledge cities, regions or even mega-regions[14]. For instance, 'knowledge-based development' (KBD) is used in this analysis as a term that involves both socio-economic and spatial development studies in which the 'knowledge city' is related as economic and geographic unit in a broader sense.

As shown before in Figure 2.8, the diversity of studies reviewed in this exploratory research (e.g. academic research, policies, urban studies, institutional reports, etc.) illustrates the difficult task of establishing a common ground for the knowledge-city as topic because of the different approaches to it. For instance, some empirical studies focus on developing indicators in order to position the performance of cities in the competitive context of the knowledge economy. Other studies highlight the experiences of specific cities in the context of the knowledge economy based on initiatives and efforts by cities to include knowledge as a key aspect in their strategies. Although these studies differ in their approach, an important finding in this review is the relevance of the knowledge city as a global contemporary phenomenon in practice [See Figure 2.9].

14 The term Mega-Regions is introduced by Florida (2008) who mapped 40 Mega-Regions of the world ranked by its population, economic activity, Innovation (patents), and the presence of star scientists.

Figure 2.9 Cities that identify themselves as knowledge cities and/or have strategic plans to become one (Source: Knowledge Cities and the Knowledge Cities Clearinghouse, 2009)

Regardless its increasing attention in practice, the existing research about cities in the knowledge economy is immature in the literature [See Figure 2.10]. For instance, the existing scientific ground is based on single or comparative case studies, mainly published as a collection of papers and with a focus on description of cities' experiences in adapting their transition to the knowledge-based economy (Carrillo, 2006; Groen & Sijde, 2002; Van Den Berg et al., 2005; Van Geenhuizen & Nijkamp, 2012; Van Winden, 2011; Yigitcanlar, 2008). Indeed, most of the cases studied focus on European cities of relatively small size (i.e. cities with a population of less than 500.000 inhabitants), with few exceptions of large cities in developing countries.

In this context, this review highlights a well-structured framework so-called 'the knowledge foundations and activities of the knowledge economy' (Van Den Berg et al., 2005) illustrated in Figure 2.11. This framework was developed to establish a comparative way to judge the performance of urban regions in the knowledge economy. It distinguishes foundations (structure) and activities (process) of the knowledge city facilitating the description and comparison between cases. Indeed, this framework was tested with nine cities across western Europe and has been validated with other cases in similar and different local contexts (Den Heijer & Curvelo Magdaniel, 2012; Van De Klundert & Van Winden, 2008). Overall, this work builds upon urban development studies balancing both the economic and spatial viewpoints of knowledge-based development, which could serve as basis to establish more specific links with the built environment and its role in the context of the knowledge economy.

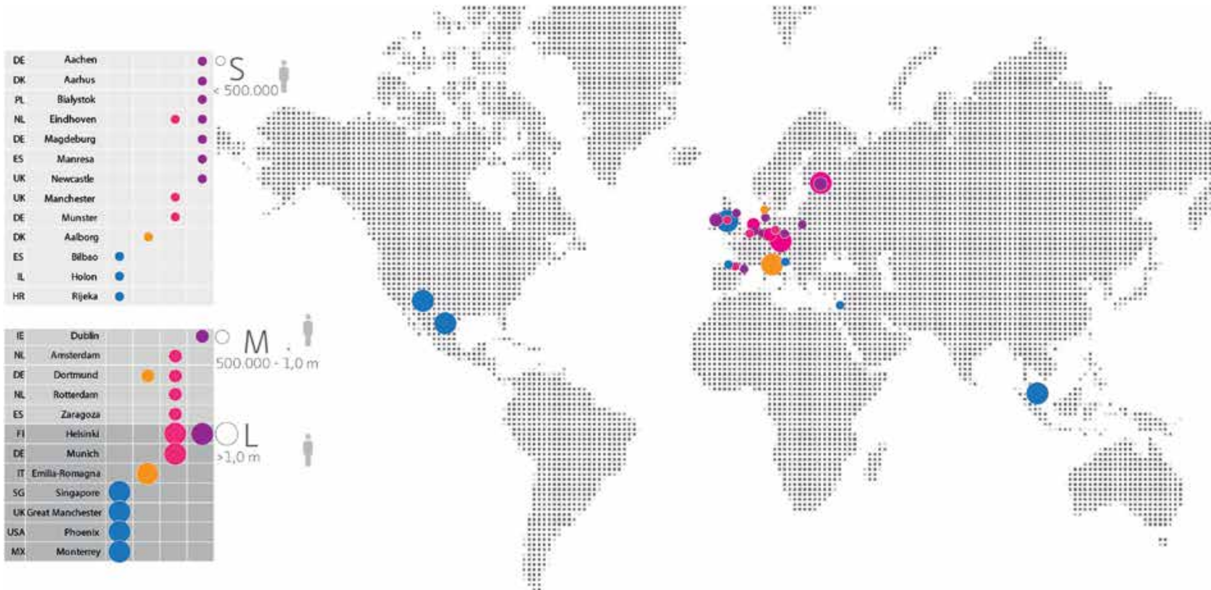


Figure 2.10 Map of some of the existing studies on cities in the knowledge economy reviewed in this exploratory research (Carrillo, 2006; Groen & Sijde, 2002; Van Den Berg et al., 2005; Van Winden, 2011). Each colour refers to a different study

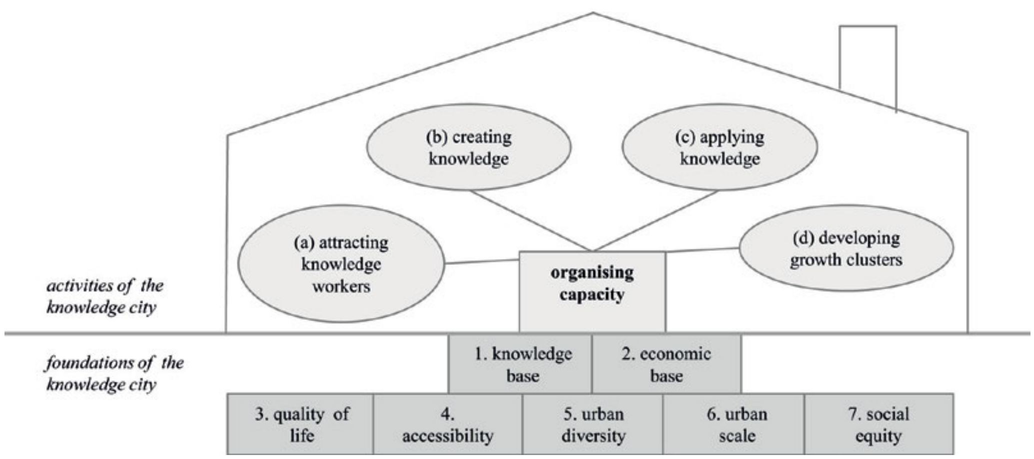


Figure 2.11 Foundations and activities of the knowledge city (Van Den Berg et al., 2005)

The review of the literature on knowledge cities helped to identify a set of common patterns in cities and regions referred here as indicators of knowledge-based development (KBD). Those indicators distinguish two categories: internal and external indicators of KBD. The internal indicators are structural aspects of cities/regions that characterise a potential environment for KBD. The external indicators are the specific actions or initiatives these cities/regions are carrying out to succeed in adopting the knowledge-based economy [See Table 2.10]. Accordingly, it takes more than knowledge-based policies or strategies for cities to remain competitive in the knowledge economy. Socio-economic development in the knowledge economy deals with many aspects such as governance (Lambooy, 2006), collaboration between key actors and networks (Fernández-Maldonado & Romein, 2012), the type of city managing its transition from industrial to knowledge-based activities (Van Winden, 2008), and other place-based aspects relevant for individuals (Fernández-Maldonado & Romein, 2008; Van Winden & Carvalho, 2008).

A. INTERNAL INDICATORS *STRUCTURE OF THE CITY-REGION: KBD POTENTIAL*	B. EXTERNAL INDICATORS *ACTIONS OF THE CITY-REGION: KBD OPPORTUNITIES*
A.1 Cities adapting new economic models and facing socio-economic transformation process. *Indicator: Strategic vision on knowledge-based development as new joint identity.*	B.1 Large investments on dedicated clusters with emphasis on specific growing industries that matches the local 'academic-business' climate and strengths. (In most of the cases those are ICT-related clusters).
A.2 Small to medium cities with population up to 1,0 ml inhabitants. *Indicator: higher intensity of knowledge-based activities and available knowledge-based jobs.*	B.2 Presence of incentive structures and incubator centres that promote entrepreneurship, start-ups and spin-offs from universities, R&D institutes and firms.
A.3 Large and well prepared student population. *Indicator: Presence of large and/or top University or higher education institutes*	B.3 Large investments in the development of physical infrastructure where knowledge-based activities take place.
A.4 Strong presence of diverse knowledge-based firms. *Indicator: amount of R&D multinationals, innovative SMEs locally rooted at regional level and/or service & business sectors companies.*	B.4 Public-private synergy and collaboration for planning and execution of knowledge-based strategies, programs and projects, involving at least two of the following actors: local and regional authorities, universities, private sectors and community.
A.5 Good connectivity and accessibility for traffic and public transport at regional, national and international levels. *Indicator: proximity to airports and well-functioning mobility infrastructure*	B.5 Leadership, active urban management and co-development networks.
A.6 Available ICT infrastructure ensuring digital access and social inclusion. *Indicator: high broadband penetration and diffusion.*	B.6 Explicit knowledge-based economy strategy with a strong orientation on a regional perspective (e.g. marketing strategy to communicate transformation processes) .
	B.7 Regional policy frameworks that support the development of all actions mentioned above.

TABLE 2.10 Collection of indicators for KBD in cities and regions based on the review of the literature

As shown in Table 2.10, only one indicator of KBD in cities/regions can be directly related to the built environment. Accordingly, 'large investments in the development of physical infrastructure where knowledge-based activities take place' (B.3) include the development of built environments such as technology campuses. In this matter, attention is given to locations accommodating the knowledge-based activities of universities, companies and other research institutes. The relevance of accommodating tech-based research is outlined in the following paragraphs.

The built environment as infrastructure resource of the Triple Helix

Research is an essential knowledge-based activity for innovation, which increasingly involves the interaction between universities, R&D companies and governments. The university-industry-government relationship is also referred to as the concept of the Triple Helix (Etzkowitz, 1993; Etzkowitz & Leydesdorff, 1995). Accordingly, this concept positions the hybrid role of universities, industry, and governments as crucial in the knowledge society because the potential for innovation and economic development resides in the capacity of these three spheres to generate new institutions and social formats for knowledge creation, diffusion and application.

The role of universities and higher education institutions have become prominent in this context since they are referred to as the engines of the knowledge economy engaged in research and educating the future entrepreneurs (Etzkowitz, 2004). At regional level, the presence of universities potentially contributes to economic development (Drucker & Goldstein, 2007). This study summarises this impact through eight different functions of modern research universities: '(1) creation of knowledge, (2) human-capital creation, (3) transfer of existing know-how, (4) technological innovation, (5) capital investment, (6) regional leadership, (7) knowledge infrastructure production, and (8) influence on regional milieu'. This last function is particularly important because it refers to the unintentional effects of the presence of universities and their activities in their surroundings, which according to the authors deserve more attention in the literature (e.g. intellectual, social, cultural, or recreational dynamics by attracting a concentration of highly educated people at a particular location).

Indeed, creating a healthy and attractive social climate is key in the development of human capital in cities (and regions) is as addressed in various urban studies (Drucker & Goldstein, 2007; Fernández-Maldonado & Romein, 2008; Van Den Berg et al., 2005). The human capital in the knowledge economy has been emphasised as source of economic growth in cities (Florida, 2002), urban competitiveness (Van Winden & Carvalho, 2008), regional innovation (Faggian & McCann, 2006, 2009) and national productivity growth (McCann, 2012). Accordingly, a city's capacity to attract and retain highly educated workers relates both to the quality of its knowledge base and to other aspects defining quality of life (e.g. housing, safety, cultural amenities, diversity, etc.).

A parallel empirical research as part of this exploratory research has shown that a relevant number of research universities are mostly concentrated in few regions around the globe and most of them are accommodated in inner city locations[15]. Correspondingly, they concentrate an important share of the human capital in urban regions [See Figure 2.12].

These findings stress the role of universities' locations in the competitive profile of cities and regions in the knowledge economy because these organisations bring highly educated human capital to a region. However, the mere presence of universities and their human capital is not enough to stimulate innovation and create wealth in cities. Although there is research evidencing that co-location with top-tier universities promotes collaboration between universities, and high-research and development firms (Laursen et al., 2010), there are challenges for cities in exploiting and managing the provision of human capital as economic assets. Accordingly, managing the interaction between universities, industry and governments is the basis to remain competitive in the knowledge economy. This involves managing the relationships among stakeholders within each of these organisational spheres, which are place-based fostered. Cities and regions have the ability to optimise the cooperation between these spheres through different activities and at different levels (e.g. from strategic to operational).

At operational level, investing in the development and management of physical infrastructure that supports the creation, diffusion and application of knowledge can be seen as a way to strengthen these relationships (Van Winden, 2008). For instance, these organisational spheres and the infrastructure that support their activities are regarded in global policies as national science systems[16]. Thus, the physical infrastructure -including the built environment- is an essential part of these systems, which is outlined in a general way as an enabler of innovation (Anderson et al., 2013; Florida, 2010). Florida (2010) outlines technology, education and transportation as large-scale system's infrastructure needed to support the current demands driven by innovation, velocity and flexibility. Similarly, this author regards the physical infrastructure as a resource-type of infrastructure that supplies a common supportive ground for these systems' infrastructure. An overview of the three systems and the role of the built environment can be summarized in Table 2.11.

15 A pilot study was conducted in this research with the purpose to reveal the geographical distribution of what are considered relevant sources of new knowledge in the context of the knowledge economy. This study collected empirical data from public sources on the top 200 universities published in The Times Higher Education rankings, and converted it into geographical information using ArcMap. It is observed that 63% of these universities are settled in inner city locations against 37% located out if cities. From the total sample, 58% of the universities have multiple campuses. Therefore, 16% of the total is settled both in urban and suburban land. Comparing the geography of these knowledge cluster with population data of cities of the world, it is observed that in the EU zone, large part of the knowledge clusters are located in medium to small cities (with population between 250.000 and less than a million inhabitants), with few exceptions such as London, Paris, Copenhagen, Dublin, Berlin and Munich). Conversely, in Asia, the knowledge cluster appeal to be located in large metropolitan areas, while in USA is apparently distributed between large, medium and small cities

16 'Public research laboratories and institutions of higher education are at the core of the science system, which more broadly includes government science ministries and research councils, certain enterprises and other private bodies, and supporting infrastructure'. (OECD, 1996)

Figure 2.12 Concentration of human capital in number of students and academic staff in a sample of 200 universities according to The Times Higher Education Top University Rankings 2011-2012

SYSTEM'S INFRASTRUCTURE TO SUPPORT THE DEMANDS OF THE KNOWLEDGE ECONOMY	>> ROLE OF THE BUILT ENVIRONMENT
Technology. From the economic perspective, technological development has acted as enabler bringing powerful and general purpose ICT in today's knowledge economy. The application of science and invention to industry is nothing new but the accelerated speed of technological developments throughout the 20th century has resulted into a massive spur to productivity, enabling 'innovation' to emerge as the most valuable resource to recovery after crisis periods and addressed as a major driver.	In this perspective, innovation in the built environment should not been limited to the application of technology for the development of physical infrastructure. Instead, physical infrastructure is a crucial one that effectively supports two new types of infrastructures referred to as 'large-scale systems' innovation' for prosperity and growth: education and transportation (Florida, 2010).
Education. If the knowledge economy is based on the new technologies applied by higly educated people to create value within organisations, then (skilled and talented) human capital is essential for economic competitiveness. Hence, universities and the higher education institutions play key roles as economic actors attracting and retaining research and development into regions.	In this regard, the physical infrastructure that supports higher education is becoming relevant. Recent research on university campuses (Den Heijer, 2011) addresses the crucial role of the built environment supporting the fulfilment of the primary function of the universities but also to support strategic goals such attracting and retaining talent. Similarly, this view is supported by experts in economic geography (McCann, 1012) by outlining the role of the universities' environments shaping the preferences of the future knowledge workers.
Transportation. New transportation systems not only have enabled cities to expand but people to commute long distance between home and work. As a result, the lifestyle of today's workers has evolved along with the transportation systems, which nowadays are more diverse and accessible, allowing faster regional and (inter) national connectivity.	In this perspective, the competitiveness among places grows as easier as talent moves and that implies the development of physical infrastructure that connects them.

TABLE 2.11 Roles of the built environment as resources supporting technology, education and transportation

In this context, the physical infrastructure comes to play a supportive role for these systems as an asset resource for urban competitiveness that can be used to target investments either in new infrastructure, expansion or efficient use of the existing one. Hence, building new- or investing on existing technology campuses can be seen as one of the resources that support these broad systems. Studying technology campuses as a research topic is connected with several contemporary issues beyond the built environment dimension. In fact, this dimension is small part of a broad range of social and economic transformations as seen in this section.

§ 2.3.2 Direction of further exploratory research in the literature

This literature review has established scientific links between contemporary policy, theoretical concepts and current research about cities in the knowledge economy. It has shown that both socio-economic and spatial aspects are strongly connected in the concept of knowledge-based development. Cities and regions are the geographic units supporting the production of knowledge and where the interaction of relevant stakeholders in the knowledge economy takes place. Furthermore, the built environment that shapes the city and accommodates knowledge-based activities is part of the entire KBD system.

The major shifts in economic structures and ICT developments related to KBD have had specific impacts on the built environment and its management at different scale levels. For example, at building level, the changing ways of doing knowledge-intensive activities (e.g. individual or team research, teaching, etc.) call for different approaches in the provision of workplaces in both, academic and industrial environments. Similarly, the hybrid profiles of knowledge-intensive organisation and their accommodation demand for concentrating their activities in close proximity to specific organisations and places, brings complexity to the strategic management of real estate at portfolio level. Last, the importance of knowledge-based development at urban and regional level posed interesting and challenging questions about the management of urban areas that involve many stakeholders with their different interests on innovation.

The following section elaborates more in-depth on the theoretical concepts explaining the relevance of spatial concentration in the processes of knowledge creation and diffusion, which can be used to explore the relationship between innovation and the built environment at portfolio and urban levels.

§ 2.4 Innovation, economy and geography

This section elaborates on concepts from economic geography, urban studies and regional studies in which 'innovation' is discussed from a spatial perspective. Indeed, the review of the literature in this section focuses on the concepts explaining the relevance of spatial concentration (of people, organisations, and their activities) in the processes of knowledge creation and diffusion, which can be used to study the relationship between innovation and the built environment at portfolio and urban levels.

Understanding innovation from an economic perspective becomes essential to examine the basic assumption of this research (i.e. the built environment is a resource steered to support the goal of stimulating innovation as pursued by different organisations in the knowledge economy). As outlined before, innovation is a core component of the knowledge-based economy. However, innovation is an uneasy concept to be operationalized because of the many approaches and definitions to it. This makes complex the relationship between knowledge, innovation, and cities, which is currently debated in academy. Understanding the ways in which innovation is defined and measured in theory is essential to further investigate such relationship.

There are several theoretical approaches to innovation pointing out its multiple dimensions. Accordingly, understanding innovation requires a distinction among (1) the definitions used to describe innovation; (2) the concepts linked to such definitions; and (3) the scales in which such concepts are applied. These approaches to innovation have evolved over the last century linking and somehow, differentiating relevant ideological streams in economic geography. Accordingly, different concepts are covered within this review in three parts.

The first part briefly highlights the neo-classical economic approach to innovation, from which early theories of innovation and space have developed. Accordingly, section 2.4.1 summarises the most relevant concepts and indicators found through the review of contemporary literature used to characterise innovation from an economic perspective. The emphasis is placed on the knowledge economy as a relevant context for technology campuses.

Section 2.4.2 refers to the economic geography approach and the theories concerned with the spatial distribution of innovation. First, it covers the concept of knowledge spillovers as discussed in agglomeration economies and the relevance of proximity in this discussion. Second, it draws the attention on the multiple dimensions of proximity as discussed in evolutionary economic geography relating the concept of knowledge spillovers with other concepts such as time and path-dependency.

Overall, the concepts and approaches distinguished in this review do not cover the entire discussion about innovation and space in economic geography, and therefore this understanding can be structured in different ways. Rather, the selection presented here is made to deliver understanding of the notion of innovation suitable to investigate the assumptions of this research.

§ 2.4.1 The economics of innovation

Innovation as the commercialisation of a new product or process is recognised as one of the most influencing ideas in economic theory, introduced by Schumpeter (1939). In his review of the literature about innovation and space, Simmie (2005) summarises four important ideas on innovation that are highlighted as Schumpeter's legacy on economic theory. First, it is innovation as the main source of dynamism in capitalist economic development. Second, history is relevant in understanding long-term economic change. Third, invention, innovation and the diffusion of innovations are different things. Last, the links between organisational, managerial, social, and technical innovations is key. Similarly, Van Oort and Lambooy (2014) recognises Schumpeter's influence when explaining the mechanism of knowledge production and diffusion in cities. Accordingly, Schumpeter (1934) positions knowledge as a result of a process of wider social significance because its generation is decisive for innovation and economic growth.

This idea of innovation as a source of economic development has developed in economic and political sciences, which positioned 'meaning of innovation' as crucial for economic growth. This is the case of a concept emphasising innovation as the process of 'learning by doing' (Castells & Hall, 1994). Accordingly, innovation is the capacity of a country to design and produce (manufacture) advanced technological inputs to adapt into productive processes. Indeed, this approach refers to technological innovation at national scale in which a linkage between the sources of innovation, production, and utilisation is essential.

Likewise, Smith (2005) outlines how other approaches to innovation build up on the etymology of the word by using the concept of 'novelty' (i.e. 'the creation of something qualitatively new, via processes of learning and knowledge building'). Therefore, this concept 'involves changing competences and capabilities, and producing qualitatively new performance outcomes'. Similarly, this view outlines the relevance of the learning process, which positions research and discovery underpinning innovation in the knowledge economy (Laestadius, 2003).

According to Smith (2005), the distinction of research as one phase of this learning process marked a new approach to innovation. For instance, two important ideas based on Rosenberg (1976, 1982) had serious considerations in today's definition and measurement of innovation: (1) research-based discovery is a preliminary phase of innovation; and (2) there is a separation between innovation and diffusion process. These ideas further developed in a so-called 'Chain-link model' (Kline & Rosenberg, 1986). Accordingly, 'innovation is not a sequential (linear) process but one involving many interactions and feedbacks in knowledge creation'. Thus, 'innovation is a learning process involving multiple inputs'. In this mode, discovering (including formal R&D) is an initiating factor of innovation in the chain model. This view outlines that the concept of 'novelty' implies not just the creation of new products and processes, but relatively small-scale changes in product performance, which might have a major technologic and economic implications (Kline & Rosenberg, 1986). Based on this approach, innovation took a multidimensional character covering a variety of activities[17].

This view has developed with theoretical concepts linking innovation to the complex meaning of knowledge in the knowledge-based economy. For instance, innovation is seen as the reconfiguration of elements into more productive combinations, including not only the development of new products in firms but also the creation of organisational arrangements that enhances the innovative process (Etzkowitz, 1993). Accordingly, the interaction between universities, industry and governments or 'Triple-Helix' can be seen as an example of a key organisational arrangement for innovation and growth in the knowledge-based economy [See Table 2.12]. Given the combinations of market and science orientations of innovation, this approach proposed that technological innovation follows 'a non-linear and netlike pentagonal model that may begin from different starting points among science, engineering, R&D, production, and marketing activity' (Etzkowitz, 2008).

THE TRIPLE-HELIX MODEL AS INNOVATION SYSTEM (ETZKOWITZ, 2008) *SIX ELEMENTS THAT CAN BE READ THROUGH AS (INPUT) INDICATORS.*
1. The presence of hybrid organizations and entrepreneurial models such as incubators; venture capital firms, science parks.
2. The establishment of the entrepreneurial university. Accordingly, the flow-through of human capital built in universities with its students gives them a competitive advantage in the knowledge-based economy.
3. Knowledge-based firm-formation through interaction with university and government – e.g. Firms spinning out of academia usually keeping close contact with their source of origin, and often locating on campus or nearby. Also, it includes firms with origins in government programs fostering university-industry collaborations.
4. The definition of innovation policies and/or science and technology policies aimed at achieving a common objective (e.g. knowledge-based economic and social development, public-private partnerships, and basics of innovation state). These are preferable indirect and decentralised policies.
5. The establishment of the region as spatial unit of innovation. This idea can be linked to the national (later on elaborated as specific regional) innovation systems, which are more than a network of institutions supporting R&D. These are composed of firms and research institutes that are distinctive and interlinked organisations that support and conduct innovation.
6. The potential for collaboration is enhanced as university technology transfer offices, research centres, clusters on a particular theme and science parks in a region become part of an interconnected web.

TABLE 2.12 Summary of six elements in the triple helix model regarded as innovation system by Etzkowitz (2008)

As seen in this review, these ideas have had serious considerations not only in theory at the scale of the firm, but also in policy at the scale of the region or nation-wide. For instance, the European Commission adopted a combination of these notions when defining innovation in early innovation regional policies in the 1990s (Smith, 2005). Likewise, the OECD adopted a similarly view in the revised version of the Oslo Manual, which is seen as 'the foremost international source of guidelines for the collection and use of data on innovation activities in industry' (OECD, 2005). Accordingly, 'an innovation is

17 According to Kaloudis (1998) innovation activities could take the form of a new product, a new process of production, an improvement in instruments or methods, the reorganization of production, internal functions, or distribution arrangements leading to increased efficiency, better support for a given product, or lower costs, among others.

the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organisational method in business practices, workplace organisation or external relations' (OECD, 2005). Furthermore, the manual emphasises that 'innovation activities are all scientific, technological, organisational, financial and commercial steps which actually, or are intended to, lead to the implementation of innovations. Some innovation activities are themselves innovative; others are not novel activities but are necessary for the implementation of innovations. Innovation activities also include R&D that is not directly related to the development of a specific innovation' (OECD, 2005).

Overall, the adoption of different definitions of innovation in global policies has developed since the early 1990s parallel to the academic debate in the search for suitable indicators to measure the multidimensional character of innovation. In this context, measuring innovation is becoming complex because of the different meanings given to innovation in the knowledge economy. As shown in this review of the literature, innovation is often measured by using either input- or output indicators. Accordingly, the first indicators focus on the aspects that create the conditions for innovation as a learning process. As said before, in the knowledge-based economy, these are concerned with the process of knowledge creation and diffusion, in which attracting and retaining knowledge workers play an essential role. Conversely, the second indicators are measures of performance, by which innovation is seen mostly as a product and/or a market rather than a process. Table 2.13 summarises a list of indicators used, both in theory and practice, to measure innovation as described from the previous definitions and concepts.

According to Table 2.13, the first three groups of indicators have received more attention especially in practice – i.e. (1) R&D data, (2) data on patent applications/grants, and bibliometric data; (3) and non-R&D data. Likewise, there are academic criticisms about the use of these indicators as suitable measurement for innovation (Freeman & Soete, 2009; Kleinknecht et al., 2002; Smith, 2005). First, R&D data is considered as a limited indicator because it focuses mainly on the measurement of an innovation input and there many other supporting activities that fall outside the narrow definition of R&D used to measure innovation. R&D data is often classified according to (1) the sector of performance – i.e. business, enterprise, government, higher education and private, (2) the sources of finance – i.e. domestic and international, (3) the socio-economic objectives, and/or (4) the fields of research. Therefore, a lot of detail in this type of data is missing. For instance, there is a criticism concerning the bias of sectorial classifications for Science, Technology and Innovation indicators especially those considered in global guidelines such as the Frascati or Oslo manuals.

Second, although patent data is a consistent indicator because it gathers detailed information about new technologies as a public record of inventive activity, it has some weaknesses (Smith, 2005). This author refers to patents as an 'indicator of invention rather than innovation: they mark the emergence of a new technical principle, not a commercial innovation'. Some types of technology and/or items are not patentable. Besides, patents are public contracts -involving long and expensive processes between the application and the grant moments- in which not all type of firms might be able and willing to start and maintain. Many firms, especially SMEs, and other organisations that carry out innovative activities are excluded from the data (including higher education institutions).

Third, bibliometric data is criticised as suitable indicator because it relates primarily to the dynamics of science rather than innovation (Kaloudis, 1998; Moed et al., 1995). As seen in this review, bibliometric data might be rather an indicator of the diffusion of innovations.

INDICATORS	Description	Theoretical sources	Use in practice
1. R&D data	This indicator focuses on measuring inputs. Initially focused on the use of datasets resulted from the collection of economic indicators compatible with industrial datasets and the national accounts such as R&D intensity, R&D expenditure, R&D/Sales ratio, R&D/GDP ratio, R&D personnel.	Griffith, Redding, and Van Reenen (2004) Dowrick (2003)	OECD, 1992, 2001, 2002, 2005 European Commission 1992, 1993, 1996, 2011 Global Innovation Scoreboard (GIS), 2008
2. Data on patent applications, grants, and bibliometric data	This type of indicators focuses on measuring outputs. The latter refers to scientific publication and citation turning around the SCI- Science Citation Index.	Granstrand (2005) Kaloudis (1998)	OECD 2002, 2005 European Commission 1992, 1993, 1996, 2011 Global Innovation Scoreboard (GIS) 2008.
3. Non-R&D data (Subject approach)	This focuses on inputs able to pick up small-scale changes in product performance which might have major technologic and economic implications on 'innovation activities' besides R&D, such as design activities, engineering developments and experimentation, training, exploration of markets for new products, equipment acquisition and tooling-up, etc.	Kline and Rosenberg (1986) Smith (2005) Evangelista, Sandven, Sirilli, and Smith (1998)	OECD, 2005 European Commission 1992, 1993, 1996
4. Product innovations identified through exert appraisal and literature (Object approach)	Examples of these indicators are database about technical and business innovations covering sources and types of innovation, industry innovation patterns, cross-industry linkages, regional aspects and so on. These indicators are widely discussed in theory by scholars claiming that traditional measures miss 'the population of innovation outputs which are routine, incremental, part of the normal competitive activity of firms, yet not strikingly new enough to be reported' (OECD, 2005)	Acs and Audretsch (1990) Archibugi and Pianta (1996) Kleinknecht (1996) Pavitt (1984)	N.A.
5. Technometric indicators	These indicators explore the technical performance characteristics of products (output focus). If focuses on details ways of measuring technological change.	Saviotti (1996) Saviotti (2001) Grupp (1994) Coccia (2005)	European Commission 1997
6. Synthetic indicators	These indicators cover a large range of subjects that have been developed for scoreboard purposes (input-output focus). 'They take into account the various aspects which constitute the technological capability of a country and aggregate them into a single figure. They are typical macroeconomic indicators aiming at comparing the positions of different countries and their changes. Their merit is to provide a clear and immediate image of a country's ranking, while the drawback is to sacrifice the inherent complexity of the process of knowledge production and distribution'. (Archibugi, Denni, & Filippetti, 2009).	Archibugi et al. (2009)	World Economic Forum, 2003, 2004, 2005, 2006 The European Commission, 2007, 2008 The World Bank OECD, 2006, 2007
7. Databases on specific topics	Developed as research tools by individuals or groups such as collaboration data (output).	Pari Patel and Pavitt (1997) Patel and Pavitt (1999) Hagedoorn and Schakenraad (1990)	OECD, 2001

TABLE 2.13 Overview of indicators used to measure innovation in theory and practice. Revised from Smith (2005).

Last, non-R&D data has been criticised because there are several definitional restrictions with respect to innovation inputs and outputs in the methodologies used to collect this type of data (Smith, 2005). His discussion focuses on whether an approach that was originally adopted for manufacturing is extendable to services, which outputs are mostly intangible. Overall, the approach is limited to technological aspects of innovation.

The significance of output indicators differs a lot according to the type of organisation for whom innovation is an essential driver (e.g. universities, companies, and municipal or regional governments). For instance, each organisation value and use indicators to measure attaining innovation (success or failure) in relation to its own core processes and aspirations. For example, the sales flowing from new products are more relevant for R&D firms as the amount of Nobel laureates are for universities, or the number of R&D spin-offs per square kilometre is for local governments.

INPUT INDICATORS - *INNOVATION AS A PROCESS*			
Quality of economic base (i.e. clusters on particular or related fields, network of institutions supporting R&D, presence of firms and research institutes that are geographically distinctive, interlinked organisations that support and conduct innovative activities)			
Quality of knowledge base (i.e Presence of world class university, HEIs and research institutions matching the economic base)			
Capacity and quality of human capital (i.e. R&D personnel, highly-educated and trained labour in technology fields)			
Supporting organisational climate (i.e. Presence of innovation policies in city/region aimed to achieve knowledge-based economic and social development, the establishments hybrid organizations and entrepreneurial models -e.g. incubators, venture capital firms, PPP, etc.-, establishments of incentives - e.g. targeted tax systems; welfare; legitimate authorities within a territory; research funding; use of legal systems to establish special rights, etc.)			
Investments on innovation activities (e.g. R&D; Training; Equipment acquisition; Market exploration; Design)			
Quality of living (i.e. safe and attractive social environment, social inclusion, equality, cultural amenities, social security, housing, and green)			
Quality of accessibility and mobility infrastructure (i.e. enough and fast digital access and transportation systems, Location-specific factors cost-efficiencies: unique locations factors such as universities, airports, labour, venture capital and quality of life features, required for innovative high-technology development)			
Capacity of research infrastructure (e.g. university technology transfer offices, research centres, labs, engineering schools, incubators, and science parks in a region)			
OUTPUT INDICATORS - *INNOVATION AS A PRODUCT*			
Patents (applications and grants)	x	x	x
Licensing	x	x	
Prototypes	x	x	
Start-ups (new SMEs spillovers of university research and/or MNCs)	x	x	x
Research grants in technology fields	x	x	x
Publications and citations	x	x	x
Engineering developments and experiments	x	x	
Databases on specific topics developed as research tools (collaboration data on technical and business innovations covering sources and types of innovation)	x	x	
Nobel Laureates	x		
Technological improvements in products and processes	x	x	
Sales flowing from new or improved products		x	x
Orientation per type of organisation	*University*	*Industry*	*Governments*

TABLE 2.14 List of indicators used to measure innovation distinguished by inputs and outputs

Accordingly, understanding these differences and the orientations of the different organisations towards innovation is relevant to outline the potential role of the built environment as an organisational resource in stimulating innovation. Table 2.14 lists the multiple indicators of innovation found through the literature. This list distinguishes input- and output indicators, and the orientation of the different organisations relevant in this research towards certain output indicators.

As seen in this section, the societal perception of innovation as a driver for economic growth has emerged and developed in theory. Although measuring innovation is a hot-topic in the political and academic debate, there are many researches investigating the mechanisms that could possibly explain innovation as a process. An important one is an academic approach associating innovation with the processes of knowledge creation and diffusion. This approach is concerned with the spatial distribution of innovation from two interrelated perspectives: agglomeration economies and evolutionary economic geography. Both perspectives investigate the geographical agglomeration of innovative activities as phenomenon arising from knowledge externalities, which is at the heart of the processes of knowledge creation and diffusion in organisations. The two perspectives will be elaborated in the next two sections.

§ 2.4.2 The geography of innovation

Definition

Externality *is 'an effect emanating from one activity that has consequences for another activity, but is not directly reflected in market prices'*

(Beaudry & Schiffauerova, 2009).

The relationship between innovation and space is based on a theoretical assumption that knowledge externalities can positively affect a firm's innovativeness because the knowledge firms create spills over to other firms or organisations (Beaudry & Schiffauerova, 2009). This approach has been investigated by many through the study of knowledge spillovers as one of the varied sources of agglomeration economies[18]. These spillovers involve tacit knowledge whose transmission depends on distance (or proximity) because this type of knowledge is embodied in people and 'can only be acquired through the process of social interaction' (Beaudry & Schiffauerova, 2009).

Existing research suggests that 'knowledge spillovers tend to be geographically bounded within the region in which the new economic knowledge is created' (Audretsch & Feldman, 1996; Feldman & Audretsch, 1996). In this view, spatial concentration seems to be very relevant in the early stages of innovation when the creation of non-codified knowledge is at the heart of the learning process. The supply of technology campuses aligns with this assumption since the concentration of innovative activities is a typical accommodation choice in technology-driven research organisations. The following section elaborates on the different views on knowledge spillovers giving a prominent role to spatial concentration creating conditions for innovation.

Knowledge spillovers and spatial concentration

Spatial concentration is an essential aspect in the academic debate explaining the mechanisms by which the presence and collective actions of firms is believed to positively affect innovation. Indeed, knowledge spillovers as source of agglomeration advantages are explained either two ways. First, the specialisation or the concentration of an industry -or similar industries- in a region, well known as localisation externalities, which recognises either monopoly (Marshall, 1890) or competition (Porter, 1990) to favour innovation. And second, the variety of industries within a geographic region known as urbanisation externalities, in which competition is desirable for innovation (Jacobs, 1969).

The study of knowledge spillovers as one of the varied sources of agglomeration economies has been reviewed and categorised by Glaeser et al. (1992) into MAR externalities, Porter externalities, and Jacobs' externalities. The influence of space in each of these externalities is present at different scales ranging from regions to the city. Table 2.15 provides a comparative overview of these three main externalities' approaches regarded as specialisation, diversity, and competition externalities.

18 According to Parr (2002), agglomeration economies are regarded as 'cost savings to the firm which result from the concentration of production at a given location, either on the part of the individual firm or by firms in general'. Various sources of agglomeration economies have been identified in the literature – e.g. infrastructure sharing, input sharing, knowledge spillovers, labour market pooling, home markets effects, consumption, rent seeking (political support), and natural advantages (Singh, 2010). This variety of sources cannot be generalised to a single phenomenon and therefore, agglomeration economies are classified into internal economies to the firm and external economies that result from the presence and collective action of other firms. Furthermore, they can be viewed from the perspectives of scale, scope and complexity (Parr, 2002).

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EXTERNALITY IN KNOWLEDGE CREATION & DIFFUSION	*Specialisation externality*	*Diversity externality*	*Competition externality*
Source	Marshall (1890)	Jacobs (1969)	Porter (1990)
Theoretical assumption	Industries specialise 'geographically because proximity favours the intra-industry transmission of knowledge, reduces transport costs of inputs and outputs and allows firms to benefit from a more efficient labour market' (Beaudry & Schiffauerova, 2009).	Diversity is the 'major engine for fruitful innovations, because the greater sheer number of and variety of division of labour, the greater the economy's inherent capacity for adding more kinds of goods and service' (Jacobs, 1969)	Local competition rather than monopoly favours growth and the transmission of knowledge in specialised and complementary industries that concentrate geographically – i.e. clusters.
Source of knowledge spillovers	Specialisation (Within a specific industry)	Diversity & Competition (Across sectors that are close technologically)	Specialization & Competition (within a vertically integrated industry)
Theory development	The 'concentration of an industry in a region promotes knowledge spillovers between firms and facilitates innovation in that particular industry within that region' (Beaudry & Schiffauerova, 2009). Specialisation encourages the transmission and exchange of knowledge (tacit or codified), of ideas and information, of products and processes through imitation, business interactions, and inter-firms circulation of skilled workers (Saxenian, 1994). A further contribution -the MAR model (Glaeser et al., 1992)- 'perceives monopoly as better than competition as it protects ideas and allows the rents from innovation to be appropriated' (Beaudry & Schiffauerova, 2009).	A diverse economy is conductive to the exchange of skills necessary to the emergence of new fields The exchange of complementary knowledge facilitates search and experimentation in innovation. 'A well-functioning infrastructure of transportation and communication, the proximity of markets, and better access to specialized services are additional sources of urbanisation externalities' (Beaudry & Schiffauerova, 2009). Competition is desirable for growth of cities and firms as incentive for innovation and speed up technology adoption.	'Strong competition in the same market provides significant incentives to innovate which in turn accelerate the rate of technical progress of hence of productivity growth' (Beaudry & Schiffauerova, 2009). The presence of the cluster suggests that much of competitive advantage resides in the locations of a firm business unit. In recent theory developments, M. E. Porter (2008) asserts that 'that even though old reasons for clustering have diminished in importance with globalization, new roles of clusters in competition have taken on growing importance in the increasingly complex, knowledge-based and dynamic economy'.
Spatial scale of influence	These intra-industry spillovers are known as localisation (specialisation) externalities can only be supported by regional concentrations.	Cities are the source of innovation, whereas a diversified local production structure gives rise to urbanization externalities.	A cluster as 'a geographically proximate group of interconnected companies and associated institutions in a particular field, linked by commonalities and complementarities' (Porter 2008). It could be the region within or across countries.

TABLE 2.15 Externalities in the process of knowledge creation & diffusion, based on the review of Beaudry and Schiffauerova (2009)

These views have encouraged a growing number of empirical researches investigating the causes of agglomerating innovative activities. Most researches have used typical economic indicators at firm and regional levels of analyses to quantify knowledge spillovers (e.g number of patents, number of inventions, the likelihood of adopting a particular innovation, R&D intensity, number of innovations, and the economic impact of an innovation after two years). However, the popular use of these indicators –especially patents and inventions counts- is also criticised in the literature because they are limited to cover the wide range and diversity of innovative activities, which differ in quality, inventive output, and economic impact (Beaudry & Schiffauerova, 2009).

Although these theories have influenced a growing body of empirical research in the agglomeration literature, the conditions enhancing growth and innovation in cities and regions remains inconclusive and ambiguous because both, specialisation and diversity are related to growth in different ways (Van Oort & Lambooy, 2014). Based on a review of empirical works, a diverse environment is considered more beneficial to innovation than a specialised industrial base because of the lesser negative impact found in diversified regions compared to specialised regions (Beaudry & Schiffauerova, 2009). Nevertheless, the authors conclude that 'more work is needed to go beyond the implicit interpretation of the underlying concepts of specialization and diversification externalities in order to fully understand such an abstract phenomenon as knowledge spillovers, their localized character and their impact on the innovative process and regional performance'. The context is outlined as a relevant aspect explaining the different externalities in the processes of knowledge creation and diffusion in different locations and time periods (McCann, 2014). All in all, it has been generally accepted that the spatial concentration of organisations and their related activities in specific geographical contexts has an effect in the creation and diffusion of knowledge.

An important concept emerging from this assumption is the one exploring the notion of proximity beyond its geographical dimension. Mainly, it has been argued that face-to-face interactions and networks are important channels facilitating the flows of tacit knowledge. For instance, formal and informal face-to-face contacts can lead to knowledge spillovers because of the exchange of information, expertise, and unexpected ideas among people working within and across organisations. Face-to-face contacts can also happen via reciprocity links among both local and global networks -e.g. visits, talks, seminars, tutorials consulting, internships, joint ventures, subcontracting, etc.- (Bathelt et al., 2004). In this case, two aspects become important. First, it is the multiple dimensions of proximities making interpersonal interaction and collaboration happen (Boschma, 2005). And second, it is labour mobility and the role of transportation making possible to reach and access actors among knowledge networks (Autant-Bernard, 2012). These two aspects are not mutually exclusive of one another and both are relevant to explore the built environment perspective in which this research is framed. The following section elaborates on the concept of proximity and its interrelationship with distance and accessibility in the process of knowledge creation and diffusion.

Proximity

In agglomeration economies, a distinction made about the multiple dimensions of proximity is a basic argument of its evolutionary and institutional school of thought[19]. This view has become important to understand how innovation as a learning process operates between regions, industries, and organisations, especially when considering the multiple geographical sources of new knowledge in a globalised world. In his critical assessment about 'proximity and innovation', Boschma (2005) distinguishes five dimensions of proximity building upon the work of the French School of Proximity and Dynamics. These are cognitive-, organisational-, social-, institutional-, and geographical proximity. Accordingly, geographical proximity cannot be assessed in isolation but only in relation to these other dimensions. Similarly, some dimensions of proximity are strongly linked to each other (i.e. organisational, social, and institutional proximity) and/or complement each other. Table 2.16 summarises and compares the five dimensions of proximity, as well as their advantages and associated problems for learning and innovation. Overall, each of these dimensions addresses potential solutions for their associated problems, which involve a sounded balance of securing proximity on the one hand, while keeping some distance between actors and organisations on the other hand.

Although Boschma (2005) concludes that 'geographical proximity is neither a necessary nor a sufficient condition for learning to take place' he recognises its facilitating role in interactive learning strengthening the other dimensions of proximity. For instance, short geographical distance favours social interaction and trust building, which might decrease cognitive distance between actors over

19 Evolutionary economic geography is concerned with agglomeration economies arising from knowledge externalities (Boschma & Frenken, 2006). For instance, Schumpeter's ideas recognizing the significance of endogenous R&D in large firms are considered as basis of modern evolutionary theory (Simmie, 2005). More contemporary definitions, outlines that 'evolutionary economic geography views institutions as primarily influencing innovation in a generic sense, and as co-evolving with technologies over time and differently so in different regions' (Boschma & Frenken, 2006, p. 291)

time. Likewise, he addresses that other dimensions of proximity can substitute geographical proximity (e.g. organisational and cognitive proximity can facilitate the coordination between actors by temporarily bringing people together, who exchange tacit knowledge through face-to-face interaction without the need of permanent co-location).

DIMENSION OF PROXIMITY	*Cognitive*	*Organisational*	*Social*	*Institutional*	*Geographical*
Definition	Actors sharing the same knowledge base and expertise.	Actors sharing relations in an organisational arrangement.	Actors sharing relations in a social context based on embeddedness, trust and commitment.	Actors sharing relations in an institutional framework based on collective norms and values.	The spatial or physical distance between actors.
Advantages for learning	Facilitates the capacity to absorb new knowledge.	Facilitate control mechanisms to ensure ownership rights and returns on new knowledge.	Facilitates the exchange of tacit knowledge and effective interactive learning.	Enables stable conditions for effective interactive learning.	Enhances interactive learning by stimulating other forms of proximity.
Associated problems for learning	Too much leads to lock-in masking the view on new technologies or market possibilities. Too little leads to ineffective communication.	Too much can create dependency and lack of flexibility limiting the exploration of new knowledge. Too little leads to lack of control increasing the threat of opportunism.	Too much can lead to closeness and missed opportunities in a changing market because of excess of trust. Too little can lead to lack of trust and commitment.	Too much can lead to institutional inertia (impeding re-adjustments for change) and lock-in (blocking exploration). Too little leads to lack of social cohesion and common values and language.	Too much leads to local closeness blocking the learning ability of (highly specialised) networks
Potential solutions	Complementary capabilities in a common knowledge base	Network-like organisation of the firm with relative decentralised units but well-coordinated.	Networks consisting of both market- and embedded relationships.	Checks and balances between institutional stability, openness and flexibility.	Balance mix of local and non-local relation and linkages.

TABLE 2.16 Summary of five dimensions of proximity based on the assessment of proximity and innovation by Ron A. Boschma (2005)

Largely, this study states that 'some, but not too much, cognitive proximity (i.e. an absorptive capacity open to new ideas) is a prerequisite for interactive learning processes to take place. The other four dimensions of proximity are considered mechanisms that may bring together actors within and between organizations' (Boschma, 2005, p. 71). In this view, geographical proximity has an indirect (and dependent) role in the process of knowledge creation and diffusion because innovation as an interactive learning process needs the other dimensions of proximity. However, it is not known what is the optimal combination of these proximities for innovation or under what circumstances some dimensions might be more relevant than others. Similarly, this paper concludes that more understanding is needed about the precise role of geographical proximity strengthening cognitive proximity over time.

Based on this framework, Boschma and Frenken (2010) introduced the notion of 'proximity paradox' - i.e. too much proximity can be detrimental for innovation by elaborating on the associated problems addressed for learning in Table 15 above. This paradox has been examined and validated in empirical research for some dimensions of proximities. However, the empirical evidence clarifying which types and levels of proximity are critical for knowledge networks is limited to specific contexts and sectors (Broekel & Boschma, 2012; Cassi & Plunket, 2014; Huber, 2012).

This proximity framework has strengthened an existing academic discussion in theoretical and empirical research on knowledge networks and innovation (Autant-Bernard, 2012; Boschma & Frenken, 2010; Coenen et al., 2004; Lagendijk & Lorentzen, 2007; Lagendijk & Oinas, 2005; Torre

& Rallet, 2005). Overall, the notion of time has gained importance whereas both, temporary face-to-face events and the selection processes over long-term periods in firms are associated to innovation and economic performance through the interrelation of proximities at the interface of global and local networks respectively.

In the one hand, temporary face-to-face events stress the importance of international labour mobility and transportation enabling collaboration among networks that are cognitively close but physically distant. On the other hand, selection processes in firms[20] stress the relevance of local conditions that meet new and changed requirements for innovation allowing firms, which are cognitively and physically close, to adapt according to open technological trajectories over time.

The last view is at the heart of modern evolutionary theory, which focuses on the dynamic processes linked to uncertainty and changes over time. For instance it is argued that 'over long periods firms have to deal with a number of difficult problems without necessarily having full knowledge of their options or the possible outcomes of different courses of action. As a result, they tend to continue along given trajectories because of previous decisions. These paths of development might turn out to be successful in the long-term. The results of these paths of development for firms and the localities in which they are located can therefore lead to either economic growth or decline…The continuation along existing trajectories is known as path dependency' (Simmie, 2005, p. 802). In this context, path dependency might help to explain the agglomeration of economic activities and the evolution of proximities as a historical development linked to economic growth and technological change.

Largely, the growing number of studies on knowledge networks and innovation has validated this proximity framework by making evident that 'actors who exchange knowledge also tend to be similar in terms of proximity' (Balland et al., 2015). Nevertheless, these researchers claim that proximity has been studied as a static concept rather than a dynamic one. In response, their study describes how types of proximity explaining collaboration might change over time based on past knowledge ties. Accordingly, they explore the co-evolutionary dynamic between proximity and knowledge networking within and between organisations.

As a result, a dynamic extension of the proximity framework is captured through five processes leading to changing proximities over time. These are learning, integration, decoupling, institutionalisation, and agglomeration [See Table 2.17]. The underlying assumption behind this dynamic framework is that proximity can be explained from collaboration and not only the other way around as it has been commonly studied. That is because this relationship might vary over time: 'In the short term proximity is expected to drive the formation of knowledge networks while, in the long run, knowledge networking in turn increases proximity levels'.

This dynamic framework of proximity has been recently tested in empirical research (Broekel, 2015). Its results identified three types of dynamics between different types of proximity in networks that are systematically interrelated. Accordingly, geographical proximity co-evolves only with organisational and social proximity in the short timeframe. This research is one of the earliest milestones to empirically explore the evolution of knowledge networks. Overall, this new perspective opens up a wide range of research questions for future research that can help clarifying our understanding of proximity and innovation linked to history and geography.

20 In evolutionary economic geography, selection is a term used to explain location decisions in firms as a way to cope with uncertainty to fit into a particular environment. For instance, agglomeration is a selection mechanism that explains concentration of economic activities in regions (Boschma & Lambooy, 1999).

DIMENSION OF PROXIMITY	Cognitive	Organisational	Social	Institutional	Geographical
Dynamics (change)	Knowledge bases of actors change continuously over time according to cumulative learning processes.	Changes at a firm level through mergers and acquisitions from technological relatedness.	Embeddedness of knowledge relationships change in an evolving social context.	Relationships between actors change through institutional change at the macro-scale	Changes according to locations decisions or organisations and their units.
Leading process	Learning	Integration	Decoupling	Institutionalisation	Agglomeration
Evolution mechanism over time	Social process based on the recombination of existing knowledge in- and outside organisations.	Progressive re-arrangement of units or establishments within an organisational structure.	Autonomy process of personal relationships from its original context within and between organisations.	Progressive integration of rules and values in actors' behaviour.	Decrease of geographical proximity between actors.
Relative degree of dynamism	Very high	Low	Low	High	Very low
Explanation	Continuous change – No need for agreements	Requires mutual agreement – It is costly	Requires mutual agreement – It is costly	Continuous change from mutual interactions	Involve high risks and costs because of trade-off

TABLE 2.17 Summary of dynamics of knowledge networks and proximity based on Balland et al. (2015)

Indeed, further research in this field points out to the development of new conceptual and methodological views that explore mechanisms for knowledge creation and diffusion such as 'the heterogeneity in the actors involved, spatial scale, selection and survival, and time and path dependency' (Van Oort & Lambooy, 2014). For instance, most of the polemic aspects of evolutionary economic theory[21] relate to context-specific factors that are time and space dependant.

In this complex and rather inconclusive academic context, it seems challenging to explore the built environment perspective framing this research. However, this evolutionary perspective involving uncertainty and path-dependant links in time and space is inherent to build environment decisions such as location decisions of innovative organisations. In his review of the literature about innovation and space Simmie (2005) collects concepts from the late 1980s and early 1990s arguing that a global economy dominated by large multi-national corporations (MNCs) has emerged. Accordingly, MNCs' decisions about where to conduct their activities (e.g. headquarters, R&D, and production) play a major role in where innovation is located. For instance, the locations of MNCs headquarters and R&D activities 'create possibilities for SMEs located in the same areas to benefit from knowledge spillovers and to exploit new ideas and niche markets for innovation' (Simmie, 2005). Accordingly, locational decisions are crucial to overcome the uncertainties involved in innovation.

Furthermore, Simmie (2005) outlines the arguments of evolutionary economists 'that there are circumstances in which path-dependant innovative activities would be concentrated in some places'[22]. This idea is developed by Frenken et al. (2007) as a concept of related variety. These are particular

21 According to Van Oort and Lambooy (2014), four polemic aspects of economic theory and empirics need attention in further research explaining urban and regional economic growth summarised as follows: (a) the development paths or life stages of firms, sectors, cities and systems of cities, (b) specific spatial networks showing relations to the agglomeration forces, (c) specific urban and regional factors explaining the transmission channels, which are time and technology dependant, and (d) factors such as the relation with institutional structures, path-dependent development, the way selection works out for new technologies and firms, innovation, co-evolution, etc.

22 According to Boschma and Frenken (2006), 'evolutionary economic geography views the traditional determinants of firm (location) behaviour as being price signals (neoclassical) and place-specific institutions as conditioning the range of possible (location) behaviours and potential locations, but not determining actual (location) behaviour and locational outcomes'

places where technological trajectories are especially open and based heavily on tacit-knowledge, which relies on clear communication and understanding (cognitive- but also organisational and institutional proximity), which in turns is facilitated by face-to-face contacts. Accordingly, successful sectors in regions diversify in a good degree overtime based on existing competences and specialisations. Once again, the time proximity facilitated by the geographic proximity to international hubs becomes important to avoid lock-in that can result from path dependant technological trajectories in regions.

In this context, the location and the mobility of highly educated and trained labour becomes a determinant factor for the agglomeration of innovative activities. It has been widely accepted that inner-urban areas have an advantage as the locations of innovation because there are plenty knowledge networks well connected by international transportation hubs. However, this last factor becomes important when explaining exceptional agglomerations of innovative activities that are not located in urban but rather in peripheral areas. Indeed, evolutionary theory is likely to contribute to our understanding about the role of the built environment on innovation through location decisions organisations are confronted with. Therefore, in order to understand the relationship between innovation and space, we must understand long-term economic and spatial change- i.e. studying campus development as a dynamic process linked to organisational, institutional, social and technological changes in specific places.

The following section concludes this chapter by summarising the main observations emerging from the interrelation of the concepts addressed in this and the two previous sections.

§ 2.5 Conclusions

What is the role of the built environment in innovation in theory?

This chapter has examined the relationship between the built environment and innovation from different theoretical perspectives in three research fields: real estate management (section 2.2), knowledge-based urban development (section 2.3), and economic geography (section 2.4). As shown in the previous three sections, there are many sources and theories related to this topic, because this is still a relatively unfamiliar topic not explicitly addressed in the literature. Therefore, this study links these fields as a foundation to build upon by addressing key concepts and sources relative to each of the fields explored in this study. The built environment is at the intersection of these three fields when understanding the concentration of innovative activities at the scale of the area that is demanded in cities and regions. Nevertheless, the role of the built environment in innovation is not explicitly addressed in all these fields.

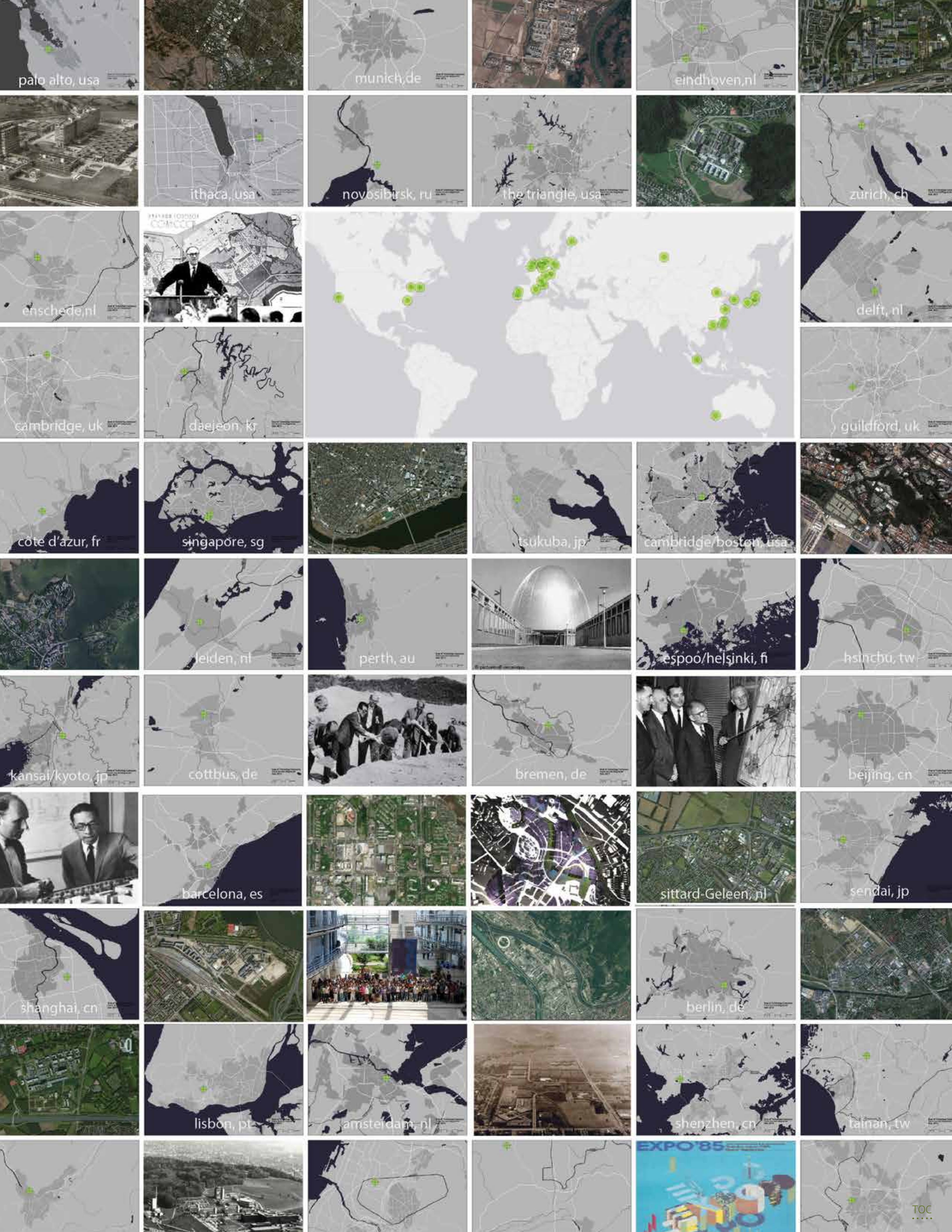
An approach to real estate management from the end-user perspective explicitly addresses the built environment as a resource steered to stimulate innovation as one of several organisational goals. This approach, referred to as corporate real estate management (CREM), is the foundation of this research and the concept of added value is the theoretical concepts through which the main research assumption is investigated.

However, most of the empirical research in this field is limited to studies investigating the added value of real estate on organisational performance mostly at the scale of the workplace, and much less at area level. This is important because in the context of the knowledge economy, attention has been placed both, in theory and empirics, to the role of urban and regional environments in innovation as a learning process. There is an increasing body of knowledge investigating the role of knowledge and innovation for economic development in cities and regions. In this context, the urban area seems to be an adequate scale level to explore the concept of added value of the built environment in innovation, which involves not only end-user organisations of real estate but also other organisations stressing innovation as a source of competitive advantage – e.g. municipalities and regional authorities. This observation moves the relationship between innovation and the built environment to a broader perspective, which is widely discussed in economic geography through the concept of knowledge spillovers. This concept is extensively studied in several theoretical and empirical researches of agglomeration economies explaining the concentration of innovative activities in cities and regions. However, there is an on-going debate in this field because the precise mechanisms explaining innovation as learning process (knowledge creation and diffusion) are ambiguous. Indeed, recent concepts developed from evolutionary economic geography may enlighten the path for future research explaining the concentration of innovative organisations in cities and regions, which are linked to context-specific aspects in time and space. Indeed, these aspects involve multiple dimensions, in which the physical dimension is often hidden but existent. This research has the disciplinary obligation to maintain the physicality of this debate.

Overall, the following observations have been made through the review of this literature that are important to clarify the relationship between innovation and the built environment:

- Innovation is a common driver of competitive advantage for different organisations in the knowledge-based economy. Although this concept has multiple dimensions in the literature, this research adopts its acknowledgement in its early stage of development as a learning process in which knowledge is created and transmitted through individuals. In this context, stimulating innovation is a goal of organisations for which this process is at their core business – e.g. technology-based research organisations. Similarly, it is a goal of organisations that benefit from this process to remain competitive in the knowledge economy – e.g. municipalities and regional governments.
- Measuring innovation through output indicators gives an insight on what organisations expect from innovation in order to compare their performance in relation to their competitors. Conversely, input indicators provide with an insight on what is needed for innovation as a learning process. Therefore, in establishing the relationship between the built environment and innovation, this research focuses on input-indicators. Nevertheless, output indicators can be used as references to compare subjects of study, in which stimulating innovation is an organisational goal contributing to performance.
- In theory, there is an unresolved issue about whether diversified or specialised environments are more favourable for knowledge spillovers. The existing empirical research shows that both, diversity and specialisation relate to growth in different aspects. However, the location of innovative activities in urban areas rather than peripheral areas is widely accepted as an ideal environment for innovation. This idea is growing in the knowledge economy because cities have abundant knowledge networks composed by heterogeneous actors who are increasingly mobile and well connected to international transport hubs. Nevertheless, there exceptional examples of concentrations in peripheral locations, which challenge the previous argument. Indeed, many technology campuses –seen as concentrations of heterogeneous innovative activities- are located in peripheral locations. In this context, assessing the potential differences in location characteristics of technology campuses and the reasoning behind location decisions can be a way to explore the physicality of innovation. Chapter 3 elaborates on this aspect.

Finally, many of the concepts addressed in this chapter are interrelated and can be used as theoretical grounds to address this topic. Some of these insights have simultaneously informed the data collection of the qualitative survey of 39 technology campuses that will be described in the next chapter. The empirical insights of the next chapter in combination with a careful selection of concepts addressed in this chapter will be integrated in a theoretical framework explained in Chapter 4.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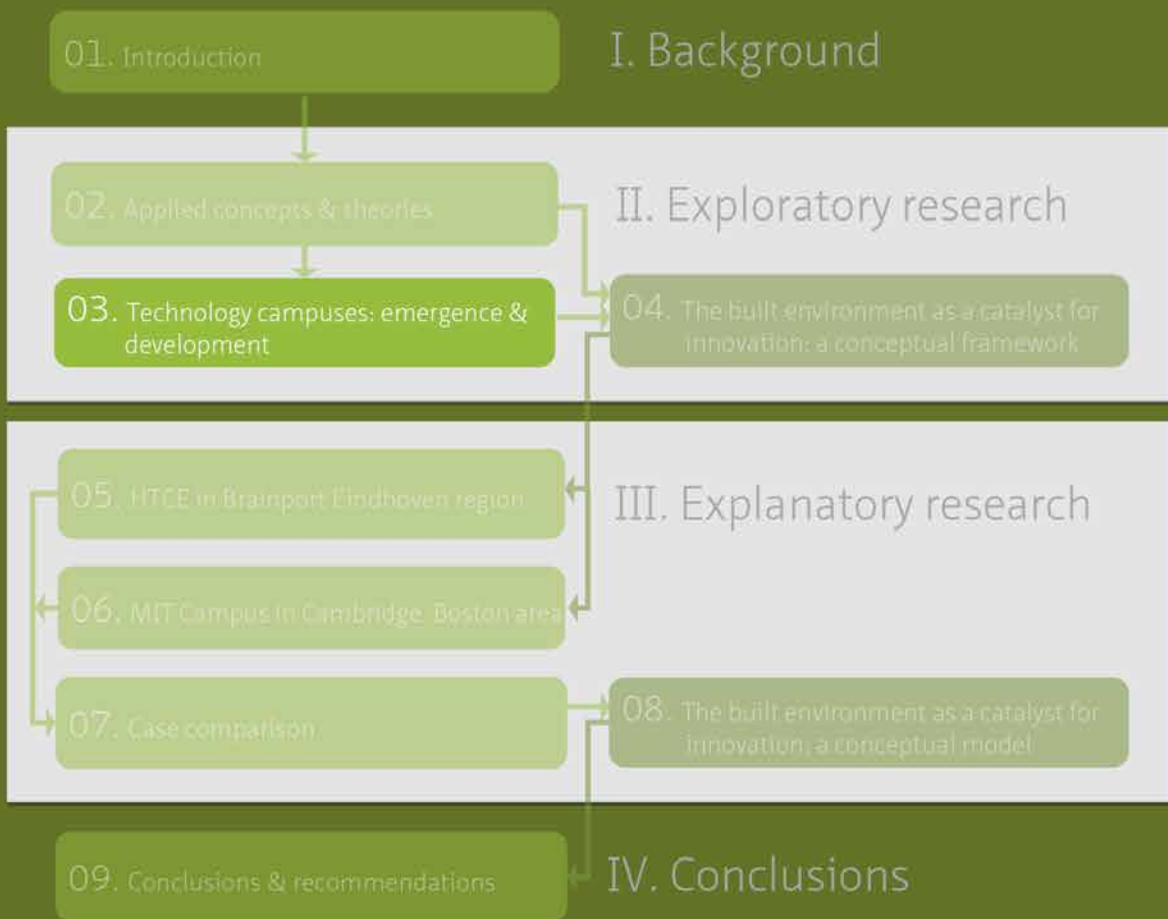
Chapter 3. Technology Campuses: emergence & development



The previous chapter outlines theoretical concepts that are relevant to investigate the role of the built environment in stimulating innovation. However, to establish connections between theoretical concepts of innovation and the built environment, we need more information about technology campuses as subjects of study. Indeed, technology campuses have been extensively studied as clusters of economic activities in the fields of urban economy, regional studies and businesses but much less from their built environment dimension. Therefore, this chapter presents the results of a qualitative survey of 39 campuses and their hosting cities, which contributes to answering the question: ***What are the distinct characteristics of technology campuses from the built environment perspective?***

This chapter aims to describe the general patterns in the demand for- and the supply of technology campuses in an international context. Thus, Section 3.1 begins with introducing the logic of this chapter and the methods used for data collection and analysis in the search for these patterns. Section 3.2 describes three periods of technological developments in which technology campuses have emerged and developed in an international context. Section 3.3 describes the general patterns in the demand for developing technology campuses by outlining the stakeholders and the goals involved in their strategic and financial structures. Section 3.4 describes the general patterns in the supply of technology campuses by describing their functional and physical characteristics. Lastly, Section 3.5 draws the conclusions of this chapter and how its findings can be used to investigate further the subject of study.

3 Technology Campuses: emergence & development

§ 3.1 Introduction

§ 3.1.1 Chapter aim and questions

This chapter aims to uncover and describe the general patterns in the demand for- and the supply of technology campuses in an international context. This is a necessary step to define technology campuses as subjects of study from the researcher's assumption (i.e. Technology campuses are built environments supporting the goal of stimulating innovation in multiple organisations).

Technology campuses have been studied from an economic and political perspective in the fields of regional studies, spatial planning, business, science and technology but much less from the built environment sciences. Thus, the main objective of this chapter is to gather empirical information that provides a definition and characterisation of technology campuses suitable for this research. The expected empirical insights will be used to develop a conceptual framework or analytical tool to further conduct the next research phase (i.e. Explanatory research or Part III of this dissertation).

This chapter addresses as main question: **What are the distinct characteristics of technology campuses from the built environment perspective?** Next to it, the following set of sub-questions guided this empirical exploration:

- What are technology campuses? When and where did technology campuses emerge and develop? Are there evident patterns in their emergence and development? (Section 3.2)
- Who are the stakeholders involved in the development of technology campuses? What are their goals? (Section 3.3.)
- Are there common patterns in the supply of technology campuses? What characteristics define the supply of technology campuses? (Section 3.4)

§ 3.1.2 Methods

This chapter answers these questions by using qualitative survey, which is one of the parallel strategies used in the exploratory research. This survey is used to fill an empirical gap on the subject of study 'the development of technology campuses as built environments' [See Figure 3.1]. Accordingly, this survey studied the diversity of technology campuses and their hosting cities with the purpose of description. Through this method, the variety of built environments referred to as technology campuses was explored, described, and compared. Since campus development is the subject under examination, this qualitative survey used documentation analysis rather than questionnaires for data collection.

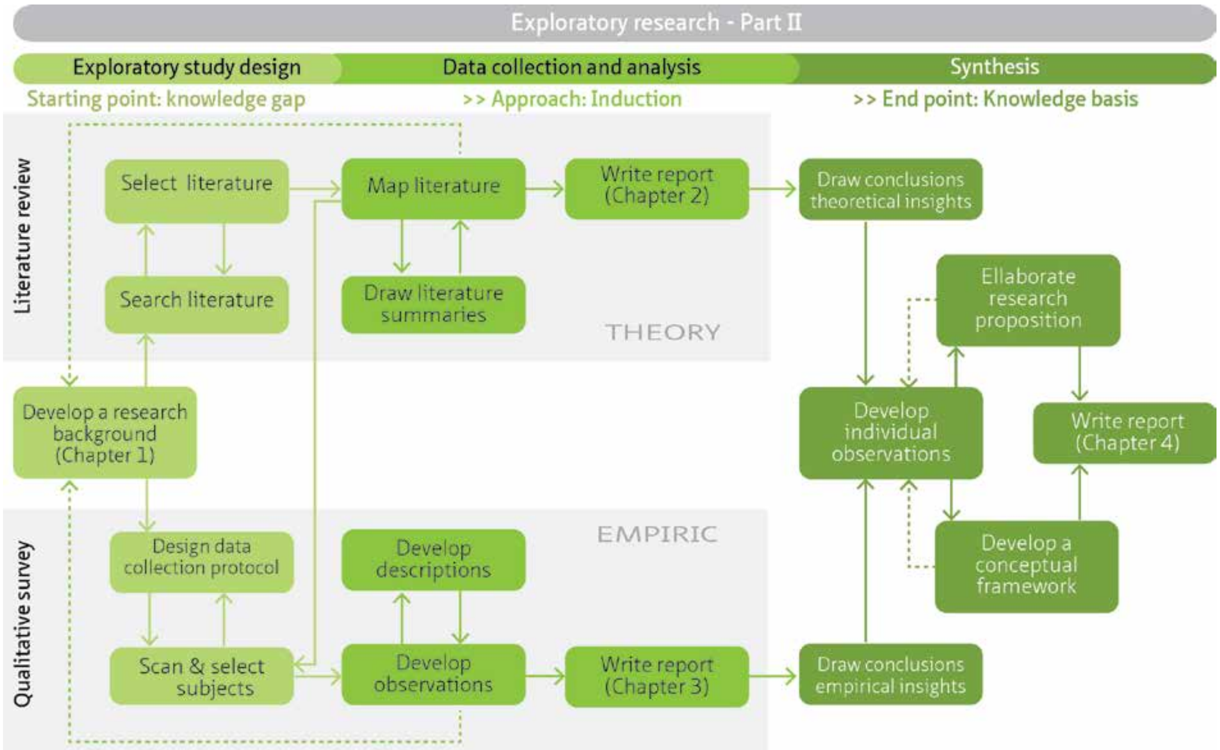


Figure 3.1 Exploratory study methods and phases. This chapter is the output of the 'empiric box' outlining qualitative survey as main method of data collection and analysis.

Next to the findings reported in this chapter, the description of technology campuses is summarised in a compendium [See Appendix B]. This compendium organises the information in a way that is suitable to compare the similarities and differences between the many built environments that technology campuses entails. Overall, the empirical insights of this chapter will be used to narrow down the focus of the study. The insights of this chapter, in combination with the theoretical insights from the literature study, will form the synthesis of the exploratory research and constitute the knowledge basis required to answer this research main question.

Data collection and analysis

The qualitative survey used an inductive analytical process that identified characteristics of technology campuses as built environment through the interpretation of data. This process involves the collection of substantial amount of data to be examined from different perspectives in the search for patterns emerging from the data. Although the analysis of the data is mainly inductive, the sampling and data collection was not entirely open but rather semi-structured. The identification of characteristics was guided by a structured protocol that distinguished predefined categories for documenting the cases. The data collection focused on specific information defining technology campuses as built environments in relation to their hosting city/region, by using an approach from corporate real estate management. Some specific data was also informed by the literature review conducted in parallel to this study.

Similarly, the diversity of the subjects studied is defined beforehand. In order to get a consistent overview of the existing realm of technology campuses, this survey selects a population of technology

TOC

campuses as large as possible[23]. After listing 50+ subjects that came across while reading the literature and newspapers, this study selected 39 technology campuses, which were consistently documented both in existing research and public documents of primary sources. The details of the sampling and data collection procedures are found in Appendix A.

This study used two main sources for data collection. First, it used document analysis of public and private records (e.g. mission statements, annual reports, policy, strategic plans, existing empirical research on the cases, maps, plans, photography, among others). Second, it used web-based databases and software (e.g. Google Maps, Google Earth, Arc Map, iTouchMap, etc.) to document the existing built realm of technology campuses.

This material is inventoried in a computer database (with spread sheet applications) and classified to organise sets of information based on a predefined categories. This organisation system helped to develop observations from the data. Simultaneously, the observations are described by means of two main techniques according to the type of content described. For instance, mapping is used to illustrate spatial data while categorisation is used to read the connections between all spatial, numeric, and non-numeric data collected.

Then, by moving back and forth between observations and descriptions, this process culminates with developing general conclusions that could logically explain the emergent patterns. These conclusions are reported as main findings in this chapter as follows.

§ 3.2 Emergence and development of technology campuses

The practice of developing technology campuses emerged and evolved in different periods of technology development, in which research became essential for knowledge creation and technology transfer. These periods are recognized as the atomic age (1945-1960); the space age and the ICT industrial revolution (1961-1988), and the digital and information revolution (1989 – present).

Undeniably, important technological developments in the 20th century originated from research advancing medical, space and defence projects, which accelerated the innovation process and the prosperity in industrialized countries. For instance, innovations such as the transistor (1947), the radar (1941-45), the computer (1943-46), the discovery of the DNA (1953), the satellite (1957), and the World Wide Web (1989), among others are good examples of the research outcomes in such periods. Since the late 1990s, the importance given to tech-based research in stimulating innovation has increased in the knowledge-based economy with the development of policies at regional and national levels. As a result, investing in research and its required infrastructure has become critical for society because this activity is essential for the creation and application of new knowledge leading to innovation.

23 Because of the diversity of built environments technology campuses entail, it is not known exactly how many of them exist. However, and estimation of 700+ is made based on the amount of science parks (400+) registered with International Association of Science parks (IASP); research parks (700+) registered with the Association of University Research Parks (AURP); and campuses of technical universities and colleges (200+) included in university rankings (The Times Higher Education University rankings).

Through literature review, a variety of built environments that match the working definition of tech-campuses are studied. The approaches and terms are different and sometimes overlapping. Most of these approaches focused on the fields of Planning, Economics & Geography, Business; Real Estate Management; and Urban Design (Bci, 2012; Buck, 2012; Carvalho, 2013; Castells & Hall, 1994; Den Heijer, 2011; Hoeger & Christiaanse, 2007; Link & Scott, 2003, 2006). Science Parks are the most studied developments because there are many of them[24].

Initially, the demand to accommodate different research activities leading to technology development was supplied both, in existing university campuses and in newly built environments that resembled the setting of university campuses[25]. The first (known) of the latter kind is Stanford Industrial Park, today named Stanford Research Park, which is the cornerstone of what would eventually be known as Silicon Valley. Eventually, this supply became a model that has been used in different regions of the world until today. This practice has given to concentration a leading role in the accommodation of research activities. The context in which the variety of technology campuses emerged and developed is described in three periods as follows.

§ 3.2.1 The post-war period & the atomic age: the origin of the R&D Park and Nuclear power in technology campuses

The historical events of the early 1940s marked an important moment for global technological developments in the 20th century. Indeed, several important technological developments trace their origin to World War II, when the complexity of modern weapons and the urgency of war inspired engineers and mathematicians in several countries to accelerate the process. Examples of these are the creation of the first transistor at AT&T Bell Laboratories in 1947 used in radio, television or other electronic device; and the first time a computer, UNIVAC, was used by the United States Census in 1951 and not for military purposes (Headrick, 2009). By the same year, Stanford Industrial Park, as it was called in that moment, start its construction. On April 7, 1953 the IBM 701, built in 1952 for the U.S. Air Force after the outbreak of the Korean War, was formally unveiled to the public as the IBM 701 Electronic Data Processing Machines (IBM Corporation, 1994, 2013b). 'For a decade after WWII, first-generation computers were so complex and costly that only the United States government could afford to operate them for military purposes' (Headrick, 2009 p.132). The IBM 701 was 'the first IBM large-scale electronic computer manufactured in quantity as well as the IBM's first commercially available scientific computer' (IBM Corporation, 1994, 2013b). It was in this period when government spending on scientific research and development gained importance in the United States, both for military and medical purpose and mostly devoted to advance defence projects. For example, in 1943 at MIT the Radiation Laboratory in Building 20 was built as one of several facilities for government radar research. Then, in 1946 The Research Laboratory of Electronics is established in this building as the peacetime sequel (MIT, 2013). These initiatives and military motives behind marked a period regarded also as the Atomic Age.

24 Nowadays, there are almost 400 Science Parks registered with International Association of Science Parks (IASP) and more than 700 research, science and tech parks are members of Association of University Research Parks (AURP).

25 Large research facilities were developed in the existing premises of universities of technology such as the Radiation Laboratory built in 1943 at MIT campus in Cambridge as one of several facilities for government radar research (MIT history line, accessed in 2013). New campuses resembled the spatial configuration of the traditional college campus, in which the self-standing buildings on the green were arranged in a functional setting that looked inwards.

The acknowledgment of an 'Atomic Age' began with the operation of the first nuclear plant located in Oblinks, Russia at the early historical moment known as 'The Cold War'. The technological developments then focused on atomic energy mostly derived from 'a race between the United States and the Soviet Union to develop nuclear bombs and missiles to deliver them anywhere within minutes' (Headrick, 2009 p.133). Despite the smaller economy of the Soviet Union compared with that of the United States, the Soviet government spent as much as the United States on nuclear weapons. In 1952 the United Kingdom engaged in the same nuclear race, followed by France in 1960 (Headrick, 2009). In the meantime, scientists and engineers found a less disappointing use for nuclear power: generating electricity. Besides the Russian case, more plants began operating in 1956 at Calder Hall, UK and in 1957 at Shippingport, Pennsylvania and the same year the first nuclear reactor in Germany was built at the Research Campus Garching of the Technical University of Munich (Hoeger & Christiaanse, 2007). Nevertheless, the use of nuclear power as a source of energy frightened society after several cases of leaks or explosions in nuclear plants occasioning among others human death, exposure to dangerous levels of radioactivity for people and ecosystems, and the displacement of communities living in their surrounding areas. Considering the costs of the disasters not only for society but also for the environment and for the economy, some countries closed their nuclear plants proving nuclear power as one of the biggest technological failures in the world's history.

Technological development was, more than ever, a sign of nation's power. Competitiveness was driven by different motives. Besides the nuclear power attention, important developments are outlined in this period. In 1956, the first telephone line cable was laid in the Atlantic Ocean (TAT-1) which was an important advance in long-distant communications once fibre-optic cables came to optimize the capacity of telephone line systems. In 1957, the Soviet scientist launched the first satellite named Sputnik into orbit around the world. This development surprised the world specially the American military research that was busy developing bombs while Soviets were secretly working on rockets that could reach any place on earth carrying a hydrogen bomb (Headrick, 2009). In 1959 the U.S. Navy built the first real satellite navigation system, which was called TRANSIT. The system was designed to locate submarines, and started out with six satellites and eventually grew to ten (Sullivan, 2012).

Parallel, the first advance in biomedical technology after the Penicillin, introduced in WWII, was the discovery of the DNA in 1953 at Cambridge University in England, explaining in codes how an organism was formed and how it reproduced (Headrick, 2009). Other experiments in this area, advanced the development of biotechnologies such as the oral contraceptive in 1956, which was put on the market in the early 1960s called 'the pill' as the most important pharmaceutical product in history(Headrick, 2009).

§ 3.2.2 The space age & ICT industrial revolution: the emergence of the Asian technology campuses

This period began with an event that changed the perceived 'war race' between the United States and the Soviet Union: the first cosmonaut, Yuri Gagarin, is put into orbit by the Soviets and ten months later, an American team launched their cosmonaut, John Glenn, into orbit too (Headrick, 2009). By the end of the same decade, two American astronauts landed on the moon in 1969. Extraordinary accomplishments in human science and technology by these two countries can be attributed to the disposal of money and talent. Soon, after Sputnik, several American and Soviet military satellites came into orbit, but it was until 1962 when Telstar, the first commercial communication satellite, began to transmit television broadcasts worldwide allowing the world to enter an era of instantaneous global telecommunications (Headrick, 2009). Besides their primary use in espionage (Headrick, 2009) , many satellites were and still been used in communications, meteorology, astronomy, mapmaking, and agricultural and geological surveying.

Despite the fact most of the technologies introduced until this moment were originated in North America or Europe, many of the items available –e.g. electronic equipment, cameras, appliances, motor vehicles- were produced in Japan. In the 60s the Japanese products began competing in the world market for consumer goods. For instance, the company Sony named before Totsuko, grew quickly when it began selling the first transistorized portable television. Indeed, by investing in R&D the company has remained strongly competitive on consumer electronics technology ever since (Headrick, 2009). Correspondingly, Tsukuba Science City, the first intervention of this kind in Japan, was built in 1968.

In 1964 Mainframes, a series of machines introduced by IBM as System/360 and developed for businesses, which is regarded as 'the most important product announcement in company history to date' (IBM Corporation, 2011). In 1977, Joseph Wozniak and Steve Jobs, who assembled their first computer circuit boards in a garage, introduced Apple II -a small desktop device-. Apple II was aimed at the small-business market and by selling thousands of units, it became an instant hit (Headrick, 2009). The birth of the IBM Personal Computer or PC is dated in 1981. It was the first time that IBM contracted the production of its components to outside companies: Intel developed the processor chip and Microsoft developed the operating system, called DOS or Disk Operating System (IBM Corporation, 1994, 2013a). Soon, by 1986 Japan entered the personal computer market overtaking the American firms in electronics manufacturing.

Parallel, a relevant advancement giving a different dimension to the computer and digital data was the 'Internet' or network of networks, developed in 1983 and allowing all kinds of computers to communicate with one another. By 1984, a million computers were connected through telephone lines (Headrick, 2009). Besides the computers, another electronic advance includes the development of GPS. In 1974 the branches of the US military launched the first 24-satellite GPS system called NAVSTAR. Between the years 1978-1985 more test satellites were launched into space to test the NAVSTAR system, which was called back then 'the GPS System'. Only until 1983 (once it was completed) it was allowed to all civilian commercial aircraft using the GPS system to improve navigation and air safety (Sullivan, 2012).

In the field of biomedical technologies, important advances took place in this period in which previous discoveries began to have practical applications. The development of laboratory equipment in 1972-73 that uses a process called polymerase chain reaction made possible to turn successful laboratory experiments into industrial products. This event marked the beginning of the biotechnology industry (Headrick, 2009). Overall, despite the government support for the development of defence devices the most important breakthroughs of the post-war years occurred in electronics and biotechnology, which open the door to the period we live in: the information age. An important issue is the change in the developments from government client oriented to customer and small business-oriented, leading to personalisation and access to technology.

As soon as Japan entered the computer market, Sendai Technopolis (1986) and Kansai Science City (1987) were built as part of a large Japanese technology program. These two areas and Tsukuba Science City -mentioned before- are examples of areas regarded as Technopoles (Castells & Hall, 1994). Accordingly, 'Technopoles are generally planned developments. They contain significant institutions such as universities or research institutes, which are specifically implanted there in order to help in the generation of new information. Their function is to generate the basic materials of the informational economy' (Castells & Hall, 1994, p. 1)

An important event for the built environment in this context is that in 1984 the International Association of Science Parks (or IASP) is created. Two years later, in 1986, the Association of University Related Research Parks (AURRP), was formed 'in response to a growing interest in research and development activities based in such unique planned properties' (AURP). The name was changed to the Association of University Research Parks (AURP) in 2001. Science Parks became an international phenomenon (Phan et al., 2005). Though, the definition of a research or science park differs widely. A well know definition of Science Parks (Link & Scott, 2003), includes three components: 'a real estate development; an organizational program of activities for technology transfer; and a partnership between academic institutions, government and the private sector'. As well, 'science parks include technology parks with a majority of tenants that are heavily engaged in applied research and development. Technology or innovation parks often house new start-up companies and incubator facilities' (Link & Scott, 2003). Next to it, there is de definition of a university research park, which is 'a cluster of technology- based organizations that locate on or near a university campus in order to benefit from the university's knowledge base and its on-going research. The university not only transfers knowledge but expects to develop knowledge more effectively given the association with the tenants in the research park' (Link & Scott, 2006).

Similarly, AURP defines a university research park as 'a property-based venture, that includes five components: master plans property designed for research and commercialization; it creates partnerships with universities and research institutions; it encourages the growth of new companies; it transfers technology; It drives technology-led economic development' (AURP). Nowadays, there are almost 400 Science Parks registered with IASP (IASP) and more than 700 research, science and tech parks are members of AURP (AURP). The number of science parks has steadly increase since the late 1990s up today [See Figure 3.2]

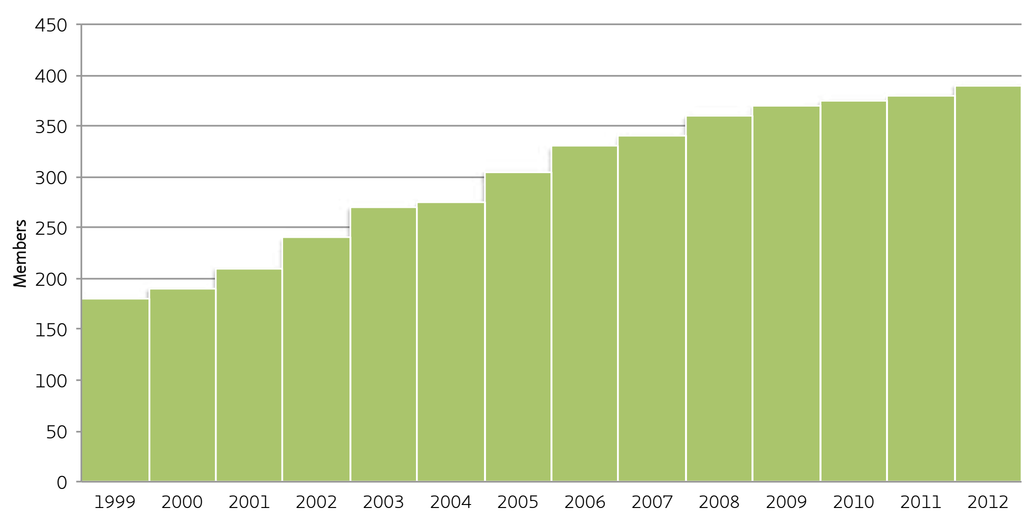


Figure 3.2 Number of Science Parks registered at IASP from 1999 until 2012 (Data: IASP, accessed in 2011 and 2016)

§ 3.2.3 The digital & information Age: Global coverage and hybrid developments

An important development opening the doors for the information revolution was in 1989 the creation of the 'World Wide Web' by Tim Berners-Lee of the European Nuclear Research Centre in Geneva, allowing computers to connect anywhere on Earth.

In this period, technology is not related to a history of global war. In fact, it is outlined the end of the Cold war with the dissolution of the Soviet Union in 1991. On the contrary, the use of technology in other conflicts allowed military strikes to minimise the civilians' casualties. First, it is the use of precision guide munitions in Gulf War (1990-1991) and the use of military Global Positioning Systems, which was crucial to navigate through the desert. And second, it is the development of high-tech tools technologies by the Defense Advanced Research Projects Agency for the U.S. military.

In 1999, the mobile phone manufacturer Benefon launched the first commercially available GPS phone, a safety phone called the 'Benefon Esc!'. The GPS phone was sold mainly in Europe, but many other GPS-enabled mobile phones would follow (Sullivan, 2012). In 2001, as GPS receiver technology got much smaller and cheaper, private companies began pumping out personal GPS products, like the in-car navigation devices from Tom Tom and Garvin.

In the fields of Biotechnology and Medical Sciences it is outlined an important event: in 1997, the first successful case of a cloned mammal, a sheep called Dolly, was born. Cloning became an important an controversial advance since the technology capable to clone a human being exist but has not been used yet for many reasons apart from technological determinism.

Nowadays, the pace of technological developments is faster than the research documenting them. Indeed, having a clear an comprehensive picture of the recent developments needs some temporal distance in order to be able to describe them. However, with the late 2000s economic crisis in 2008, some issues might be a subject of change both in the market conditions and institutional structures that may affect the development of technologies.

Along with technological advancements, several technology campuses have been built all over the world. A preliminary global scan of these areas has shown that the physical interventions are diverse in terms of design concepts, scale of developments, location characteristics, and denominations. Some can be regarded as the terms described before. Moreover, it has been observed a pattern of change in the focus of the research activity they accommodate. This could be associated to the conditions of the historic periods outlined here. For instance, the variety of campuses has shifted from industries relevant during the ICT industrial revolution towards emergent ones resulted from the knowledge-based economy (e.g. Biotechnology and Digital media). In some cases, the physical interventions initiated to accommodate specific industries have adapted the shift in the economic conditions brought by the knowledge-based economy[26]. Indeed, the proximity of companies to universities and/or higher education institutions is one crucial response adapting this shift, given the relevance of tertiary education in productivity growth highlighted in global developmental reports (OECD, 2011). Correspondingly, the focus of regional policies on education, innovation, cities and regions are central issues where universities have emerged not only as engines to attract knowledge workers and to create knowledge, but also as engines of urban transformations (McCann, 2012).

26 Stanford Industrial Park, nowadays so-called Stanford Research Park at the heart of Silicon Valley, is a good example of adapting this economic shift towards knowledge and innovations as main drivers.

In this context, the term campus is increasingly addressed in contemporary research and in different regions. There are different definitions for the word campus, evolving since its origin in the late 18th century from Latin campus 'field' (Oxford-Dictionaries) which was primarily associated to the grounds and buildings of a university or college. Recent research on the management of the university campus (Den Heijer, 2011) outlines a definition that distinguished the spatial, functional and managerial perspectives of these term. The author refers to the university campus as 'location(s) of the university of the collection of the university and university-related buildings that are either used or owned (or both) by the university and have a role in achieving the institutional goals'.

Other definitions of campuses involve several institutions besides universities. For instance, an inventory research -commissioned by the Dutch Ministry of Economic Affairs, Agriculture and Innovation- on Dutch campuses, science parks and similar initiatives (BCI, 2012), identified two type of campuses in the Netherlands. The first type are Science & research parks, defined as 'Park-like' industrial estates, where R&D is carried out by universities, hospitals, research institutes and companies. The second type is Open Innovation campus, defined as 'former' business campus where a 'anchor tenant' carry out R&D, in which other companies can establish themselves and interrelation and research collaboration is actively encouraged[27]. Based on this approach, a definition on campus meets four criteria: 'First, a campus focuses on research and development. Second, a campus has a high quality environment with research facilities where multiple companies can use. A third important criterion is the presence of a manifest knowledge carrier, such as a university, college or a large research department' (Buck, 2012). One can say, this definition of campus is similar to the one described for Science parks.

Moreover, international research on the urban design of the campus (Hoeger & Christiaanse, 2007) refers to it in relation to the city. In fact, several denominations for campuses are addressed involving other stakeholders: Greenfield campus, High-Tech campus, Corporate campus, and the New Urban campus. Despite the absence of an overall definition of campus, this research outlines the contemporary relevance of these objects for urban planning and the diversity of their urban developments.

In the urban context, a contemporary view of similar areas is the one addressed as knowledge locations (Carvalho, 2013). Accordingly, 'knowledge locations are planned-based initiatives aimed at agglomerating knowledge-intensive activities in a designated area or district. The concept of knowledge location encompasses a number of manifestations such as science parks and quarters, technology hubs, knowledge campuses or creative factories and districts, with a deliberate element of planning and policy aimed at promoting that agglomeration'. This definition is wider in scope and strengthens the relevance of the existing diversity of these areas, as well of the diversity of the different approaches studying them.

27 Open Innovation is a business model that has been promoted in practice for cluster development (Chesbrough, 2003). Accordingly, 'Open Innovation is a paradigm that assumes that firms can and should use the external ideas as well as internal ideas, and internal and external paths to market, as they look to advance their technology'.

§ 3.2.4 Answers to guiding sub-questions

What are technology campuses?

A revised definition of technology campuses is given based on the exploratory study of technology campuses in the literature and their periods of emergence and development. Overall, the integrated definition of technology campuses as seen in this research connects different fields of studies such as architecture, urban design, real estate management, planning, economic geography and business.

Definition

Technology campuses *are built environments facilitating the concentration of organisations in designated areas. They have been planned to- or evolved at accommodating tech-based research activities leading to the advancement of technologies. These advancements are believed to be a result from the expected interaction among the organisations performing such activities.*

When and where did technology campuses emerge and develop? Are there evident patterns in their emergence and development?

Technology campuses are built environments that emerged and developed over the 20th century. Indeed, the empirical information collected from the survey ratifies that the development of technology campuses as built environment phenomena is linked to the periods of technological development in industrialised countries [See Figure 3.3]. Similarly, the sample studied is located across industrialised countries in North America, Europe, and Asia-Pacific [See Figure 3.4].

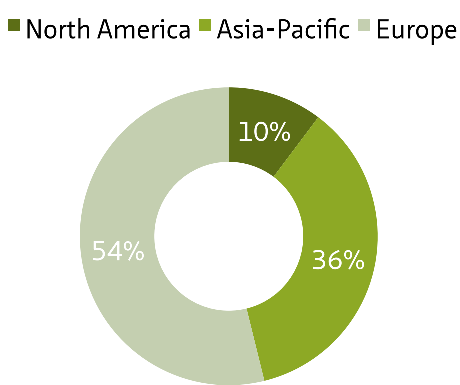


Figure 3.3 Periods of emergence and development of the Technology campuses surveyed

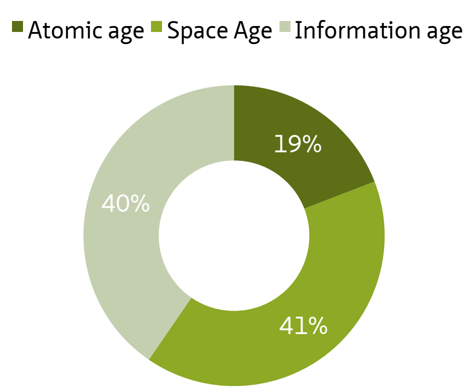


Figure 3.4 Periods of emergence and development of the Technology campuses surveyed

An overview of the cases documented in this research, outlining the places and periods of emergence (or significant development changes) are illustrated in Figure 3.5. Accordingly, the number of technology campuses -developed and documented in this research- has increase over time. During the post-war period or atomic age, a pattern is observed between the development of technology campuses and the attention placed to advancing technologies after the WWII in the U.S.A., Russia (or the former Soviet Union in this period), and Europe.

During the space age and ICT industrial revolution, the emergence of the first technology campuses in Asia is linked to the entrance of Japan and South Korea in the computers and electronics market, and the support of national governments encouraging industrial development in these countries. Similarly, more developments emerged in Europe as part of wide-national strategies to encourage sciences and technology.

Last, this pattern of development increased both in Europe and Asia during the Digital an Information age, and the increasing attention of tech-based research in the knowledge economy. This intensification of campus developments is specially perceived in Europe.

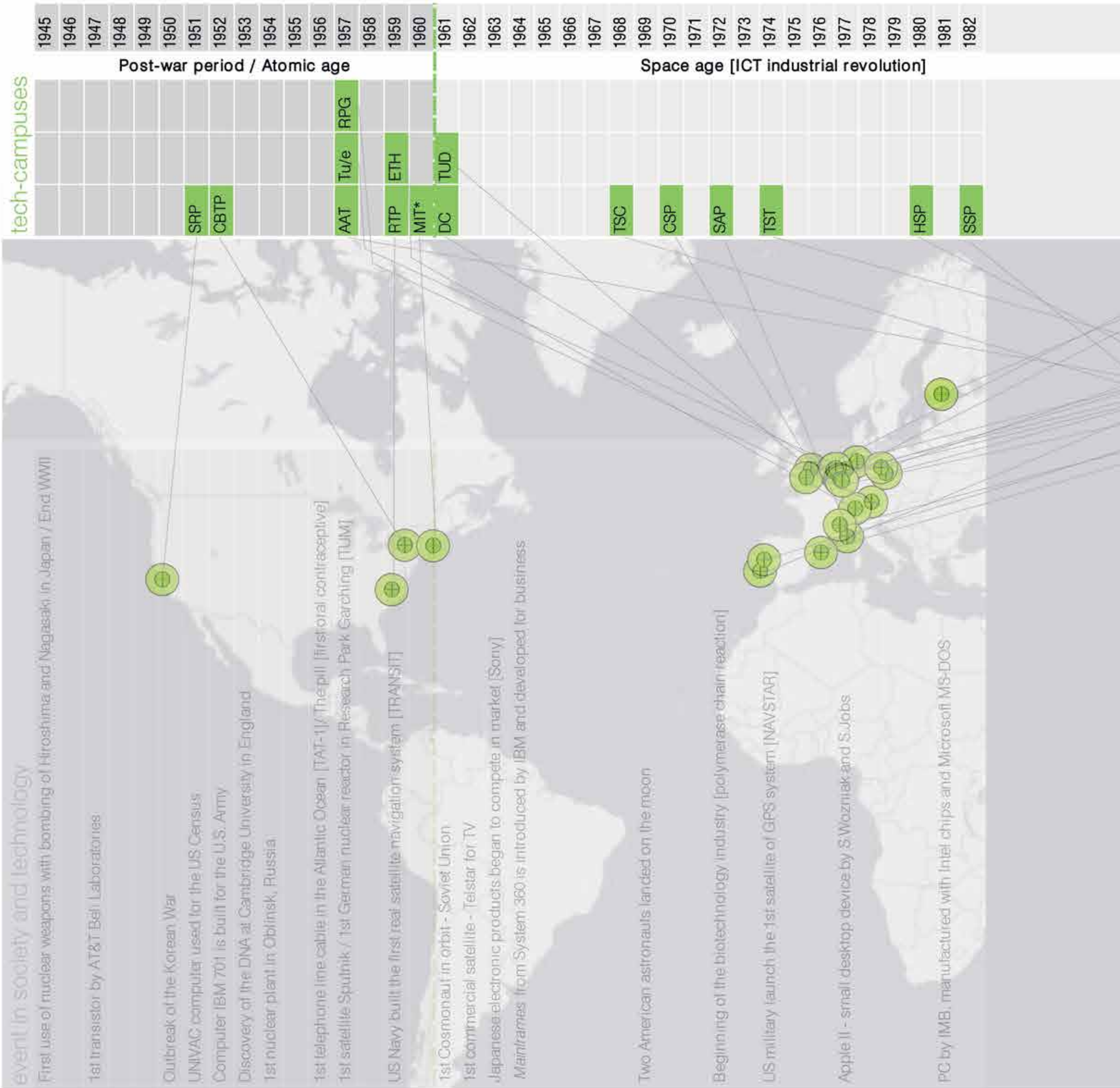


Figure 3.5 Emergence and development of technology campuses in relation to periods of technology advancements in industrialised regions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KSC
ZGCP
BTU
ZJHTP
BAHU
SHIP
HTCE
SPA
BP
GIANT
RWTH
Development of Internet [network of networks] / GPS is allowed for commercial aircraft
IASP [International Association of Science and Research Parks] is created
Japanese design & manufacturing of chips overlook Americans
Invention of the WWW
Dissolution of Soviet Union
Development of GPS
1st successful cloned mammal [Dolly the sheep]
1st commercially-available GPS phone
Small and cheaper In-car GPS devices [Tom-Tom and Garmin]
The late 2000s Economic Crisis

§ 3.3 Distinct patterns in the demand for technology campuses

The following paragraphs describe the general patterns in the demand for developing technology campuses by outlining the stakeholders and the goals involved in their strategic and financial structures. In doing so, this section aims to answer the questions: *Who are the stakeholders involved in the development of technology campuses? What are their goals?*

§ 3.3.1 The Triple Helix as main stakeholder developing technology campuses

Three main types of organisations have developed technology campuses: universities; companies and governments. Unquestionably, these organisations correspond with the three spheres whose relationships form the so-called Triple Helix concept: university-industry-government. Within these three main parties, three main stakeholders' roles have been identified.

The founder

This stakeholder is the group of individuals or entity that established the campus. For instance, technology campuses have been founded by several entities: public and private universities; private companies; government-owned companies; governmental entities at national and municipal levels; and established Public Private Partnerships (PPP). Depending on the case, technology campuses have been founded either separately by one of these entities, or the cooperation between two or few of them when partnerships are not officially established. Therefore, three main types of funding sources are distinguished characterising the ownership structures of technology campuses: public-, private-, and mixed capital. Moreover, it is observed as a pattern that several campuses originally founded by one entity -with public or private capital- have recently established PPP. This outlines the relevance of cooperation when raising capital investments needed to (re) develop physical infrastructure for research such as campuses.

The data collected on actual capital investments in this survey was limited to very few cases and not suitable for comparison[28]. However, it is publicly known that universities, companies, and governments in developed economies have invested millions of euros or dollars developing technology campuses[29]. Only in Europe, €86 billion has been allocated on research and innovation including 'Research Infrastructure'[30], Entrepreneurship, ICT development and human capital actions in the period 2007-2013 from EU structural funds (European Commission, 2015). This financial support to research

28 The documents analysed in this survey provided little financial data on the investments made in technology campuses. However, some institutional documents and journalism records address relevant figures sizing the financial investments in these built environments. For example, Royal Philips sold High Tech Campus Eindhoven for EUR€425 million in 2012. Similarly, Tibco Software sold Stanford Research Park for US$330 million in 2015.

29 Recently, the development of new technology campuses has been announced in press releases. In 2013, Google announced the investment of US$120 million in its campus so-called Googleplex. In 2012, the development of New York Tech campus in collaboration between the city of New York and Cornell University was announced, which investments amounts US$2 billion.

30 'Research infrastructures refers to facilities, resources and related services used by the scientific community to conduct top-level research in their respective fields, ranging from social sciences to astronomy, genomics to nanotechnologies' (European Commission, 2015)

infrastructures has been gaining importance in the context of European policy through EU framework programmes. Recently, Horizon 2020 supports research infrastructure with the allocation of about €2.5 billions between 2014 and 2020 (European Commission, 2015).

The manager

This stakeholder is the group of individuals or entity steering the functioning of the campus in use. It distinguishes several advisory and management structures that embody the responsible planning and management of property resources. For instance, an observed pattern is that technology campuses are increasingly managed by designated management units, which tasks are concerned not only with the management of the property but also with the development of the research cluster. It is also observed that the same management units are sometimes involved in the marketing and promotion the object to attract and support companies, or institutions. Therefore, these management units have several management divisions. For instance, Real Estate Management units or departments manage several technology campuses. In most of the cases, these structures correspond to the campuses that are funded with private capital. Nevertheless, in some campuses the structures of these management units are not clearly defined in the data found. Specially, in management structures that recently involve external parties that took no part in the foundation of the campus.

The promoter

This stakeholder is the group of individuals or entity stimulating -through activities such as marketing- the establishment and the development of campuses. Overall, external parties increasingly promote technology campuses. This pattern is predominant in campuses that are developed through public and private partnerships. Overall, this exploration identified two types of promoters. There are official promoters who are formally marketing the site. In some cases, they are involved in decision-making of the campus. For example, Asian cities/regions actively promote and market their technology campuses. In fact, some of them have been designated as especial development zones. As well, there are unofficial promoters who are the external stakeholders who informally market the object as a positive brand for the city.

Figure 3.6 illustrate an overview of main stakeholders defining and influencing the demand for developing technology campuses framed into the Triple Helix model (Etzkowitz, 2008). Indeed, this model helps to emphasize interactions between these spheres in specific roles when developing campuses. For instance, the identification of these cooperation levels suggests a sort of alignment in goals between these spheres. In fact, some similar goals and concepts are observed in several cases. These are discussed in the next section.

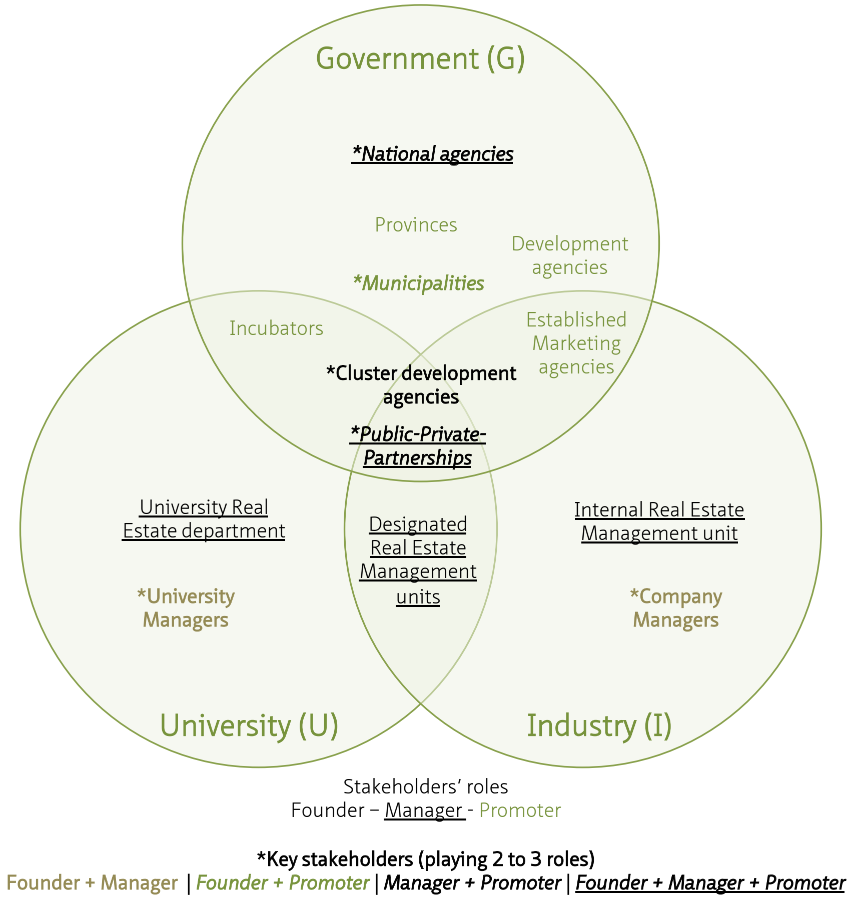

Figure 3.6 Overview of main stakeholders defining and influencing the demand for developing technology campuses framed into the Triple Helix model (Etzkowitz, 2008)

§ 3.3.2 The strategic campus: goals on technology campuses and cities

The survey of technology campuses confirms that the goals driving their developments and those of their current contexts are diverse, and some times multiple within one case. Although differentiation is outlined in the founding visions of technology campuses and their hosting cities, some similar goals and concepts are outlined in several of them. After a systemic review, eighteen different goals were initially identified on technology campuses and their hosting cities (or regions). Considering those that were predominant in the sample[31], a list of twelve main goals of technology campuses is being recognised an arranged according to their high proportion within the sample. A summary of the goals identified is described in Table 3.1.

Overall, the goals of technology campuses and their hosting cities are not only varied but also have a clear tendency at encouraging socio-economic development. Moreover, these goals are essentially reflecting those specific actions or initiatives carried out by cities or regions to succeed as knowledge-based

31 Those goals were prevalent above the average of the total number of cases.

cities/regions identified in literature and policy analysis (Chapter 2). Similarly, the words 'Innovation, Technology, Knowledge and Collaboration' –among others- are predominantly addressed as valuable for growth and development within such goals. In fact, the cloud of valuable words identified in the goals of technology campuses and cities are either the same or closely related to the aspects previously identified in literature as the enablers and the drivers leading the fundamental transformation of today's knowledge-based economy. It is not surprising to observe the tendency to encourage economic development in the goals of the cities. However, it t is unexpected at the level of some organisations that have made these sites possible, such us universities. Possibly, the increasing relevance of universities, industry and governments and their relationships in today's economy has influenced their roles and the direction of their goals, including their real estate goals.

CODE	GOALS	# CAMPUSES	% SAMPLE
G1	Encouraging Innovation for economic growth and development	25	64%
G2	Attaining Economic growth and development (Employment, business activities and prosperity)	24	62%
G3	Encouraging Technology development for economic growth	22	56%
G4	Increasing attractiveness of place to live, to work, and to do business; and so, International competitiveness.	22	56%
G5	Encouraging Academia, Science and R&D for economic growth	21	54%
G6	Encouraging cooperation and collaboration among academia, industry and public parties (Supporting entrepreneurship and partnerships)	19	49%
G7	Increasing Economic resilience and sustainability (Promoting diversity of sectors and cluster development)	18	46%
G8	Supporting social infrastructure (community development; skills and learning capabilities development, human values and culture)	18	46%
G9	Enhancing creative culture, ideas growth and smart society development.	17	44%
G10	Supporting environmental sustainability and green development. (Improving urban quality and infrastructure development; encouraging renewal and relation of existing built environment)	17	44%
G11	Encouraging knowledge interaction, exchange, and networking. (Increasing chances for meeting and sharing; ecosystems of knowledge creation and exchange)	14	36%
G12	Strengthening competitive advantage in the knowledge economy (Strengthening knowledge sectors and positioning in the global knowledge economy)	12	31%

TABLE 3.1 List of main goals of technology campuses and their hosting cities within a sample of thirty nine subjects.

Once again, the model of the triple helix helps to illustrate the cloud of words aligning the goals of each of these spheres, even though they keep their distinctive status [See Figure 3.7]. In this figure, the cloud of words used to describe the goals of technology campuses and their cities are clustered according to their correspondence in connotation. In addition, it outlines those words that are the same as the aspects leading the fundamental transformation of today's and the knowledge-based economy identified in literature. Similarly, alignment in the goal of these spheres and its influence in real estate decisions can be emphasized by operationalizing the list of goal according to the predominance of a goal in both campuses and cities. For instance, scores are given considering the campus's goal -as embedded within the organisational goals- more relevant for decision-making than the goals of the city as their context[32]. Table 3.2 operationalizes the goals technology campuses outlined by both campuses and cities in most cases.

32 Scores are given in this order: City's goal (1 point); Campus's goal (2 points); Both City and Campus's goal (3 points)

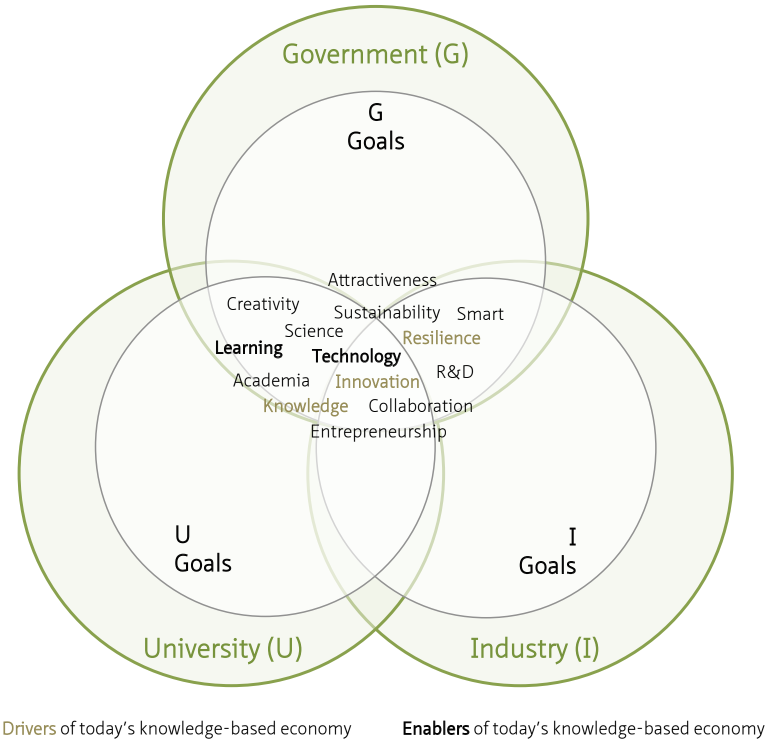

Figure 3.7 Cloud of words used to describe the goals of technology campuses and cities linked to the concept of the triple Helix and the aspects leading fundamental transformation in today's knowledge-based economy according to the literature.

CODE	GOALS	SCORE
G5	Encouraging Academia, Science and R&D for economic growth	46
G1	Encouraging Innovation for economic growth and development	45
G2	Attaining Economic growth and development (Employment, business activities and prosperity)	44
G6	Encouraging cooperation and collaboration among academia, industry and public parties (Supporting entrepreneurship and partnerships)	37
G4	Increasing attractiveness of place to live, to work, and to do business; and so, International competitiveness.	36

TABLE 3.2 Overview of most common goals of technology campuses and their hosting cities.

From an economic development perspective, it is observed that several cities have developed campuses as specific measures to attract business and promote themselves in an international context. For example, the designation of their administrative boundaries as special zones is one of these measures (e.g. Tsukuba as International Strategic Zone in Japan or Daedeok as Special Research and Development Zone). Some of these zones give advantage on regulatory standard requirements (e.g. tax incentives) and financial help from governmental body and local autonomy. An interesting pattern observed is that large campuses built as cities or outside cities are founded with public capital and increasingly with the establishment of PPP.

On the whole, the focus of this description on real estate goals as embedded within the organisational goals, confirms that the context of the knowledge economy and the aspects leading to today's economic shift, as described in literature and in policy, are essential to understand the contemporary general factors influencing decision making on these sites outside the organisational boundaries. For instance, Innovation, Knowledge, Resilience, Technology and Learning are addressed as major aspects influencing the context of decision-making in technology campuses.

Nevertheless, specific factors such as particular needs and/or available means influencing the ultimate built environment of the campuses were not investigated at the scale of this description. Indeed, these particular aspects are related to the decision-making at certain times which (re) define specific real estate goals within the organisational boundaries. Then, the reasoning of their existence cannot be generalised to all technology campuses. In fact, those reasons are inherent to each case and more in-depth information is needed to clarify the reasons of their existence.

§ 3.3.3 Answers to guiding sub-questions

Who are the stakeholders involved in the development of technology campuses?

Technology campuses have been developed by three main types of organisations: universities, companies and governments, which also recognised as the spheres whose relationships form the so-called Triple Helix concept: university-industry-government. Within these three spheres three main stakeholders' roles have been identified, whose (inter) actions have made these sites possible: founders, managers and promoters. Thus, a large number of stakeholders are identified. Some entities play more than one or two roles in the development of technology campuses over time, which are identified as key stakeholders. The findings shows the different bodies involved in the development of technology campuses positioned in relation to each spheres of the Triple Helix and how each of them keep their relative independent and distinct status. Moreover, it shows in which roles the developments of the campuses have been carried out separately and/or jointly emphasizing where interaction between these spheres take place when developing the infrastructure required to accommodating research activity. In fact, the identification of these cooperation levels, which joined efforts have brought about technology campuses, suggests a degree of alignment in goal between these spheres.

What are these stakeholders' goals on campus?

The survey of technology campuses confirms that the goals driving campus developments are diverse and multiple even within one case. For instance, while differentiation is outlined in some founding visions of technology campuses and their hosting cities, similar goals and concepts are identified in several of them with a clear tendency at encouraging social and economic development. In fact, the goals of technology campuses essentially reflect the actions or initiatives carried out by cities or regions to succeed as knowledge-based cities/regions identified in literature and policy documents. The tendency of universities and companies having these goals addresses the possible influence of the economic relevance of the Triple Helix relationships on the overlapping roles of its constitutive organisations and so, the direction of their goals, including the real estate goals.

§ 3.4 Distinct patterns in the supply of technology campuses

The following paragraphs describe the general patterns in the supply of technology campuses by outlining their physical and functional characteristics (i.e. the supply of technology campuses refers to the product of manmade decisions with tangible characteristics defining its operational dimension). In doing so, this section aims to answer the questions: *Are there common patterns in the supply of technology campuses? What characteristics define the supply of technology campuses?*

§ 3.4.1 The operational campus: the form and function of technology in cities/regions

This survey analyses the physical and functional data of technology campuses by using concepts from architecture, urban planning, urban design and real estate management theories [See Appendix C]. Analysing the operational dimension of these built environments implies the description of the product that gives form and meaning to urban planning and design concepts. This analysis established links between five physic/functional characteristics and existing concepts from other fields, which were identified as relevant for this research through the review of the literature in the previous chapter [See Table 3.3].

	FORMAL/FUNCTIONAL CHARACTERISTICS	*LINKS WITH THEORETICAL CONCEPTS OF INNOVATION*
1	Location and settlement	Clusters, Competitive advantage, Proximity, Connectivity, Accessibility.
2	Spatial and functional layout	Proximity (geographic, social and cognitive); face-to-face interaction; creativity
3	Size and Density	Social interaction, Proximity, Diversity (of people, ideas, buildings and functions).
4	Block pattern	Creativity; Small blocks and Chances of encounter and interaction; Diversity; Walkability; Accessibility
5	Appearance	Attractiveness of place; Added value of real estate (e.g. supporting image and culture)
Source	*Theories on the built environment (Architecture, Urban planning, Urban design, Real Estate Management)*	*Literature review on the role of the built environment in innovation (Urban economy, Urban planning, Real Estate Management)*

TABLE 3.3 Overview of formal and functional characteristics of technology campuses in relation to relevant theoretical concepts linked to innovation

This section describes as follows the common patterns identified, when analysing four of the five physical and functional characteristics of technology campuses: (1) location, (2) layout, (3) size and density, and (4) block pattern[33]. The following paragraphs outline the common patterns in each of these characteristics, followed by an explanation.

33 The sources documenting this qualitative survey were not suitable to collect data on the appearance of technology campuses. Therefore, this characteristic is not empirically documented.

1) Location patterns

Most technology campuses in this sample (1) are located in developed regions, (2) have a border condition, and (3) are near to- or in universities' premises.

According to the geographic position of the sample studied, it is observed that most technology campuses are located in developed regions of the world and few on BRIIC countries. They are all industrialised countries [See Figure 3.8]

Figure 3.8 Geographic position of the 39 technology campuses surveyed in this research.

First, the analysis of the location characteristic describes the position of the technology campus in relation to the city or region as a whole. Therefore, topology has served to identify a set of relationships that the campuses and the cities can have with each other. Most of these relationships are related to specific developments of their temporal and social context. Through mapping, five topological relations were identified between the campuses and their hosting cities and summarised in Table 3.4.

Most of these relationships are dynamic because they relate to particular developments in their contexts. For instance, the most predominant relationship in the sample is City Touches the Campus. In most of the cases, they are located at the edge of the city. In some cases, they are in the city but the sites have a border condition e.g. separated by a river, or a highway. For the first cases, it can be said these areas were built outside the city but due to distinct or combined urbanisation processes, they are already at the edge of the city. Such urbanisation processes could be related to the expansion of the city to their peripheries due to population growth, the settlement of other companies nearby these

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sites, or to the combination of both processes. In fact, this border condition of technology campuses is observed globally with a representative number of campuses in this group in the total international sample. Thus, technology campuses categorised as Touches may evolve to Contains or Overlaps depending in the particular dynamics in each context. For instance, this study found out that more than one relationship between campuses and cities could be already perceived in some campuses. This duality results from particular characteristics of the context in which campuses developed. Examples of all types of relationships are illustrated in Figure 3.9 (More details are found in Appendix B).

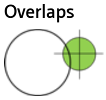
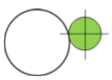
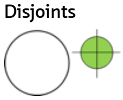
RELATIONSHIP	*DESCRIPTION*	*SUBJECTS*
Equals 	City is the same as Campus. It includes those areas that were newly built as towns and/or cities. These were built and planned from scratch to accommodate clusters of technology. They are located only in Asia.	4/39
Contains 	City contains Campus. It includes those areas that are inside the urban fabric but they are perceived as distinct campus with borders.	12/39
Overlaps 	City and Campuses have multiple points in common. It includes those areas that integrate with the urban fabric and in many cases the borders between the sites and the city are not clearly defined or perceived.	6/39
Touches 	City touches Campus. It includes those areas which are located in a border condition in relation with the city. In most of the cases, they are located at the edge of the city. In some cases, they are in the city but their locations hold a border condition e.g. separated by a river, or a highway.	17/39
Disjoints 	City shares nothing with the Campus. It includes those areas located in areas outside the city borders but are not a distinguished as independent cities itself.	8/39

TABLE 3.4 Five types of topological relationships between the campus and the city.

Second, this description recognises the position of the technology campuses in relation to specific elements of the city or region as relevant in this research (e.g. university campus, core city centre, and airport). Accordingly, most technology campuses locate within 30 minutes from university campuses by using public transportation. Moreover, nearly the half of the sites analysed are university campuses. Thus, a large number of technology campuses are located within one kilometre or a walking distance of fifteen minutes from a university campus. In comparison, this is predominant in campuses located in cities that contain and disjoint them. The largest distance to a university from a technology campus is 32 km and happens to be in a campus located in a city that disjoints it. . An overview of the positions of the sites in relation to global knowledge clusters is illustrated in Figure 3.10.

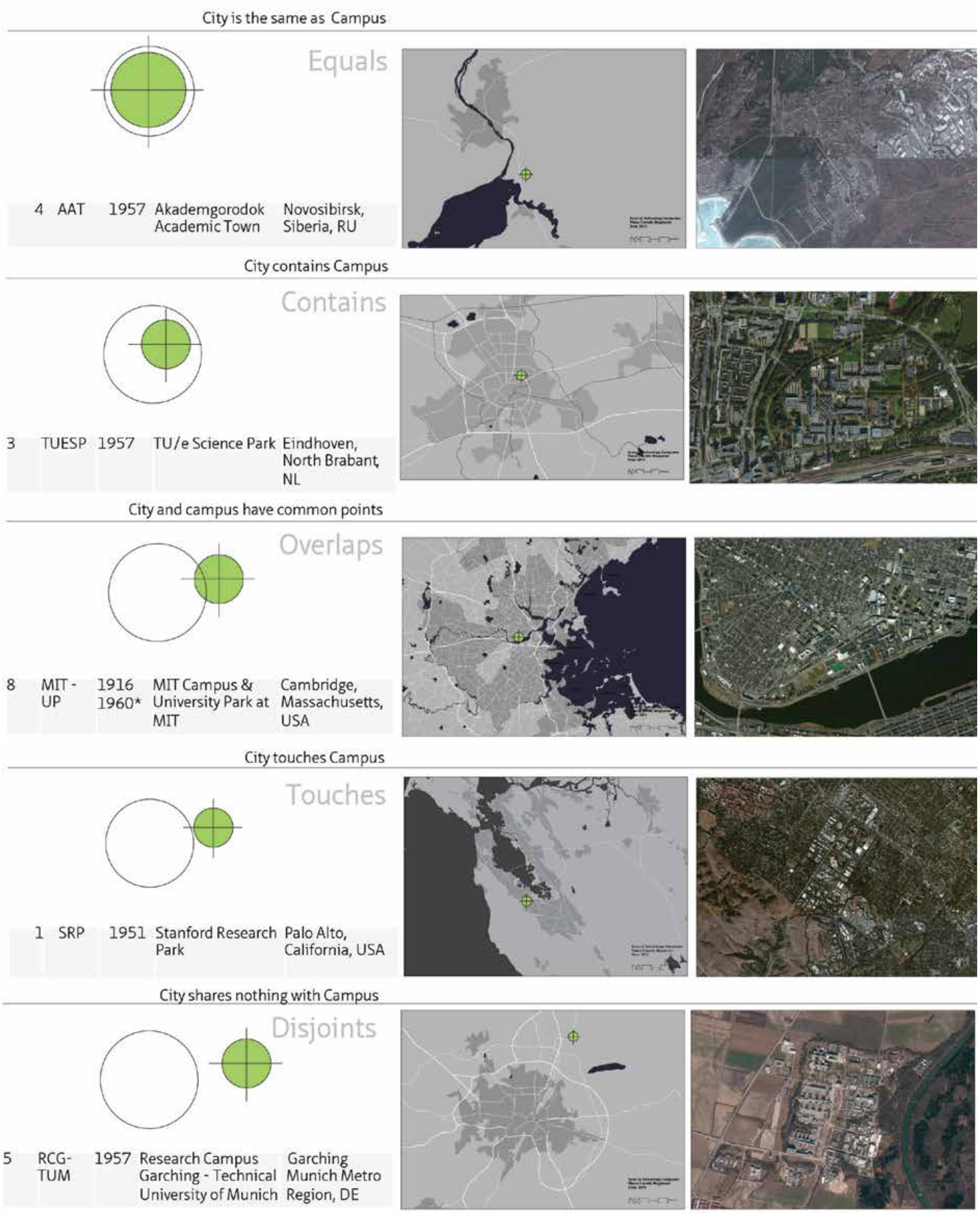


Figure 3.9 Examples of the five types of topological relationships between the campus and the city

Figure 3.10 Global location of the technology campuses in this study (green) in relation to the location of knowledge clusters (blue). The latter is the mapping of 200 universities, which corresponds to the list of Top 200 universities in The Higher Education World University rankings 2011-2012 whereas, the larger circles represent the higher the rank in the list. It is important to outline that 63% of the universities in this list have campuses in urban locations.

Furthermore, most technology campuses locate in places that can be accessed from the core of their hosting cities within 60 minutes using public transportation. Besides, at least the half of the sites studied can be reached within 30 minutes from the core of their hosting cities by public transport or walking. A campus located in a capital or global city has an advantage in terms of attractiveness. Last, the traveling distances of technology campuses from airports is rather varied and no pattern was identified within the sample.

2) Layout patterns

Most technology campuses emphasize their character as clusters of built forms, which is dominated by compact and practical planning and design arrangements.

The ways in which buildings cluster in technology campuses varies widely from case to case depending on specific layout characteristics. The comparative analysis distinguishes two types of spatial layouts in technology campuses based on the relative physical proximity among campus' buildings: compact and dispersed layouts. For instance, compact layouts are common in campuses that locate in relatively small to medium plots with semi-squared shapes, allowing walking distances of less than 30 minutes within the campus. On the contrary, dispersed layouts are arrangements in most large campuses, which plots have long shapes, making walking distances within the campus less convenient for its users.

Similarly, the organisation of clustered space distinguishes three functional layouts of technology campuses based on the perceived functional proximity among those buildings: diagrammatic, practical, organic layouts. For instance, diagrammatic arrangements present distinct shapes and spatial hierarchy. On the contrary, practical arrangements exhibit uniformity, rationality, and the use of straight shapes. Last, organic arrangements show also uniformity but the shapes are mostly results of specific geographic features of the plots.

Overall, most technology campuses in the sample studied have compact and practical layouts. Accordingly, there is a common pattern in arranging technology campuses in relatively small areas reached by walking distances, and in practical ways that the campus functions as a uniform and rational planned whole. An overview of the most common patterns of spatial and functional arrangements in technology campuses identified in this analysis is illustrated in Figure 3.11.

Figure 3.11 Overview of patterns in the layout characteristics of technology campuses

3) Size and density patterns

Technology campuses occupy large portions of land in cities and regions, which accommodate large and diverse populations with the possibility to expand in the future.

Technology campuses are defined first, by the concentration of tech-based research activities accommodated in a cluster of buildings; and second, by the variety of organisations carrying out these activities. Functionally, the supply of technology campuses is characterised by its end-users and their activities. The survey shows that technology campuses accommodate large populations (i.e. hundreds or thousands people depending on the size of the development). An important pattern identified is that campuses accommodate diverse organisations important for the knowledge base and economic base of cities in the knowledge economy (Van Den Berg et al., 2005). For instance, technology campuses accommodate at least two of type of tech-based research organisations (e.g. universities, institutes, and firms). Firms are the most common end-users of technology campuses according to this sample.

Besides, technology campuses accommodate the agglomeration of diverse research activities, both on the types of research (e.g. fundamental research or R&D) and the fields of focus. Indeed, R&D clusters -sometimes combined with basic research or production- are the common type of clusters in the sample studied. Biotechnology, Material sciences and Information technologies are the most common fields of research present in the sample of technology campuses studied.

Although there is a similar pattern in accommodating large populations, the number of people and organisations accommodated in technology campuses differ widely among subjects in the sample. For example, the number of users ranges from 210 up to 238.341 people. These variations among the campuses may relate also to the varied population and densities of their hosting cities. The population accommodated in these campuses in mainly represented by the number of employees. Only three campuses possess data distinguishing number of students.

Similarly, the number of organisations accommodated in technology campuses differs widely among the sample (i.e. from 15 up to 1.400 organisations in a single campus). Nevertheless, the data and analysis techniques used in this study were limited to investigate the density of these built environments. Therefore, the data collected do not provide with information that characterise the density of technology campuses in a broad sense. Overall, the analysis of the sample emphasized that technology campuses are large clusters of people and buildings.

In this context, the size of the land occupied by technology campuses (its people and buildings) varies widely. Initially, campuses were distinguished according to their perceived scale in relation to its hosting city into large, medium, and small size. Nevertheless, based on data about the area occupied by technology campuses, the difference in size is vast (i.e. from 22 up to 28.500 hectares). Accordingly, the largest of the sample is indeed, a campus that is the same as a city. In order to compare, a reference to an existing area is used to identify a size range of technology campuses[34]. Although the size of technology campuses differs widely, most technology campuses are smaller than the reference used in this research. Nevertheless, a considerable number of technology campuses occupy thousands hectares in cities and regions. The diversity of sizes is illustrated in Figure 3.12.

34 This study used central park in Manhattan, New York as a reference for being a clearly defined area, which is well known and easy to identify by many. The surface of central parks is 341 hectares.

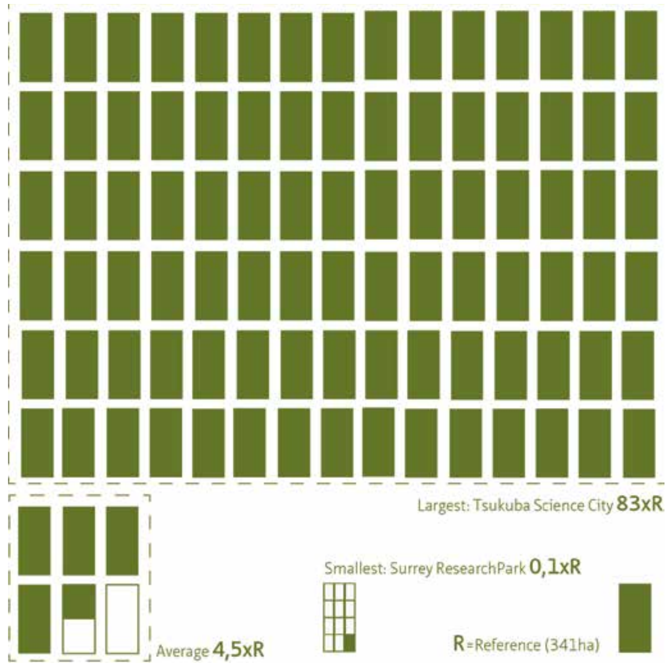


Figure 3.12 Different surface sizes of technology campuses compared to Central Park in Manhattan, New York as reference (R).

Last, this study observed that the diversity of amenities offered in campuses relates to their size and locations characteristics. For instance, all campuses that were planned and built as cities provides residential space and supporting functions such as cultural amenities, sport and retail facilities. Similarly, those campuses in the outskirts of the city have central (congress-like) facilities with mixed functions (sometimes including hotels). An important pattern in the sample is that most cities hosting campuses are small to medium size cities, which have a significant knowledge base (e.g. prestigious research university or institute). Only six capital cities host campuses and since the late 1980s. This is important because large cities have the capacity to attract and retain knowledge workers easily than small cities. That is because of the quality and diversity in the provision of amenities besides having a good knowledge base.

4) Block patterns

Technology campuses are designed and built with the idea of self-standing buildings in the green, making them introverted built environments regardless the influence of different planning models.

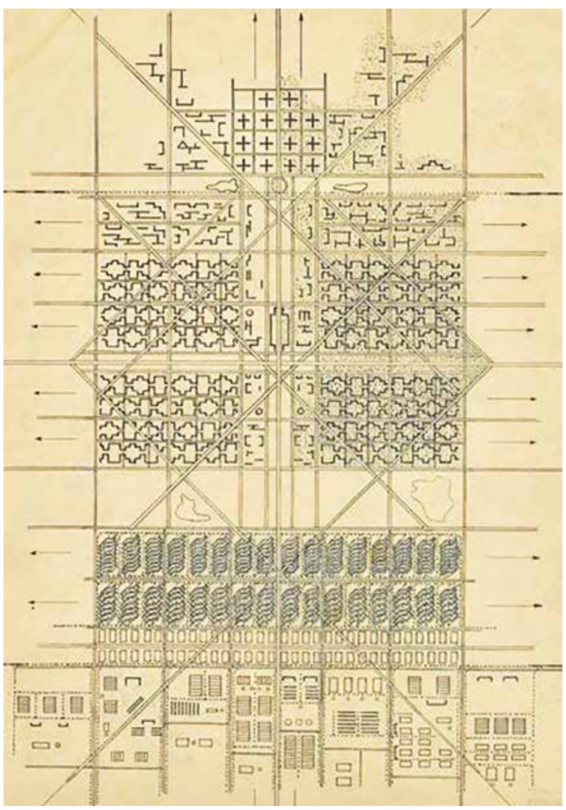
The block patterns of technology campuses are planned regular patterns with variations in the shape and configuration of the streets and the buildings. For instance, the free-standing building is the predominant building unit. The shapes and size of the buildings are diverse among technology campuses but in most of the cases, these buildings are arranged in an orthogonal configuration.

Correspondingly, the configuration of the streets differs widely among technology campuses. For instance, four street features are found within the sample. The first two focus on the form of the street: (1) grid-shaped, and (2) irregular-shaped streets. The other two, focus on the function of the street: (3) continuous street pattern with an open road network, which is accessed as an integral part of the city; and (4) discontinuous street pattern with a closed road network characterised by designated access points at campus level and cul-de-sac streets for building accessibility.

Based on these features, this research distinguishes two main types of block patterns that differ mainly on the continuity of the campus' street pattern from its urban context. The first block pattern in technology campuses is the superblock, which has a discontinuous street pattern or closed road network. As described in the Modernist era, in this pattern free-standing buildings are set in a green area organised and 'isolated' by a loose and maxi grid of high-speed arteries with different shape. In fact, this block patterns distinguish specific entrances to the sites.

The second block pattern in technology campuses is the multiple blocks of different sizes and shapes, which have a continuous street pattern and an open road network. Likewise, free-standing buildings are set in areas that are mostly green fields, but the street and its continuity with the city system is also defining the use of the land. This pattern is predominant in most technology campuses.

Overall, these regular patterns seems to be influenced by various planning principles applied in the design of new modern cities. For instance, the modernist theory of the Radiant City (Le Corbusier, 1933) can be identified through the comparative analysis. This is evident in those subjects that were built as completely new cities envisioned by national governments. Examples of those are Tsukuba Science City, developed by the Japanese government as a satellite city next to Tokyo [See Figure 3.13] and Akademgorodok developed by the former Soviet Union as an ideal academic town in Siberia.

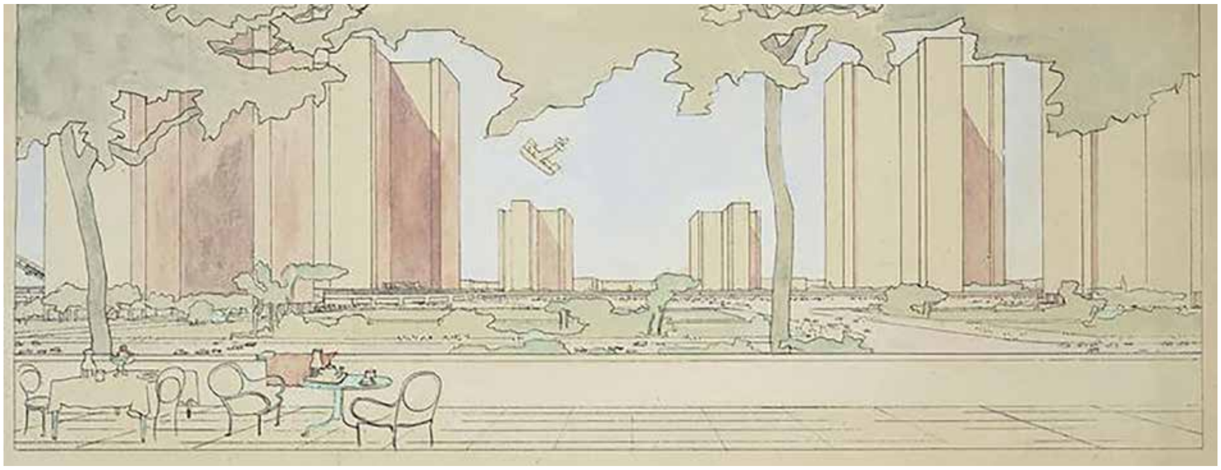


1 Le Corbusier's 'The Radiant City' (1933) ©FLC-ADAGP

2 Core District of Tsukuba Science City. Map image: Esri 2013

Figure 3.13 Example of configuration similarities between technology campuses and urban modern principles. The idea of Le Corbusier's contemporary city as 'a spectacle or order and vitality' is reproduced literally in Tsukuba Science City with a central functional area like a forum, surrounded by green.

Similarly, the spatial ideas of the Modern Cities can be also compared to contemporary aesthetics visions present in some technology campuses [See Figure 3.14]. Furthermore, the main idea of the English Garden City of having houses looking inward toward a central green in which the traffic is excluded and the use of a curvilinear road schemes is clearly recognised in some technology campuses [See Figure 3.15]. On the contrary, the principle of the small blocks is not clearly perceived due to the prevalence of free-standing buildings as main block pattern. Nevertheless, this can be more perceived in some campuses which block pattern follow the street configuration of its urban context [See Figure 3.16].



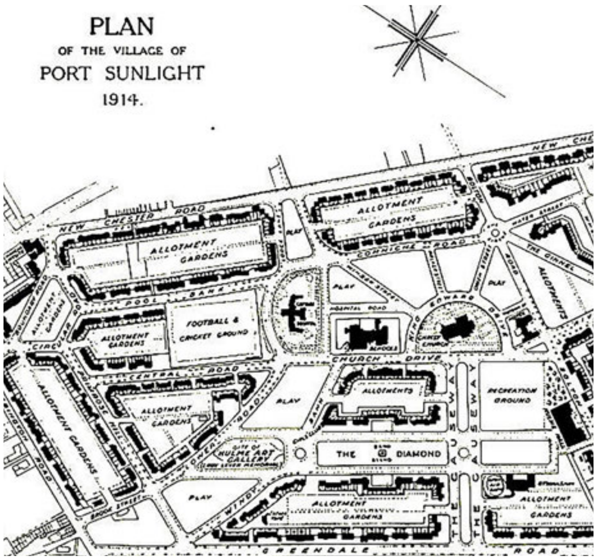
1 *Le Corbusier's a contemporary city's vision ©FLC-ADAGP*

2 *Philips High Tech Campus Vision (Collage: Martine Nederend. Source: Philips High Tech Campus Vision, 1999)*

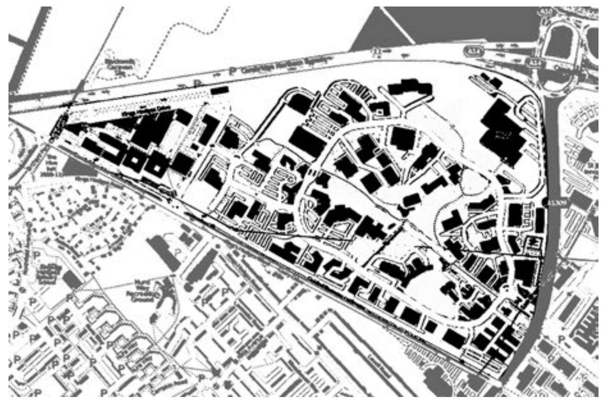
Figure 3.14 Example of aesthetics similarities between technology campuses and urban modern principles. Large open spaces, green structures and uniform buildings dominate both ideas. 'We must built in the open...The city of today is dying thing because it is not geometrical. By using a uniform lay-out. The result of a true geometrical layout is repetition. The result of repetition is a standard, the perfect form' (Le Corbusier, 1929)

These examples illustrates how the built environment of technology campuses seems to be influenced by planning principles that have been used in the past to develop new cities. Some of these principles have been highly criticised in planning theory and practice because it has generated introverted areas that depend on car accessibility and lack vitality. In fact, this can be seen in many technology campuses, whose arrangements correspond to these principles. For instance, in some technology campuses the buildings do not stand on the green as a group that accommodates interconnected organisations but as individual protagonist of a sterile green carpet.

Overall, the lessons from planning theory can be used to interpret the block pattern interrelated to the other characteristics of the built environment. For instance, the block pattern of the campus is linked to the layout, size, and location characteristics, in which the size and use of the building gains importance in the shape and configuration of technology campuses.

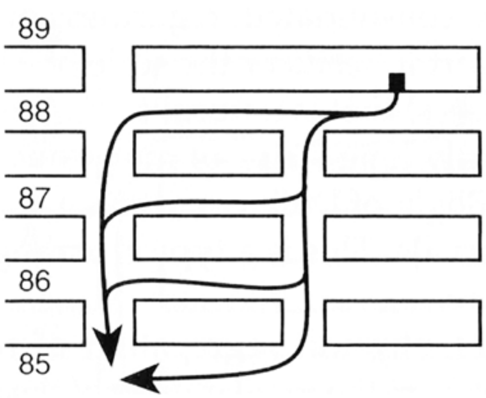


1 *Plan of Port Sunlight, England (Davison, T., 1916)*



2 *Cambridge Science Park. © OpenStreetMap contributors (Edited)*

Figure 3.15 The plan of Port Sunlight, England (1) as described in Kostof (1991) introduced for first time the idea of the superblock. It is observed the disposition of the buildings towards a central green area excluding traffic and the use of curvilinear road scheme. The same idea can be noticed in technology campuses such as Cambridge Science Park (below) in which the freely disposition of buildings in a curvilinear road scheme which are accessed through cul-de-sac streets safeguarding the central green area.



1 *Movement across small blocks (Jacobs, 1961)*

2 *Northern area of Stanford Research Park,Palo Alto. © OpenStreetMap contributors*

Figure 3.16 The principle of small blocks described by Jacobs (1961) (1) can be distinguished in those campuses that follow the street pattern of their cities. For instance, a section of the northern part of the Stanford Research Park (below) has shown the influence of the urban street pattern in the campus (in this case the grid). Nevertheless, it also evidences the differences in block patterns when self-standing building is the main building pattern, in which the small grid starts to disappear the more the campus expands away from the city. This example illustrates that the size of the building is a relevant aspect of the block pattern of technology campuses.

§ 3.4.2 Answers to guiding sub-questions

Are there common patterns in the supply of technology campuses? What characteristics define the supply of technology campuses?

This survey identifies common patterns in the supply of technology campuses. These are distinguished when looking at both the formal and functional characteristics accommodating the concentration of tech-based research activities. Accordingly, five main characteristics of technology campuses have been studied emphasizing the forms and functions: location, layout structure, size and density, block pattern, and appearance. Empirical and theoretical information is provided for the first four qualities. However, with respect to appearance only theoretical but no empirical evidence about its importance is provided in this exploration. These characteristics are summarised in Table 3.5.

	FORMAL/FUNCTIONAL CHARACTERISTICS	*LINKS WITH THEORETICAL CONCEPTS*	*EMPIRICAL PATTERNS*
1	Location and settlement	Clusters, Competitive advantage, Proximity, Connectivity, Accessibility.	Five topological relationships with the city related to urban development in time (Equals, Touches, Overlaps, Contains, Disjoints)
			Predominant features: (a) located in industrialised regions, (b) border or isolated condition, (c) close proximity to universities, and (d) relative good accessibility to city centres.
2	Spatial and functional layout	Proximity (geographic, social and cognitive); face-to-face interaction; creativity	Two types of spatial layouts according to the physical proximity of buildings (compact and dispersed), and three types of functional layouts according to the functional proximity of buildings (diagrammatic, practical, and organic).
			Predominant features: (a) compact, and (b) practical layouts.
3	Size and Density	Social interaction, Proximity, Diversity (of people, ideas, buildings and functions).	Predominant features: (a) Diversity in the type of research activities and type of organisations accommodated in campuses; (b) concentration of diverse people; (c) variety of sizes which relevance is relative to the context of each campus.
4	Block pattern	Creativity; Small blocks and Chances of encounter and interaction; Diversity; Walkability; Accessibility	Two block patterns: superblock (with a closed road network), and multiple blocks of different sizes and shapes (with a open road network) /
			Predominant features: (a) planned regular block patterns; (b) self-standing building on the green as main building unit whereas the size of the building becomes relevant; (c) and diverse shape and configuration of the streets.
5	Appearance	Attractiveness of place; Added value of real estate (e.g. supporting image and culture)	Not available in data collected.
Source	*Theories on the built environment (Architecture, Urban planning, Urban design, Real Estate Management)*	*Literature review on the role of the built environment in innovation (Urban economy, Urban planning, Real Estate Management)*	*Qualitative survey of 39 technology campuses*

TABLE 3.5 Overview of formal and functional characteristics of technology campuses linking theoretical concepts and empirical patterns

The four characteristics emerging from the empirical data are interrelated and altogether can be used to describe the supply of technology campuses:

- The **location** shows most technology campuses are found in industrialised regions; they have a border condition regardless its relation with the hosting city; and are near to (or in) universities' locations. Similarly, the analysis of this characteristic suggests that the different relationships observed between the campus and its hosting city/region are associated with specific spatial dynamics in their contexts.
- The **layout** emphasizes the clustered character of technology campuses as built environments, which is dominated by compact and practical arrangements in their designs.
- The **size and the density** show technology campuses occupy large pieces of land intended to accommodate large populations in cities/regions.
- The **block pattern** shows that technology campuses are designed and built with the idea of self-standing buildings on the ground as predominant building unit. The analysis shows an association between these patterns an influencing planning principles of modern architecture during the 20th century.

Furthermore, these characteristics can be seen as relevant campus planning and design aspects to focus the attention, considering their persistent association with theoretical concepts explaining innovation (e.g. proximity, accessibility, interaction, and diversity). Certainly, the descriptive nature of this research cannot tell these concepts have influenced well-known planning and design practices in technology campuses. However, the interrelationships between these concepts and the physical characteristics of technology campuses can be further investigated.

§ 3.5 Conclusions

The following paragraphs draw the conclusions of this chapter by answering its main question. Furthermore, it outlines how its findings can be used to further investigate the subject of study.

What are the evident characteristics of technology campuses from the built environment perspective?

Describing the demand for- and the supply of technology campuses has provided evidence that documents them from a built environment's perspective. Indeed, this survey illustrates that technology campuses are planned built environments envisioned and developed by universities, firms, and/or governments to stimulate innovation and encourage socio-economic development. Therefore, their form and function are the result of explicit goals and intentions. In some cases, their spatial configurations have been influenced by modern and contemporary urban planning concepts but not all of them can be attributed to planning principles. Thus, the explicit intentions that shaped the built environment of technology campuses cannot be generalised.

This chapter provides empirical evidence that depict several technology campuses as the products of preconceived and idealistic planning models. For instance, on the location characteristic it is outlined that most campuses' locations have an isolated condition. Indeed, this condition outlines many of these areas were built outside the city reproducing the Greenfield campus model. However, some of them are already in- or at the edge of the city due to distinct or combined urbanisation processes (e.g. cities have grew and expanded to their peripheries, other organisations have settled in the peripheries of these campuses, or the combination of both processes). Certainly, these campuses did not develop spatially with the city. They were built from scratch as preconceived models with their own internal structure.

This view is emphasized in terms of layout characteristics. For instance, most technology campuses have a compact and practical layout regarding their spatial and practical organisation, in which their buildings are deliberately arranged in a certain way in response to a plan and a program.

Essentially, most of these ideal models illustrated in this study were the contested answer to the problems of the industrial city. Today's technology campuses seem to be fitting the demands of the 20th century. Replicating today campus models from the 1950s, just because they have evolved at a successful development, is a debatable approach to steer the built environment as a resource to stimulate innovation. The spatial and economic conditions that influenced such developments then, were different than the ones society is facing now and will face in the future. It may be the case that the current supply of technology campuses is not aligned with the changing demand for concentrating research activities in the knowledge economy.

The ways of doing research and the profile of the researchers –so-called a knowledge workers today- have changed with advancement of technology and globalisation. People and organisations' needs, routines and preferences are not the same as 50 years ago. Organisations spent many resources trying to fit their changing demands into their existing and aging buildings via transformation, interior adaptation, and public space interventions. The information developed in this chapter illustrates that campuses have not changed much in the last 50 years. This knowledge makes room for debating the replication approach in the practice of campus development, which can become a successful way to waste resources.

All in all, the outcomes of this qualitative survey build upon empirical knowledge required to continue investigating the role of the built environment in innovation. The findings contained in this and the previous chapter will be integrated to develop a research proposition and a conceptual framework.

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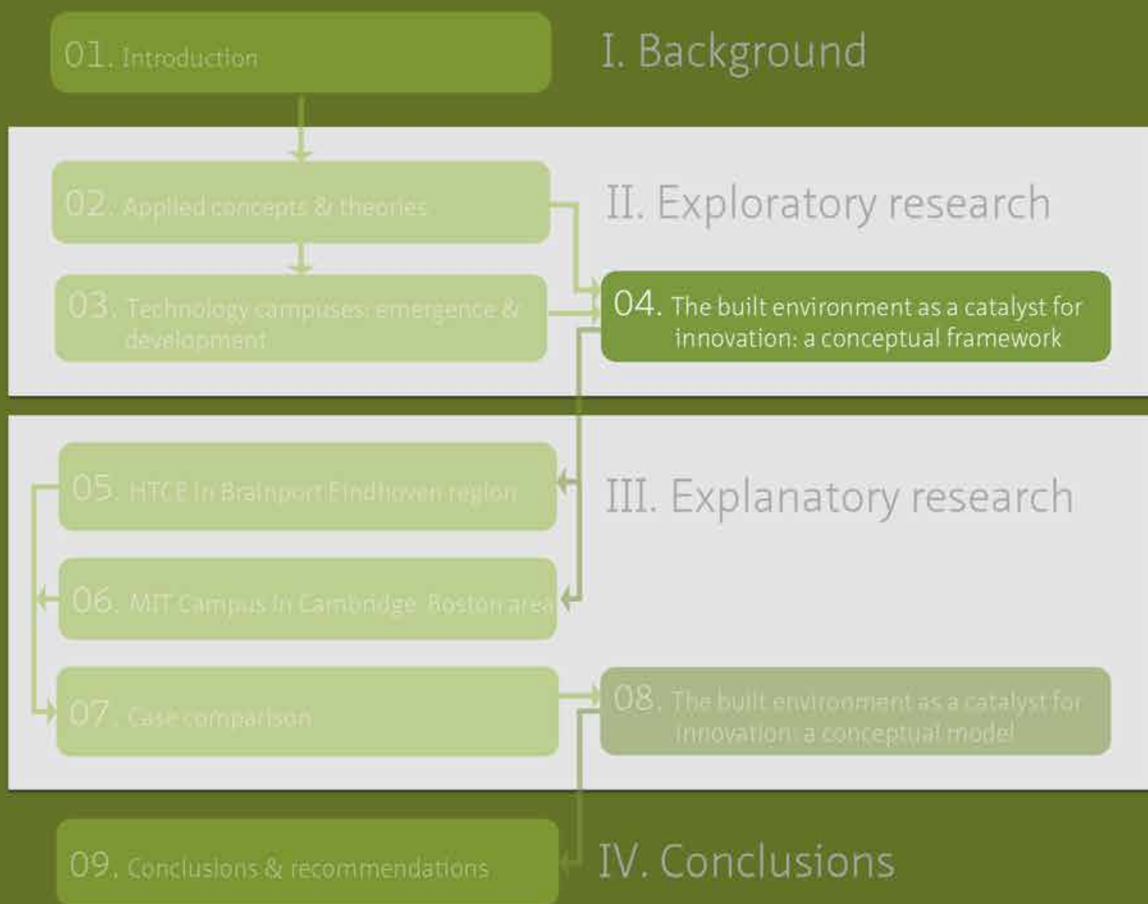
Chapter 4. The built environment as catalyst for innovation: a conceptual framework



The previous two chapters provided insights and familiarity with the object of study 'the role of the built environment in stimulating innovation' from theory (Chapter 2) and the subject of study 'technology campuses' from practice (Chapter 3). These theoretical and empirical insights are necessary to examine further the relationship between innovation and the built environment from the perspective of interest in this research. For instance, more in-depth information and with a focus on specific concepts and context is needed to provide an understanding of such relationship. Therefore, this chapter integrates the insights of the previous chapters, which contribute to answering the question: ***How can we study the development of technology campuses and simultaneously provide understanding of the role of the built environment in innovation? By using which concepts from theory and cases from practice?***

This chapter proposes a conceptual framework with the aim to help to uncover the role of the built environment in stimulating innovation at the area level. Thus, section 4.1 begins providing the logic of the chapter, which builds upon a research proposition. This latter is based on the empirical patterns identified while exploring the development of 39 technology campuses in Chapter 3, in relation to the theoretical concepts of innovation reviewed in Chapter 2. Section 4.2 proposes and describes a conceptual framework to focus and shape the research process. Section 4.3 outlines how the framework informs the methodological design of Part III by influencing the selection of the next research strategy, subjects of study and data collection instruments. Lastly, Section 4.4 draws the conclusions of this chapter by answering its guiding question.

4 The built environment as catalyst for innovation: a conceptual framework

§ 4.1 Introduction

§ 4.1.1 Chapter aim and questions

This chapter aims to develop a conceptual framework to gain and provide a further understanding of the role of the built environment in innovation. This framework has a twofold instrumental purpose. Its first purpose is to elaborate on a research proposition based on the combined theoretical and empirical insights from the exploratory research (Part II of this dissertation).

The second purpose is to develop an instrument to explain and examine the research proposition in the next research stage (Part III of this dissertation). Overall, this framework will inform the methodology of the next part of this research by suggesting the most suitable strategies, data collection and analysis instruments, as well as the subjects of study to investigate its research proposition. In brief, this framework will be used as an analytical tool developed to match empirical information to the research proposition of this study.

This chapter, therefore, asks ***'How can we study the development of technology campuses and simultaneously provide understanding of the role of the built environment in innovation? By using which concepts from theory and cases from practice?'***

§ 4.1.2 Methods

This chapter is the end-result of an inductive process involving iterative observations and descriptions from two simultaneous strategies used in the exploratory research: literature review (Chapter 2) and a qualitative survey of technology campuses (Chapter 3).

As shown in Figure 4.1, the design of the exploratory study has its starting point in two knowledge gaps. The first is a theoretical one about the object of study 'the role of the built environment stimulating innovation in the knowledge economy', which is limited but has the potential to be explored in the existing literature. The second is an empirical one about the subject of study 'the development of technology campuses as built environments', which is extensively studied in the fields of business, economics, regional studies but much less from the built environment sciences. Both strategies were applied almost in parallel with the purpose to gain familiarity with the object and subject of study while narrowing down the research area and the focus of further empirical study.

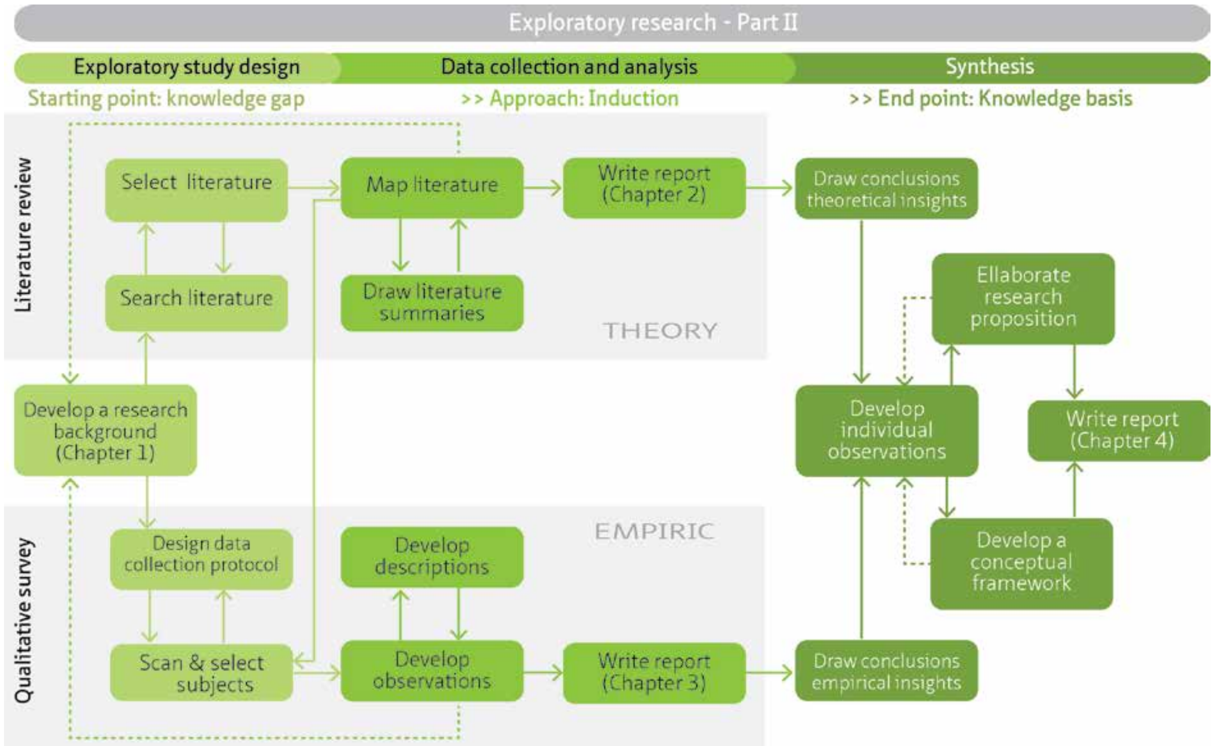


Figure 4.1 Exploratory study methods and phases. This chapter is the combined output of the literature review and the qualitative survey outlined in the rectangle on the rigth.

First, the review of the literature on the built environment and innovation in the context of the knowledge economy provided theoretical notions, which can be applied at area level to study the development of technology campuses. These theoretical insights defined a research area, ranging from different fields of studies such as corporate real estate management, economic geography, urban planning, architecture, urban development and regional policy (see Chapter 2).

Second, the exploratory survey of 39 international subjects on their patterns of emergence and development provided a list of evident characteristics of campus development, which are linked to some theoretical notions found in the literature. These empirical insights are collected in a compendium, which is a database of information on the cases that can be consulted for further observations (see Chapter 3).

The combined insights of these two chapters form the synthesis of the exploratory study of this research and constitute the knowledge basis required to answer its main research question. The details about the data collection procedures of each strategy can be found in Chapter 2 and 3 respectively. The following paragraphs elaborate on the individual observations based on the theoretical and empirical insights of the previous two chapters, from which a research proposition is drawn.

§ 4.1.3 Innovation and the built environment: insights from theory and practice

This section integrates the theoretical and empirical insights of the exploratory research (Chapters 2 and 3). In other words, it connects the empirical patterns observed in the development of 39 technology campuses in relation to theoretical concepts of innovation and the built environment from the fields of economic geography, urban studies in the knowledge economy and real estate management. The assumption behind this connection is that such concepts (and their interrelations) can be applied at the area level to examine the role of the built environment in stimulating innovation through the study of campus development. Accordingly, there are four interrelated notions capturing most of the findings of the exploratory research that forms the research area or knowledge basis to continue this research [See Figure 4.2]. These 'key' notions and what they entitle for this research are indicated as follows:

- **Knowledge creation and diffusion**: understood as the core processes of technology-based research organisations[35] leading to innovation in regions and cities.
- **Geographic concentration** (of technology-based research organisations): assumed as a basic setting enabling knowledge creation and diffusion.
- **Competitive advantage**: understood as the driver for innovation of technology-based research organisations as well as cities and regions in today's economic context.
- **Role taking:** understood as a necessary capability to steer resources aimed to stimulate innovation.

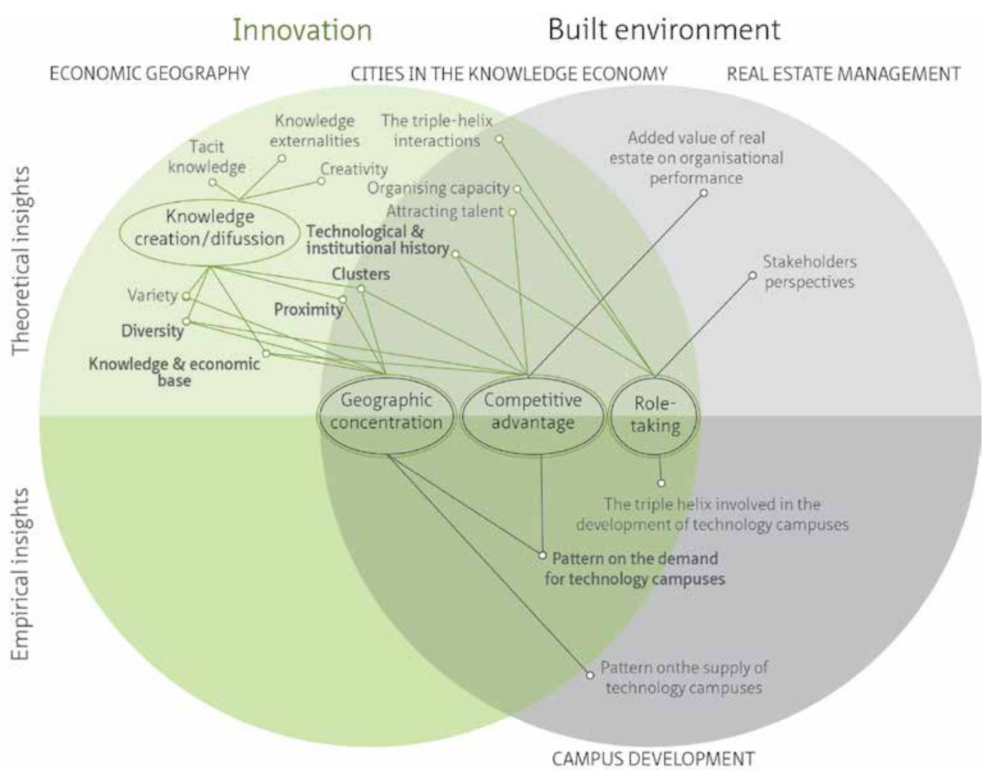


Figure 4.2 Map of the research area outlining the main theoretical and empirical notions about innovation and the built environment and their interrelations through concepts identified in this exploratory study

35 This research uses the term technology-based research organisations to refer to a specific type of knowledge-intensive organisations such as research universities, research institutions and R&D firms that focus on the development of technologies.

The first notion is a theoretical insight used to define innovation in this research as a learning process in which knowledge is created and transmitted through individuals first and transferred to develop new or improved technologies later. This notion is based on existing approaches in the fields of economic geography and urban development in the knowledge economy explaining the relevance of knowledge spillovers in urban and regional growth. The definition of this notion applies to this research in the sense that these processes are inherent to research in technology fields, which is the main activity to be accommodated in technology campuses. The other three notions are playing a central role connecting theoretical and empirical insights about innovation and the built environment and explained as follows.

One of the main theoretical assumptions from agglomeration economies suggests that the 'geographic concentration' of knowledge intensive organisations plays a central role in the process of knowledge creation and diffusion for economic growth development. Correspondingly, the notion of concentration is inherent to the definition of technology campuses as built environments considering their distinct supply and demand characteristics – e.g. an organised concentration of buildings and facilities accommodating organisations (or divisions within an organisation) that are meant to be close in relation. According to the empirical insights of this exploratory study, technology campuses are defined as geographical concentrations that meet three conditions:

a. They are composed by organisations, which have technology-based research activity as common demand to be accommodated.
b. These organisations accommodate their activities in a confined built environment, regarded as campus, which is contained in another built environment, called city or region as common supply characteristic.
c. There is an attracting force that makes these organisations to stay closer, regarded as the core processes they share to perform research in a way that add value for them.

Indeed, the third condition in this definition of technology campuses above links to the notion of 'competitive advantage', which is identified as driver for economic development and growth in the review of the literature on innovation in the knowledge economy (see Chapter 2). Correspondingly, 'competitive advantage' is a pattern in the demand for many technology campuses in practice. Indeed, the empirical insights suggest that most of the goals behind the development of technology campuses are economic development goals in the framework of the knowledge economy – e.g. stimulating innovation. Thus, the geographical concentration of technology-based research organisations and their activities is perceived as a source of competitive advantage in the global knowledge economy. According to the theoretical insights from real estate management, increasing performance is why organisations spend resources on real estate. Thus, this view can help to explain how competitive advantage is a reason for technology-based organisations and cities to develop technology campuses in stimulating innovation.

Last, the notion of *role taking* is addressed in the review of the literature –not as explicit as here- as a capability of organisations, cities and regions to make use of their natural advantages and resources to stimulate innovation for economic growth. In the knowledge economy, this notion is expressed by the interaction of industry, governments and universities know as the triple helix. In the built environment, insights from real estate management position the perspectives of stakeholders as influencing the ways in which real estate add value to the performance of organisations. Correspondingly, the empirical findings suggest that the development of technology campuses is a result of role taking by stakeholders in these three spheres of the triple helix. Indeed, an in-depth study of campus development can help to understand how the built environment becomes as a resource input for innovation via *role taking*.

As illustrated in Figure 4.2, these four notions are not mutually exclusive of one another. They are connected through specific theoretical concepts that can be further studied to understand the role of the built environment in stimulating innovation. For instance, the findings suggest a link between the notions of ‘knowledge creation and diffusion’ and ‘geographic concentration’ of technology-based research organisations. This link is identified through the concepts of proximity, clusters, variety and diversity in the fields of economic geography and the concept of knowledge & economic base in urban studies in the knowledge economy.

Similarly, the concepts of knowledge & economic base, clusters and diversity are also the link between the notions of ‘geographic concentration’ and ‘competitive advantage’ in theory. Not surprisingly, these two notions are connected in the practice of campus development since both ‘geographic concentration’ and ‘competitive advantage’ are inherent to the demand for technology campuses observed in the comparative study of existing technology campuses. Moreover, the notions of ‘competitive advantage’ and ‘role taking’ are also connected through the concept of technological & institutional history studied in evolutionary economic geography. In simple words, this suggests that the concepts of *knowledge & economic base, clusters, proximity, diversity, variety and technological & institutional history* are relevant theoretical foundations to explore the role of the built environment in innovation. And so, the *demand for campus development* becomes the empirical angle to understand such role. Overall, these concepts are the main connectors of both theoretical and empirical notions about innovation and the built environment. Accordingly, they can be framed to further investigate the role of the built environment in innovation with in-depth information.

Summing up, the empirical and theoretical insights described above mapped the research area in which the role of the built environment in innovation is further studied. Accordingly, there are four key notions linking innovation and the built environment (knowledge creation and diffusion; geographic concentration; competitive advantage; and role-taking). The last three are identified both, in the practice of campus development and in theories of economic geography, urban studies in the knowledge economy and real estate management. These four notions are connected trough five theoretical concepts (knowledge & economic base; clusters, proximity; diversity; technological & institutional history) and one empirical assumption (the demand for developing technology campuses). Based on these insights, the following paragraphs develop a proposition to frame these elements and relationships in order to move to the next step, which is drawing a conceptual framework.

§ 4.1.4 Research proposition

The basic assumption of this research is that stimulating innovation is a goal pursued by different organisations involved in the development of technology campuses and driver of competitive advantage in the knowledge economy. Therefore, from the researcher’s point of view stimulating innovation is one of the ways in which the built environment has an effect on the competitive advantage of these organisations. This assumption, which comes from the CREM field, indicates the existence of a relationship between the built environment and the performance of organisations addressing stimulating innovation as a goal. Indeed, the insights described in the previous section suggest a logic connection between specific notions, which can serve to investigate this research assumption.

Accordingly, the knowledge economy is the contemporary context in which this assumption is investigated. In the knowledge economy, innovation is a major source of growth in technology-based research organisations, cities and regions to achieve competitive advantage. Innovation is also the output of the process of knowledge creation & diffusion leading to the advancement of technologies applied to develop new or improved products and processes. Indeed, the creation and application of new knowledge is a core process of technology-based research organisations, whose geographic concentration appears to be essential for this process.

However, the mere concentration of technology-based organisations in an area, city or region is not a sufficient condition to make innovation happen. The insights of the exploratory study suggest the notion of role taking as 'a capability of organisations, cities or regions to steer the resources that are deliberately put in to stimulating innovation'. Indeed, the built environment -specifically campus development- is considered both, in the literature and practice, as one of those resources. Thus, role taking is considered an input of the process leading to innovation, in which the built environment is a steered resource via management, planning, or design capabilities.

An important characteristic of the built environment that makes it different from other resources (e.g. capital) is that is not explicitly meant to support the processes leading to stimulate innovation. The built environment is usually developed to shelter people's activities but can simultaneously support different organisational goals beyond supporting end-user's work (e.g. stimulating innovation and maximising investments among others). Moreover, the built environment can be re-used or adapted to changing goals over time (e.g. manufacturing buildings that have been transformed into offices or housing). In this context, this research develops the following as main thesis or proposition:

The built environment is a catalyst for innovation depending on three context-related conditions: demand, supply and time.

These three conditions define the way in which the built environment is steered in a way that facilitates the processes leading to innovation. Nevertheless, the function of this catalyst facilitating or speeding up such processes depends upon other input resources, which have different functions within the entire process, such as the concentration of technology-based research organisations.

Overall, the empirical insights of the exploratory study suggest that despite the diversity in the contemporary definitions and the realities of existing subjects, technology campuses share the following characteristics: they are deliberately clustered and (quasi-) isolated built environments developed to stimulate innovation. Although there is no evidence confirming these supply characteristics have an effect on the processes leading to innovation, there must be reasons to believe they do. Indeed, those reasons may explain why society and organisations spend resources on developing campuses to accommodate technology-based research activities rather than developing other types of built environments. For instance, this research estimates reasons such as the influences of (1) theoretical concepts assumed to stimulating innovation (e.g. proximity), (2) established urban planning or design principles (e.g. modern movement) and (3) path dependency in organisational decision-making (e.g. persistence in accommodation choices). Accordingly, the case study research (Part III) attempts to uncover these -and perhaps other- reasons by applying the research proposition to specific subjects of study. The proposition is detailed as follows:

The development of technology campuses is a catalyst for innovation depending on the goals and activities of organisations involved in their developments, their location characteristics and the historical events shaping their emergence and development.

Thus, in order to explain how the built environment is a catalyst for innovation in the development of technology campuses, this dissertation proposes a conceptual framework that organises the main concepts found in the review of the literature and in practice connecting innovation and the built environment. This framework is described in the following section.

§ 4.2 Towards a conceptual framework explaining the built environment as catalyst for innovation

This section presents a conceptual framework developed to explain how the built environment is a catalyst for innovation in the development of technology campuses. The framework is presented in two parts. The first focuses on the logic of the framework by defining its purpose and describing the overview of its main components. The second introduces the concepts of the framework that give meaning to the proposition, by illustrating the theoretical and empirical insights that have the potential to provide understanding on the relationship between innovation and the built environment. Furthermore, this section explains the relationships between these concepts.

§ 4.2.1 Logic of the framework

This conceptual framework is the preliminary result of individual observations from theoretical and empirical insights that explored a relationship between innovation and the built environment. This framework represents the conceptual status of the aspects to be studied when explaining the research proposition and how these aspects interrelate with each other. Accordingly, this framework defines the research focus of the next phase. It is developed both as a frame for understanding the main relationship addressed in the research proposition and as an analytical tool to match further empirical information to the research proposition of this dissertation.

This framework has been built through an iterative process that involved identifying key concepts, establishing links among them and challenging those relationships. Indeed, these sounded steps or activities developed as the observations and insights emerged throughout the theoretical and empirical exploration. Therefore, the framework has been revised several times and it is subject of revision in the future. In this context, the framework presented in this chapter is the version of the researchers' research area and focus after the exploration research.

Figure 3 illustrates the logic of the proposed framework with the main concepts and relationships to be investigated in Part III of this dissertation. This framework set the concepts explaining the built environment as catalyst for innovation in terms of input-processes-output within a context. The knowledge economy appears as the macro context of this research because in this context innovation is a major source of growth in different organisations wanting to achieve competitive advantage (e.g. technology-based research organisations, cities and regions). Accordingly, there are six inputs necessary to carry on the processes of knowledge creation and diffusion leading to innovation. Indeed, the built environment is positioned through campus development as an input-resource steered to facilitate other input-conditions leading to innovation.

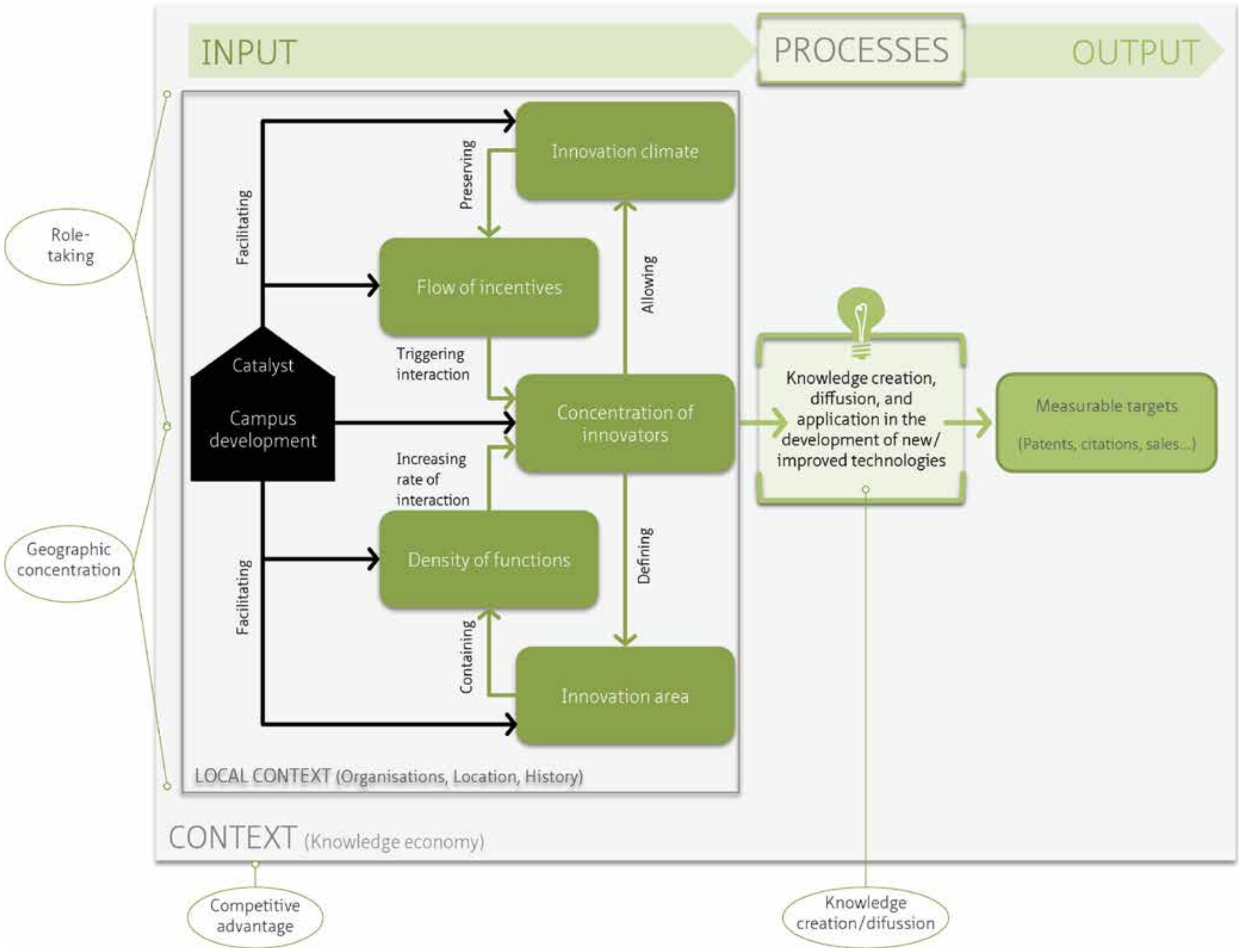


Figure 4.3 Conceptual framework of the built environment as catalyst for innovation in the knowledge economy demonstrated in terms of input- processes-output.

Correspondingly, the output indicators of innovation focus on the measurable targets delivered through the processes of knowledge creation and technology transfer. In the knowledge economy, these outputs are set as measurable goals by different organisations that want to remain competitive in such context. These organisations correspond to three different spheres of the Triple Helix: universities, industry and governments. As shown in Chapter 2, each of these organisations measures innovation according to their different core businesses and aspirations. In explaining its proposition, this chapter emphasises on the input indicators or the necessary conditions facilitating innovation[36]. This choice is not arbitrary. Both, outputs and process are placed in the framework to provide understanding of the entire system. However, the attention is placed on the input-conditions because most of the key concepts from the theoretical and empirical insights that can possibly explain the relationship between innovation and the built environment belong to this angle.

36 An overview of the outputs used to give an indication of innovation (e.g. patents applications and grants, citations or prototypes, among others) can be found in Chapter 2

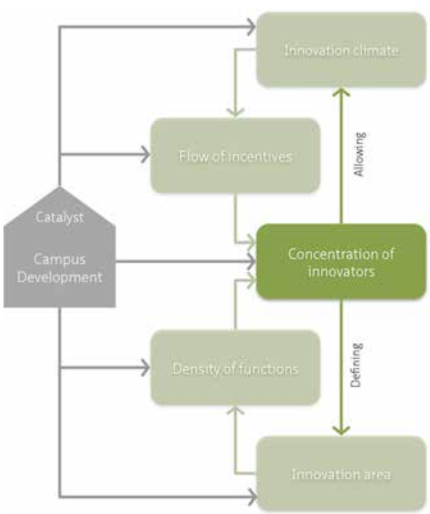
In this framework, the research proposition is outlined giving to the built environment a particular function as catalyst, which facilitates the process of knowledge creation and diffusion in an intermediary way – i.e. facilitating other conditions leading to innovation. Accordingly, 'the development of technology campuses is a catalyst for innovation depending on the goals and activities of organisations involved in their developments, their location characteristics and the historical events shaping their emergence and development'. These three conditions are part of a local context, defining the way in which the built environment is steered to facilitate the other conditions leading to innovation. That is, the function of the built environment as catalyst facilitating the process of knowledge creation and diffusion depends upon other input resources, which have different functions within the entire process (e.g. the concentration of technology-based organisations among others indicated in the framework). Accordingly, each of the inputs is a necessary but not a sufficient condition to stimulate innovation. Therefore, they are interdependent because their functions are based on the interactions among each other, which are correspondingly shaped by the local context. The following paragraphs describe each of the input conditions and their functions in the framework.

§ 4.2.2 The input-conditions leading to innovation and their relationships

The following paragraphs outlines a selection of the theoretical and empirical insights that explain the research proposition resumed as follow:

The development of technology campuses is a catalyst for innovation depending on the goals and activities of organisations involved in their developments, their location characteristics and the historical events shaping their emergence and development.

Concentration of innovators

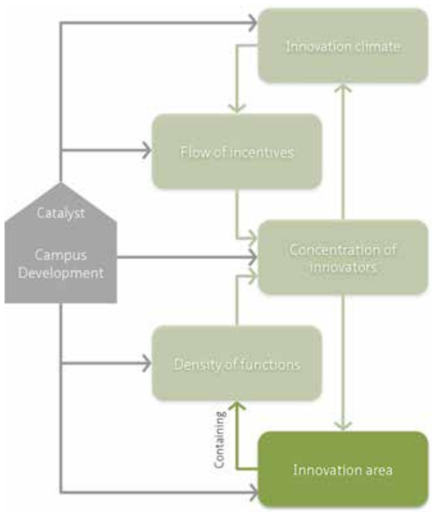


This input condition refers to the vital parts of the system through which technology-based knowledge is created and applied. In other words, innovators represents the organisations engaged on research activities in technology fields (both, basic research and R&D). On the one hand, we have the universities, HEIs and research institutes advancing knowledge, while on the other we have firms transferring that knowledge into industrial products.

In theory, these two parts refers -in the same order- to the University/Industry spheres in the Triple Helix concept (Etzkowitz, 2008) and to the Knowledge-base/Economic-base in knowledge cities (Van Den Berg et al., 2005). In agglomeration economies, the presence and collective actions of firms is believed to positively affect innovation via specialisation or diversity(Beaudry & Schiffauerova, 2009). The presence of these interconnected innovators in one location (including firms and universities) is addressed in cluster theories as sources of competitive advantage (Porter, 1990). This has gained importance in the knowledge economy since business companies are much more tied to locations because they are dependent on highly-educated staff and on their integration into local networks (Porter, 2008; Van Den Berg et al., 2005).

In practice, innovators define the demand for accommodating technology-based research activities that leads to develop real estate (e.g. campuses). Indeed, empirical insights shows that innovators are the main end-users of technology campuses that decided to concentrate in a defined area to perform their primary processes leading to innovation. Similarly, innovators are two of three stakeholders involved in the development of technology campuses either as founder, managers and/or promoters. This input condition is primal for innovation because without innovators –as represented in organisations and the individuals in these organisations- the process of knowledge creation and diffusion is non-existent. Indeed, two other input-conditions for innovation derive from the concentration of innovation: the innovation area and the innovation climate.

Innovation area



This input condition refers to the geographical area allowing contacts between the concentrated innovators. The innovation area is determined by the positions of the innovators in a territory and by the physical characteristics of such territory enabling contacts and interactions between the innovators in a specific way.

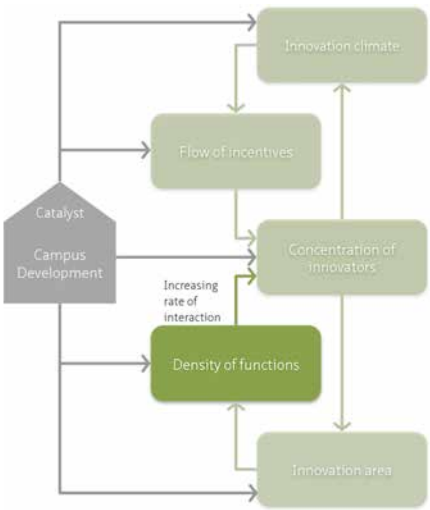
In theory, Etzkowitz (2008) refers to a similar notion as the 'triple helix region' by analysing the 'transformation of regions from a geographical, cultural and industrial area to an innovation entity, which is an area that has more an identity rather than a precise dimension'. This identity becomes a brand from the business perspective. However, the natural features of the innovation area are as representative as the business located in it for branding. Two well-known examples of these are Silicon Valley and Route 128 also pointed out by Castells (1985), who outlined 'technology as the leading force of human progress that is re-shaping the logic of cities, regions and nations; and the location patterns of high technology manufacturing in specific areas as the new industrial space'.

The geographical dimension (scale and connectivity) of the innovation area is addressed in theory as important aspect of this condition. That is because contacts and interactions among innovators allow the spillovers of tacit knowledge, which transmission depends on distance (spatial and temporal). This suggest that knowledge spillovers tend to be geographically bounded (Audretsch & Feldman, 1996). This theoretical assumption is widely discussed in agglomeration economies through the concept of proximity[37]. Accordingly, the notion of proximity is explored in other dimensions besides the geographical one and linked to several other concepts (Autant-Bernard, 2012; Balland et al., 2015; Bathelt et al., 2004; Boschma, 2005; Boschma & Frenken, 2010; Lagendijk & Lorentzen, 2007; Torre & Rallet, 2005). Mainly, it is argued that face-to-face interactions, collaboration, networks and selection mechanisms are believed to facilitate the flows of tacit knowledge. However, it is not yet resolved which types and levels of proximity are critical for knowledge networks. Nevertheless, geographical proximity is recognised as facilitating the other dimensions of proximities. Indeed, the notion of time has gained importance in this discussion by which the temporary face-to-face contacts allowed by labour mobility stresses the role of connectivity within and across the innovation area. In this context, the location and the mobility of highly educated and trained labour becomes a determinant factor for the agglomeration of innovative activities and so, for the definition of the innovation area in its geographical dimension.

37 More details about the theoretical discussion of the Proximity concept can be found in Chapter 2.

In practice, the innovation area shaped the concentration of innovators that tends to be labelled in a way that refers to a specific territory. Several innovation areas are referred to as regions, districts, hubs, belts, corridors, or even campuses, emphasising their distinct geographies, scales and connectivity settings. Accordingly, location characteristics become an important local factor explaining the link between innovation and the built environment. Indeed, the different location characteristics emerging from the empirical insights make this connection even more interesting. For instance, the density of functions is another input-condition for innovation that derives from the distinct innovation area.

Density of functions



This input condition refers to the existent mix of activities or functions and its distribution in the innovation area ensuring frequency (or increasing the rate) of interaction between the innovators. Correspondingly, the presence of diverse activities or functions may attract more innovators in an area.

In theory, this is linked to the concepts of diversity of people, ideas and functions in cities promoting creativity, innovation and growth (Florida, 2002, 2008; Glaeser et al., 1992; Jacobs, 1961; Pentland, 2014; Van Den Berg et al., 2005). This condition has an important social component because knowledge sharing and idea generation are strongly tied to social interaction and trust developed among innovators through frequent interaction. In aglommeration economies, this refers to the social dimension of proximity facilitating the exchange of tacit knowledge and effective interactive learning based on trust and commitment (Boschma, 2005).

A sounded dense environment in terms of functions (i.e. with a balanced mix of functions and users distributed in the innovation area) may allow chances for interactions that can generate ideas and knowledge spillovers. However, the optimal density of functions providing a positive social context for innovations is difficult to determine since it has been outlined that too much social proximity can be detrimental as well (Boschma, 2005; Boschma & Frenken, 2010).

Nevertheless, the presence of diverse functions in regions and cities is a major component of quality of life, which is crucial in attracting and retaining knowledge workers (Van Den Berg et al., 2005). According to McCann (2012), the built environment in which the future knowledge workers develop is shaping their consumption preferences. Recent studies (Groot et al., 2011) research cultural factors and consumer preferences as ways to understand why clustering takes place rather than the traditional production type of externalities considered as relevant. Accordingly, it is crucial understanding to what extent location behaviour of people is driven by the different types and characteristics of the amenities that places may offer. This approach is supported and applied in other urban studies in the context of the knowledge economy (Faggian & McCann, 2009; Fernández-Maldonado & Romein, 2008; Florida, 2008).

In practice, the location characteristics of the subjects surveyed suggest differences in the presence and distribution of functions within certain territories or innovation areas. For instance, empirical insights showed that cities and regions hosting technology campuses have different demographic characteristics, urban profiles and mix of functions. Nonetheless, when considering the campus an innovation area itself, it is observed that they accommodate diverse populations and activities. That is within a limited area, campuses concentrate diverse people and their activities. Nevertheless, not all campuses have a mix of functions or the same distribution of them, which can ensure frequency of interaction between innovators. These empirical differences -along with the theoretical argument of the unresolved degree of social proximity necessary for innovation- make this condition and interesting concept to be explored in the framework.

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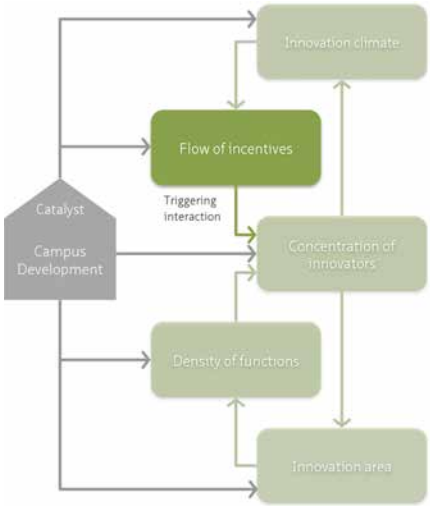
Flow of incentives



This input condition refers to the actions required by the innovators to start and carry-on the processes of knowledge creation leading to its application to develop new and improved technologies. Examples of these incentives are research expenditure, institutionals frameworks and policies, entrepeneurial activities, among others ensuring the availability of research jobs in technology fields where the new knowledge can be created and applied. These incentives or actions can be strategically organised in close collaboration between different parties.

In theory, this is referred to as the organising capacity of a region to develop one or more activities of the knowledge city (Van Den Berg et al., 2005). These activities include some of the aspects already mentioned above such as attracting and retaining knowledge workers and creating and appliyng knowledge as important processes of innovation. According to Van Den Berg et al. (2005), 'organising capacity is understood as the ability of those responsible for solving a problems to convene all concerned partners (public and private, internal and external), in order to jointly generate new ideas and formulate and implement a policy that responds to fundamental developments and creates conditions for sustainable economic growth'.

In an earlier research Van Den Berg et al. (1997) defined organising capacity as the entire process including 'the identification of needs, the development of ideas and policies, the implementation of them and the monitoring of results'. Important havings to carry on this entire process are a vision, strategic networks, leadership, political and societal support and communication (Van Den Berg et al., 2005).

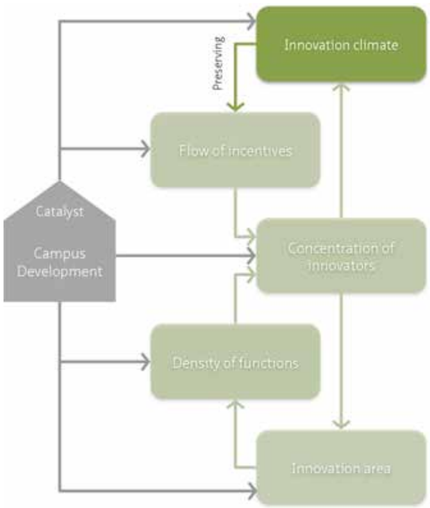
This definition can be applied to the Triple Helix concept as the concerned partners creating the conditions to stimulate innovation in an area. According to Etzkowitz (2008) role-taking increases the interactions between each of these spheres, which identities are enhanced through new ways of relationships with other spheres. The proactive role of the stakeholders in the Triple Helix is an important aspect of this condition because their relationships determine the actions that will trigger interaction between innovators concentrated in an area. The quality of these relationships is crucial because, as outlined before in Chapter 2, each of these spheres has its own insterests on innovation.

Correspondingly, the synergy created in a region through a concerted allocation of roles and activities strenghten the attractiveness of the innovation area for organisations, which are willing to locate and/or remain in it. That is because a continous flow of incentives facilitates the conditions for socio-economic growth and development for organisations and knowledge workers.

In practice, the flow of incentives is evidenced at strategic level with the organisations involved in campus development. Many of the campuses and cities surveyed in this exploratory research have an intended knowledge-based and/or science & technology policy or vision. Indeed, the involvement of different stakeholders in the three spheres of the triple Helix is common in the development of technology campuses. Although, the interests of these stakeholder may differ, it seem that some of their goals align in the context of the knowledge economy. Thus, it is observed that some stakeholders' roles overlap among different actors. That is the case of promoter of the campus because it increasingly represented by hybrid (and sometimes non-traditional) structures involving public and private parties. Similarly, the incentives to attract and retain research organisations is explicitly adressed in specific contexts where the development of the campuses is a top-down approach led by local and/or national governements.

This is the case of many campuses in Asia that have been declared special research and development zones that give advantages to companies on regulatory standard requirements. In other regions the incentives are more softer and targeted to increase the attractiveness of the areas for knoweldge workers in terms of safety, social security and quality of living.

Innovation climate



This input condition refers to the interrelated economic, institutional and technological developments happening in a local context creating the appropriate momentum for innovation. Certainly, the innovation climate is determined by concentration of innovators in a specific time and place because their presence shapes institutional, technological and economic change in those temporal and spatial contexts. Correspondingly, this climate preserves the flow of incentives necessary to carry on the processes leading to innovation.

In theory, this is related to the approach to innovation from evolutionary economic geography. In this approach institutional and technological trajectories influence innovation because both institutions and technology co-evolve over time and differently per region (Boschma & Frenken, 2006). As mentioned in Chapter 2, this approach is based on Schumpeter's ideas outlining the importance of endogenous R&D in large firms influencing the agglomeration of innovative activities.

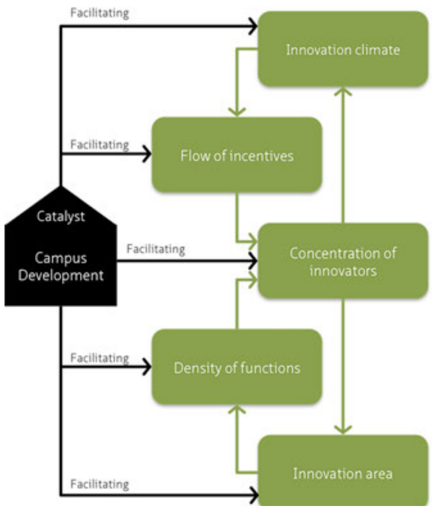
From this viewpoint, selection processes in firms (i.e. location decision in firms as a way to cope with uncertainty and change involved in innovation) make them to continue along existing trajectories over time that can lead to either economic growth or decline. This is known as path-dependency, a concept that can explain the agglomeration of economic activities and the evolution of proximities as a historical development linked to economic growth and change (Simmie, 2005). Further studies (Frenken et al., 2007) refer to the idea of related variety as a special circumstance that happens in places where technological trajectories are open and based heavily on tacit-knowledge. Accordingly, successful sectors diversify in a good degree over time based on existing competences but avoiding lock-in that can result from path dependant technological trajectories. That is through the time proximity facilitated by the geographical proximity to international hubs.

The evolutionary perspective considers the relationship between the different dimensions of proximity and collaboration among knowledge networks a dynamic one that may change over time (Balland et al., 2015) – i.e. some levels of proximity may increase the formation of knowledge networks in the short term while knowledge networks may increase proximity levels in the long term. Likewise, this means that the different dimensions of proximities co-evolve among each other in different timeframes. These insights can help clarifying our understanding of proximity and innovation linked to history and geography, which differ according to the contexts.

In practice, the innovation climate is suggested through different observations from the empirical survey of campuses. The most obvious observation is the link between the emergence (and development) of technology campuses in specific places and specific periods of technological change in history. Another observation is the change in campus labels along with changes in technological trajectories. Similarly, relevant economic sectors in the cities/regions that host technology campuses have emerged in line with the dynamic technological trajectories. Furthermore, some of these subjects are home of R&D divisions of multinational corporations with a long trajectory, or well-known and historically rooted universities of technology.

Overall, the innovation climate is an input condition that may allow this research to provide explanations between the relationship between innovation and the built environment through the understanding of long-term change. Indeed, studying campus development as a evolutionary phenomenon seems key to understand the relationship between the built environment and innovation through decisions taken over time and responding to temporal contexts.

The presence of a catalyst: campus development



This input refers to the built environment as a physical resource facilitating all the other conditions, which are necessary to stimulate innovation. Accordingly, the built environment is neither necessary nor a sufficient condition for innovation. However, this research recognises and outlines its facilitating role stimulating innovation by strengthening the functions of the other five conditions for innovation outlined in this framework.

In the review of the literature about cities in the knowledge economy, the built environment is addressed as a type of physical infrastructure or resource facilitating the processes of knowledge creation and diffusion (Florida, 2010; Van Winden, 2008). For instance, the built environment is referred either as infrastructure (e.g. laboratories and facilities for research) part of 'science systems' by policy makers (Oecd, 1996) and/or organisational resources capable of attracting highly-educated people and knowledge workers by scholars (Den Heijer, 2011; McCann, 2012). This contemporary position matches the traditional view of real estate management in which real estate is the fifth resource in achieving organisational performance, next to people, technology, capital and information (Joroff, 1993).

This theoretical assumption has been investigated through the concept of the added value of real estate in the field of corporate real estate management (De Jonge, 1996; De Vries, 2007; Den Heijer, 2011; Lindholm et al., 2006; Nourse & Roulac, 1993). Accordingly, stimulating innovation is referred to as an added value through which the built environment supports organisational performance via alignment between organisational- and real estate strategies. That is because innovation is recognised as a key performance aspect in organisations whose core businesses are driven by technology (e.g. universities of technology, research institutes and R&D companies in technology fields). Furthermore, this research has identified innovation as a key aspect of many more organisations in the knowledge economy, which benefit from the successful performance of technology-driven organisations (e.g. municipalities and/or regional governments or agencies). Overall, this specific added value has been investigated from the CREM perspective mostly at the scale level of the workplace in buildings, which effect on organisational performance has been difficult to measure and demonstrate. However, the review of the literature from economic geography and urban studies suggest a relationship between innovation and the built environment at a larger scale. Therefore, this research attempts to provide understanding of such relationship by studying the added value of real estate stimulating innovation at area level. Accordingly, the framework positions 'campus development as catalyst for innovation' in order to clarify both, the subject and object of study under investigation.

This framework uses the word catalyst as a synonym of enabler of the activities performed by individuals, organisations and the society as seen in CREM theories. It does so, to outline the facilitating role or function of the built environment in the whole system described in the framework –i.e. input-processes-output. Accordingly, when all the previous and interdependent input-conditions for innovation exist; the presence of a catalyst only increases the potential of these conditions in the entire system without

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being affected or spent in the processes leading to innovation. This notion outlines three important attributes of the concept of added value developed through the review of the CREM literature.

First, the added value of real estate is versatile - i.e. the built environment is steered in a way that can stimulate innovation and simultaneously support other organisational goals depending on the organisations' driving forces that are subject to change over time[38].

Second, the added value of real estate is interdependent - i.e. the potential role of the built environment stimulating innovation is estimated by different stakeholders and is often perceived as a combined effect of interdependent real estate strategies[39]. This attribute poses the presence of potential 'inhibitors' reducing the function of the built environment as catalyst for innovation. These are the conflicts created by a lack of balance in the different perspectives of the stakeholders, for whom stimulating innovation is a goal but whose different perception may have a combined negative effect frustrating this goal.

Last, the added value of real estate is intermediary - i.e. the function of the built environment as catalyst for innovation can be demonstrated through real estate decisions and interventions[40]. Existing empirical research studying innovation as an aspect of organisational performance has mainly focused on real estate decisions at the level of the workplace and in office environments. In theory, location, amenities and facilities are suitable real estate decisions to explore stimulating innovation as added value. Accordingly, studying past decisions and interventions through the development of technology campuses might clarify the relationship between innovation and the built environment. In turn, these can reveal a variety of crucial decisions and interventions that can be used to support innovation as an organisational goal through real estate in the future.

38 In the CREM literature, innovation is an aspect of organisational performance measured through different performance criteria (i.e. distinctiveness, competitive advantage, productivity and profitability) depending on the different driving force of each organisation. These forces may change in organisations with the dynamic demand of the businesses in organisations. In contrast, the built environment can be re-used or adapted to those changing needs and goals over time.

39 In CREM research, added values (or real estate strategies) relate to each other depending on the different criteria used to measure performance (i.e. distinctiveness, competitive advantage, productivity and profitability) by the different stakeholders and their perspectives (e.g. strategic, functional, financial and physical). For instance, innovation is related to other six aspects of organisational performance as seen in different studies. According to most of the studies, innovation, user satisfaction and image are mutually dependent aspects of organisational performance from at least three different perspectives and performance criteria.

40 The review of the literature distinguished two levels of adding value through real estate: strategic and operational. For instance, positioning hierarchically real estate strategies, decisions and interventions clarify the paths to attain organisational performance through real estate. Accordingly, stimulating innovation is considered a real estate strategy and so, this strategy leads the course of action for real estate decisions and interventions at operational level.

§ 4.3 The conceptual framework and the methodological design of Part III

This section outlines how the framework described above informs the methodological design of Part III by guiding the selection of the next research strategy, the subjects of study, the data collection instruments, as well as the analysis and interpretation of findings.

§ 4.3.1 Case study research

As mentioned before, the conceptual framework developed in this chapter aims to gain and provide understanding of the role of the built environment in innovation. This framework elaborates on a proposition that the built environment is a catalyst facilitating five conditions for innovation. Accordingly, this framework will be the instrument to explain and examine this proposition, which is based on the interrelation of several concepts that have the potential to provide insights and understanding on the role of the built environment in innovation. Therefore, the descriptive nature of the model suggests the selection of a research strategy through which in-depth qualitative information can be collected and analysed to understand the complex issues addressed in the framework and so, to test its usefulness in practice.

Accordingly, Part III of this dissertation employs case study research to clarify the relationship between innovation and the built environment as indicated in the framework. Case study research is a powerful strategy to corroborate and revise the theoretical constructs in the framework based on empirical evidence in context. For instance, empirical insights from the study of cases can help to revise the conceptual framework that might develop into a conceptual model. Indeed, case study research is considered as a suitable strategy not only for its potential for understanding a specific phenomenon in rich detail, but also for theory building based on the development of context-dependent knowledge (Eisenhardt, 1989; Eisenhardt & Graebner, 2007; Flyvbjerg, 2006; George & Bennett, 2005).

Eisenhardt (1989) refers to the term 'building theory from cases' as a research strategy involving one or more cases from which theoretical constructs, propositions and/or midrange theory can be created based on empirical evidence. This notion implies developing theory inductively, which emerges from observed 'patterns of relationships among constructs within and across cases and their underlying logical arguments' (Eisenhardt & Graebner, 2007). Accordingly, developing theory inductively from cases is important in this research because the relationship between innovation and the built environment established in the conceptual framework is not explicitly addressed in existing research. Nevertheless, this exploratory research has shown that this relationship is increasingly important for organisations in the knowledge economy and this conceptual framework suggest that there are theoretical notions whose interrelations can help clarifying such relationship based on empirical evidence.

Similarly, Flyvbjerg (2006) outlines case study research as a method that has the potential for either testing and building hypothesis and not only at the first steps of a research process as it is often misunderstood. He outlines 'the force of example' as an important source of scientific development next to formal generalisation. In this context, case selection becomes critical in corroborating the research proposition because the accumulation of context-dependent knowledge of this study could be transferable to another relatively similar circumstance. The following paragraphs elaborate on this aspect.

§ 4.3.2 Case selection

This process focuses on the selection of cases that are particularly interesting to investigate the research proposition. This means cases are selected because they are suitable to clarify the relationships among the constructs established in the conceptual framework. This view aligns with the concept of theoretical sampling by which cases are chosen because of their likelihood of offering theoretical insight (Eisenhardt & Graebner, 2007). Furthermore, the use of multiple cases is suggested as strong for theory building because it allows comparison and the possibility to verify the consistency of the emergent findings (Eisenhardt & Graebner, 2007; Yin, 2014). In this research, cases are selected because of their potential to elaborate on the proposition. The choices about which and how many cases are selected will be discussed as follows.

The choice about which cases are to be compared is based on their exemplarity highlighting the general aspects described in the conceptual framework to explain the proposition – i.e. input-process-output and context. Initially, this research considers suitable cases all the 39 technology campuses that are part of the exploratory survey because they emerged and developed to accommodate technology-based research as main activity, which is relevant in the process of knowledge creation and diffusion leading to innovation.

Furthermore, exemplar cases in the broad context of the knowledge economy are technology campuses in which stimulating innovation is explicitly addressed as a goal of the organisations involved in their developments. This criterion narrows down the sample to 25 cases in the exploratory survey of technology campuses.

Similarly, exemplar cases in terms of inputs and outputs are technology campuses whose organisations have had success in realising this goal. In the field of real estate management this criteria is sensitive because successful cases are considered paradigmatic cases. According to Flyvbjerg (2006), a paradigmatic case 'operates as a reference point and may functions as a focus for the founding of schools of thought'. Nonetheless, this research has shown that successful innovation is hard to define because its measurement is becoming complex especially in the knowledge economy.

For instance, the review of the literature shows innovation is often measured with output indicators, which differ a lot according to the type of organisation (e.g. universities, firms and cities). For example, each organisation measures output of innovation in relation to their core processes and driving forces (e.g. the amount of Nobel laureates and the number of publications are more relevant for universities as the sales flowing from new products are for R&D firms and the number of R&D spin-offs per square kilometre is for cities)[41].

Conversely, the input indicators of innovation focus on aspects creating the conditions for innovation as a learning process. In the knowledge economy these are concerned with supporting the processes of 1) creating and transferring knowledge; 2) and attracting and retaining knowledge workers. After a systematic review, both input and output indicators listed before in Chapter 2 are used to estimate the success of these 25 technology campuses in attaining innovation as another selection criteria of cases. However, the assessment of this sample is limited to few available inputs indicators because the data on outputs indicators collected in the exploratory survey was not available for all the cases and also too diverse for comparison.

41 These differences are discussed in Chapter 2

Accordingly, the 25 cases that addressed innovation as a goal were ranked based on scores[42]. As a result, 12 cases (whose scores were above the mean) were identified as suitable cases to outline the general aspects described in the conceptual framework and explaining the proposition in terms of inputs, process and context.

Second, the choice about the number of cases to be compared is based on three practical criteria, which are important for conducting case study research because of the amount of information to be analysed as suggested in the framework. First, the case is well documented in English. Second, the information on the case is accessible. And third, the analysis of the cases is done timely on the research schedule.

Considering the last aspect, two cases are most suitable to be compared. Accordingly, this study selected the cases with the two higher scores in the list. However, considering the two other aspects the first case in the list is rejected. Accordingly, the second and the third cases in the ranked list were selected. These are the campus of the Massachusetts Institute of Technology (MIT) in Cambridge – Boston area in USA and the High Tech Campus Eindhoven (HTCE) in the so-called Brainport Eindhoven region in the Netherlands. Interesting for this study is that these two technology campuses are all known as successful cases in terms of outputs in their own contexts. An overview of the entire case selection process is illustrated in Figure 4.4

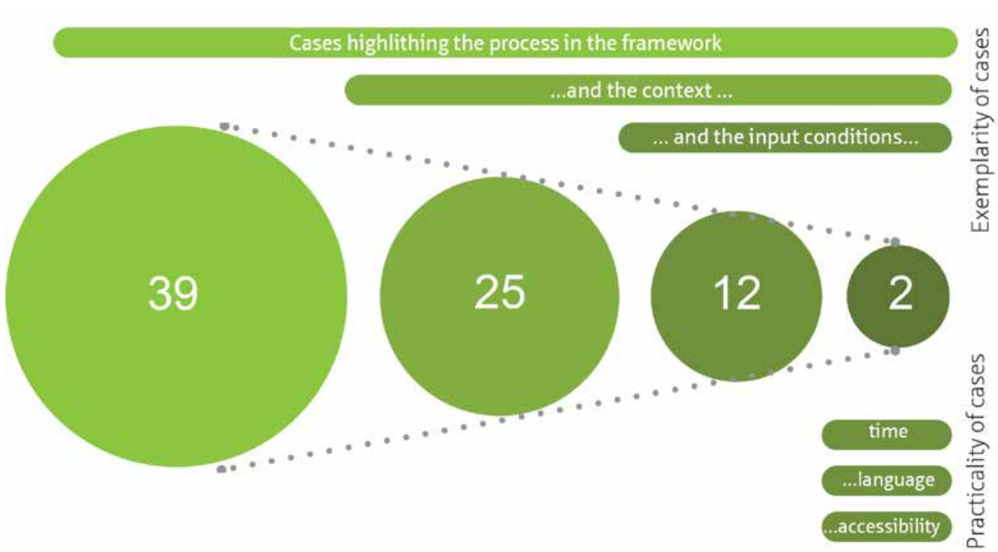

Figure 4.4 Cases considered to be exemplars to elaborate on the research proposition ranked scores that are based on the extent of input indicators of innovation in each case.

Another important feature that the comparison of these cases may offer to make the proposition more robust is the evident differences of these campuses in terms of their demand for accommodating research activities (i.e. academic and business core-processes) and supply of built environments at the scale level of interest in this research (i.e. inner-city and peripheral location). The following section discusses the importance of these differences within the case study design.

42 These scores resulted from points assigned to each input indicators of innovation according to the information available.

§ 4.3.3 Data collection, analysis and synthesis

Case study research is a strategy that makes use of multiple data collection instruments such as interviews, observations, archival data and surveys among others. The details about relevant sources and data collection procedures are further described in Chapters 5 and 6 per each case respectively. Instead, this section focuses on the way in which the data collected is analysed and interpreted for corroborating the research proposition.

This case study research is designed by using differentiating comparative analysis as described by Pickvance (2001). Accordingly, this variety of comparative analysis has its starting point in three observed similarities in the two cases selected – i.e. cases that have developed to accommodate research activities and processes leading to innovation; cases that explicitly address 'stimulating innovation' as a goal; and cases that according to input indicators are considered to be successful in attaining such goal. However, the end-point of the analysis is to explain the research proposition in terms of the variation given by the contexts in which these campuses develop.

The consistency of this type of analysis is provided by a procedure referred to as literal replication (Broekel, 2015). Accordingly, literal replication allows the systematically examination of the similarities and differences of the cases in two international contexts. Indeed, the conceptual framework states the conditions under which the particular relationship between innovation and the built environment is likely to be found. Thus, the framework constitutes the analytical tool developed to match empirical information to the research proposition of this study. Furthermore, it becomes the vehicle to verify and revise the concepts and relationships involved in the proposition. In this context, it can be said that the data collection and analysis begins with a deductive approach guided by the concepts in the framework. Nevertheless, the synthesis and interpretation of findings emerging from the empirical evidence will be used to revise the conceptual meaning of the framework. In this sense, this iterative process aligns with the inductive approach that characterise theory building from cases. The emerging insights from the comparison will be used to develop the conceptual framework into a model, which is the main outcome of this dissertation. An overview of the overlapping analysis and synthesis processes and the inductive-deductive approach of the case study research is illustrated in Figure 4.5.

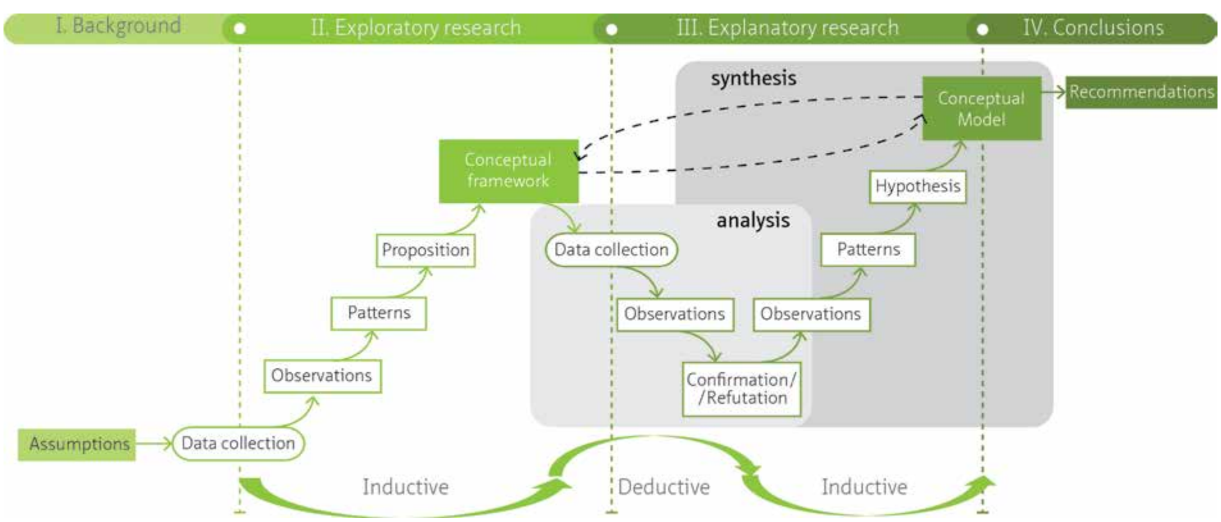

Figure 4.5 Case study research processes within the entire research approach of this dissertation

§ 4.4 Conclusions

How can we study the development of technology campuses and simultaneously provide understanding of the role of the built environment in innovation? By using which concepts from theory and cases from practice?

This chapter has presented a conceptual framework developed to provide understanding of the relationship between innovation and the built environment. Accordingly, this framework is developed through a variety of concepts that emerged from patterns in the theoretical and empirical insights of the exploratory study (See paragraph 4.1.2). This framework suggests and indirect relationship between the built environment and innovation at area level. Therefore, the framework contains the following research proposition:

The development of technology campuses is a catalyst for innovation depending on the goals and activities of organisations involved in their developments, their location characteristics and the historical events shaping their emergence and development (See paragraph 4.1.3).

Accordingly, the built environment plays a role facilitating five conditions for innovation that together are required to stimulate innovation. For instance, the built environment is neither necessary nor a sufficient condition for innovation. However, this research recognises and outlines its facilitating role stimulating innovation by strengthening the functions of the other five conditions for innovation outlined in this framework. These conditions are interdependent because their functions are based on the interactions among each other, which are correspondingly shaped by the local context. Overall, the main theoretical construct in this framework comes from the field of corporate real estate management in relation to concepts from urban studies in the knowledge economy and economic geography (See paragraph 4.2).

Furthermore, this framework guided the methodological design of Part III of this dissertation (see paragraph 4.3). Its descriptive nature and the variety of concepts and relationships in it, suggested the use of case study research as main method or strategy to explain the proposition. Indeed, in-depth empirical data from two cases might help to corroborate or refuse the concepts and relationships proposed in the framework. In case of corroboration, this knowledge can help to revise the framework that can develop into a conceptual model capable of verification with more cases.

In this context, theoretical sampling is used to select the cases. For instance, this approach suggested the used of exemplar cases that highlight the main characteristics in the conceptual framework – i.e. context, input, process and output. Based on this and another practical reasons, two campuses will be studied in the case study research. These are the High Tech Campus Eindhoven (HTCE) in Brainport Eindhoven region in the Netherlands and the Massachusetts Institute of Technology (MIT) campus in the Cambridge-Boston area in the U.S.

Part III of this dissertation focuses on these two cases (Chapters 5 and 6 respectively), their comparison (Chapter 7) and the theory emergent from them (Chapter 8).

PART III Explanatory research


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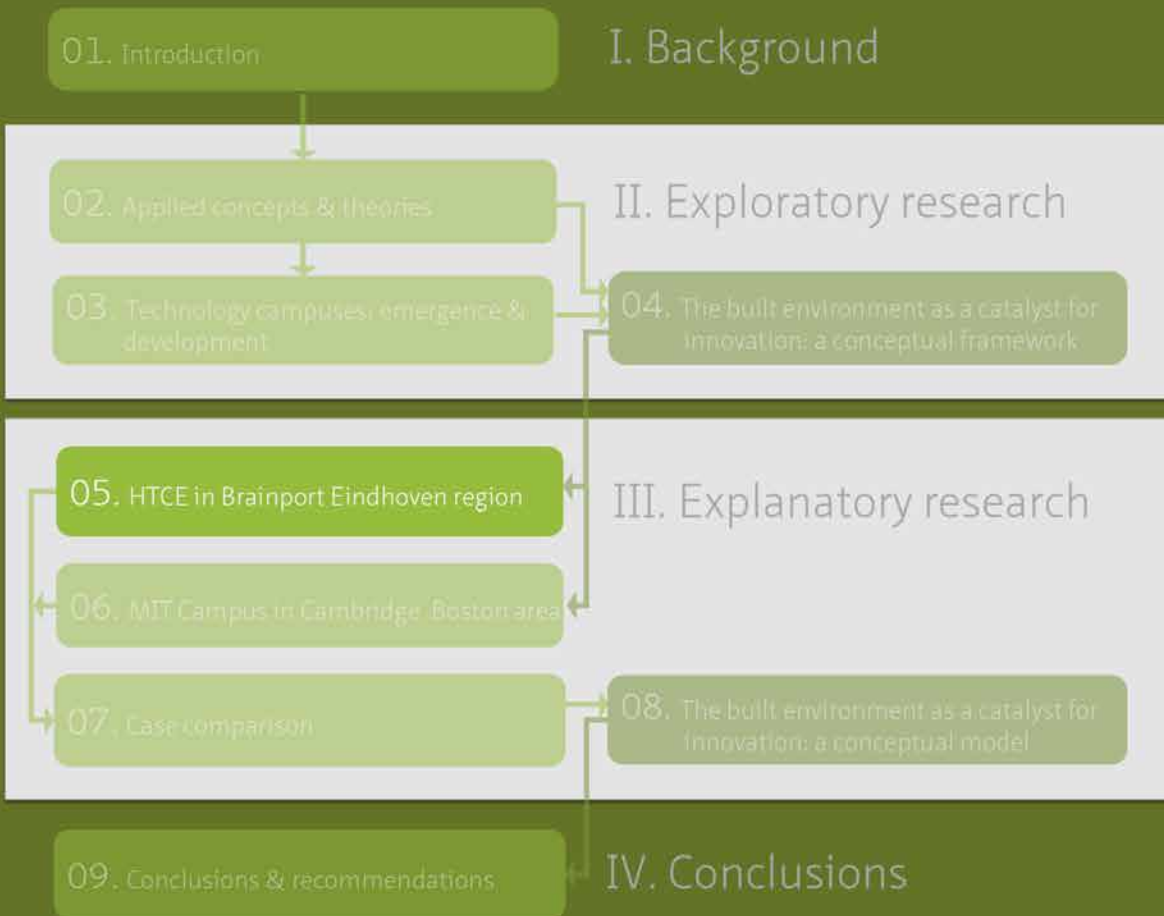
Chapter 5. HTCE in Brainport-Eindhoven region.



The previous chapter proposed a conceptual framework as an analytical tool developed to match empirical information to the research proposition of this dissertation. Hence, this research requires case studies to assess the usefulness of this framework in validating its proposition. This chapter presents the analysis of the first of two case studies using the proposed conceptual framework. This case is High Tech Campus Eindhoven (HTCE), whose in-depth study contributes to answering the question: ***What campus' interventions have facilitated the conditions leading to innovation in HTCE and in Brainport-Eindhoven region and how?***

This chapter presents an in-depth study of HTCE's development, with the aim to uncover patterns of the built environment as a catalyst for innovation in Brainport-Eindhoven region. Thus, Section 5.1 begins introducing the logic of the case and the subject of study. Section 5.2 presents the aspects determining the context and relevance of the subject of study. Section 5.3 documents with empirical information how the built environment in HTCE has served as a catalyst for innovation in Brainport-Eindhoven region. Section 5.4 discusses the findings of the case study. Lastly, Section 5.5 draws the conclusions of this chapter and how these results can be used to answer further the central question of this research.

5 Chapter 5

§ 5.1 Introduction

§ 5.1.1 Chapter aim and questions

This chapter aims to gain and provide an understanding of the roles of the built environment in stimulating innovation in a particular context, in which this goal has been successfully attained as perceived in this research. The context selected in this case is the Brainport-Eindhoven region, a well-known high-tech industrial cluster in the Netherlands and in Europe. The High Tech Campus Eindhoven (HTCE) in Brainport-Eindhoven region is presented as the subject of study or unit of analysis. The HTCE is defined as the land and buildings used by the tenants of HTCE Site Management B.V. in the city of Eindhoven, to fulfil their common ambition of advancing research and development (R&D) for economic growth.

This chapter, therefore, asks '***What campus' interventions have facilitated the conditions leading to innovation in HTCE and in Brainport-Eindhoven region and how?***' Next to it, the following set of sub-questions guided this case study research:

- How has the HTCE been developed? Why is the 'Touches' characteristic of the HTCE in relation with the city evident?
- To what extent has HTCE's development been influenced by theoretical discourses of stimulating innovation? Is this influence explicit or accidental? Is it possible that the dynamics accommodated on HTCE have indirectly helped supporting such discourse?
- What campus' interventions have facilitated the conditions leading to innovation in HTCE and in Brainport-Eindhoven region and how?

§ 5.1.2 Approach and methods

The built environment as a catalyst for innovation is the object of study or analytical frame in which the study is conducted. A basic assumption of this study is that stimulating innovation is a goal which successful achievement can be explained in two ways: 1) by measuring targeted outputs derived from the processes of knowledge creation, diffusion and its application and 2) by understanding inputs conditions allowing such processes. These insights derived from a central proposition developed in the exploratory research that the built environment is not a direct input of these processes but it can be a catalyst for the inputs of innovation. Thus, the built environment might facilitate some conditions that altogether enable the processes crucial to attain the goal of stimulating innovation.

The campus is the built environment unit, through which this assumption will be investigated. For instance, the study focuses on the development of technology campuses as an evolutionary process linked to specific and interrelated developments of the context in which innovation takes place (e.g. social, economic and technological developments). The study of the campus development is, therefore, observed as a historical phenomenon linked to a spatial and temporal context.

Gaining and providing understanding of this phenomenon in context can help to stimulate design, planning and management decisions, aiming for an efficient use of resources and thus, better built environments. In this way, in case of finding common phenomenon in different contexts, the practical and scientific result of this study can have a wider impact.

Conceptual framework

HTCE and the Brainport-Eindhoven region explicitly address 'Stimulating innovation' as a goal in their strategic visions. According to the review of the literature (Chapter 2), innovation in the knowledge economy is measured by means of different inputs and outputs regarding the processes of knowledge creation, diffusion and its further application to develop technologies. These indicators provide evidence on how this goal has been successfully attained in these places [See Appendix E]. In addition, they constitute the reasons why HTCE is considered an exemplar case uncovering the role of the built environment in the innovation process from a survey of 39 campuses (Chapter 3).

This chapter uses the conceptual framework developed during the exploratory research (Chapter 4). This framework organises key concepts and relationships embedded in the proposition [See Figure 5.1]. Accordingly, the framework is used as an analytical tool developed to match the empirical information to be observed in the case, to the research propositions of this study.

According to this framework, the input indicators focus on the aspects creating the conditions required for the processes of knowledge creation and diffusion. The built environment is positioned in this model as one of the input conditions, which are interdependent. Each of them has a particular function supporting these processes by complementing each other's functions. Therefore, each of them is a necessary but not a sufficient condition to stimulate innovation.

Correspondingly, the output indicators of innovation focus on the measurable targets delivered through the processes of knowledge creation, diffusion and its application in the development of technologies. In the knowledge economy, these outputs are set as measurable goals by different organisations that want to remain competitive in such context These organisations correspond to three different spheres of the Triple Helix: universities, industry and governments. As shown in Chapter 2, each of these organisations measures innovation according to their different core businesses and aspirations. In explaining its proposition, this chapter emphasises on the input indicators or the necessary conditions facilitating innovation[43].

43 An overview of the output indicators of this case study can be found in Appendix E.

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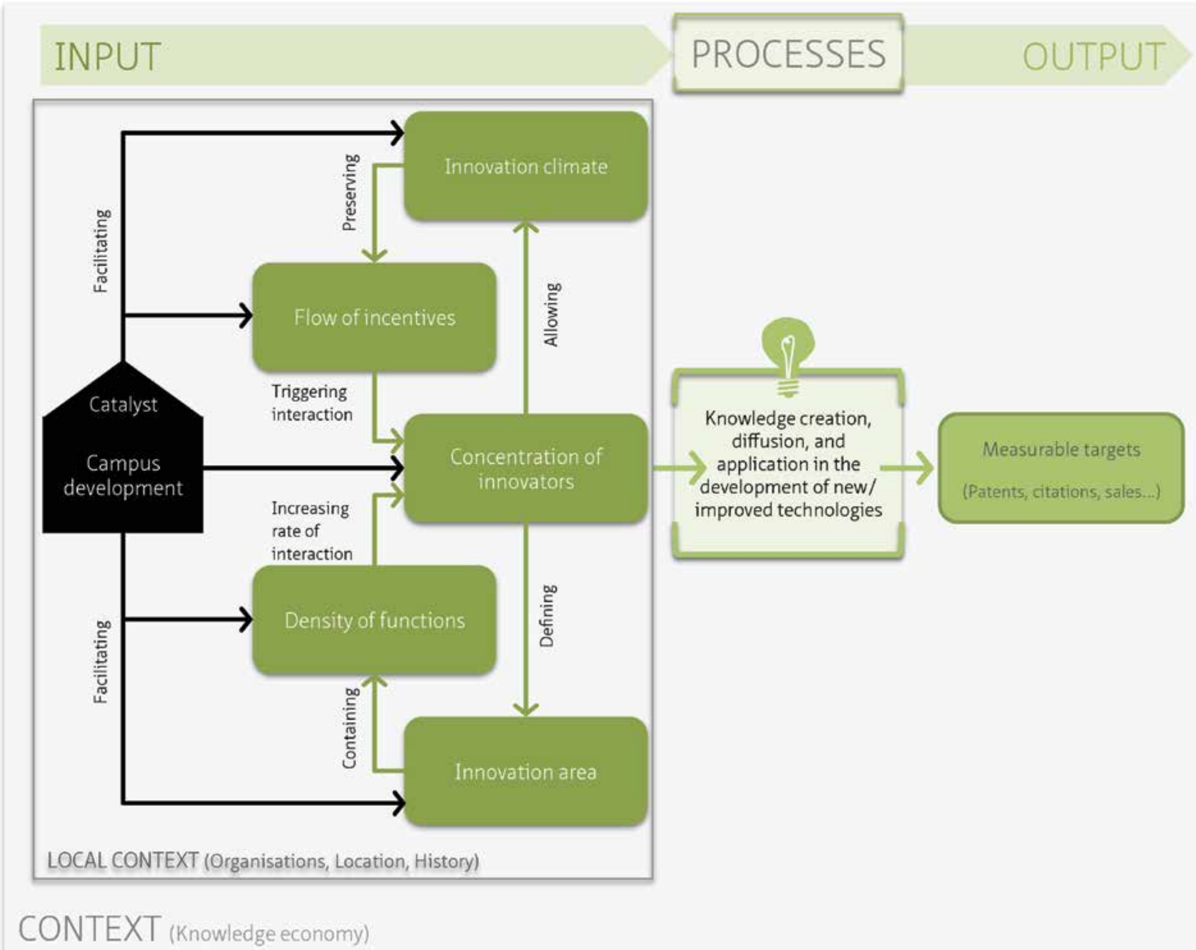


Figure 5.1 Conceptual framework representing the measurement of innovation in the knowledge economy. It distinguishes input- and output indicators.

The framework is the vehicle for analysis using replication logic. This procedure will facilitate a further comparison of the cases. The combined insights of this and the next chapter will be used to revise this conceptual framework and develop a hypothesis emerging from the empirical evidence.

Data collection

The information analysed and presented in this chapter relies on data collected by means of open interviews, observations in site, web search, attendance of seminars, review of documents and relevant readings. The data collection procedures and more detailed information about the case are described in the Case Study Protocol in Appendix D. The following paragraphs introduce the unit of analysis in context: the campus in its hosting the city.

§ 5.1.3 The HTCE

The campus studied in this chapter is home of over 125 different organisations engaged on R&D activities, in the fields of Health, Energy and Smart Environments. The location of this tech-campus is the Brainport-Eindhoven region. There are three research universities and five universities of applied sciences in this region[44]. A research university and two universities of applied sciences are located in the city of Eindhoven. There is a concentration of R&D firms and top technology institutes in the region, which has positively influenced the transformation of this region in one of the most prosperous of the Netherlands and Europe. This transformation is a process has evolved along with interrelated developments in education, technology and economy in which the presence of specific organisations in the area has played a crucial role.

The strategic campus

In 2012, HTCE was officially established as a site for different tenant-organisations managed by HTCE Site Management B.V. However, the emergence of this tech-campus traces back to the accommodation of research activities of Philips in the early 1960s and major corporate decisions in the late 1990s. Indeed, the evolution of research processes in Philips influenced heavily the development of HTCE.

Royal Philips[45] is a Dutch multinational company founded in Eindhoven in 1891, which started as a chemical company and rapidly grew to a diversified technology company, as other Dutch chemical companies at the time[46]. Indeed, one of the results of this rapid growth was the emergence of its industrial laboratory, established to help the other departments of Philip's industries. In 1914, the Philips Physics Laboratory, well known as the Nat.Lab[47], was established in Eindhoven to safeguard the company's patent position in lamps. During the early years, the Lab focused on physics and chemistry and later on electrical and mechanical engineering. Also, the lab culture outlined the importance of fundamental research in the discovery and advancement of knowledge.

Initially, the Nat.Lab was accommodated in the city centre of Eindhoven until its growth needed the expansion of the lab's physical plant[48]. Since 1963, the activities of the Nat.Lab began moving to a group of facilities in the neighbouring village of Waalre referred then as Complex W. During the 1980s and 1990s, the lab culture experienced an important change, since the goals of the Nat.Lab shifted

44 The higher education system in the Netherlands has a three-cycle degree system, consisting of a Bachelor, Master and PhD degree. The Netherlands has a binary system of higher education, which means there are two types of programmes: research oriented education (wetenschappelijk onderwijs, WO), offered by Research Universities and professional higher education (hoger beroepsonderwijs, HBO), offered by Hogescholen, or Universities of Applied Sciences (Bologna Follow-Up Group, 2006). Research universities are those awarding doctorate degrees, which are primarily research degrees (PhD). In the Southeast Netherlands, a PhD title can be obtained at Eindhoven University of Technology, Maastricht University and Tilburg University.

45 Former Koninklijke Philips Electronics NV

46 The emergence of multinational companies in the Netherlands between 1880 and 1920 was particularly marked with the emergence of chemical companies such as Philips (Koninklijke Philips N.V.), Shell (known then as Koninklijke Petroleum), Akzo Nobel and DSM. According to De Vries (2005) the factors explaining the rapid growth of these companies are 'the growth in world trade, the emergence of new technologies creating possibilities for new products and the stimulation of a competition process that gave rise to mergers and co-operation'

47 In Dutch, Philips Natuurkundig Laboratorium.

48 In the second half of the 20th century, the Nat.Lab experienced a rapid growth. From 300 employees in 1946 the Nat.Lab became an organisation employing 2.130 people in 1965 (De Vries, 2005)

towards the needs of the products divisions in Philips rather than seeking new ideas and developments. The Nat.Lab became an important knowledge centre for Philips in the fields of design and systems.

In the 1990s there was a dramatic reduction of Philips, which nearly went bankrupt in the early 1990s, losing 4.2 billion guilders (US$2.3 billion) in 1990. In 1997, Philips decided to re-locate its HQ from Eindhoven to Amsterdam as part of a corporate strategy which measures included reducing costs and supporting image to recovery from an economic downturn. In reaction to this announcement, the municipality of Eindhoven sought for an agreement with Philips. After negotiations and a deal that included the purchasing of Philips's inner-city properties by the municipality, Philips decided to concentrate in one location all its research departments dispersed in Eindhoven. The location selected for a 'new campus' was Complex-W. In 1998, the site was named Philips High Tech Campus which goals for concentrating these activities were attaining 'synergy, greater efficiency and better returns on research and development'. Besides the shrinking Nat.Lab, the new campus began accommodating other Philips laboratories and sales departments.

In 2003, Philips adopted the Open Innovation model to carry out their R&D activities, meaning that Philips began co-operating with external parties in their innovation processes. To accelerate their innovation processes, Philips selected to work with partners who share and complement their expertise, knowledge and processes. In the same year, Philips decided to open the campus to other high-tech companies, which began locating in campus. In addition, Philips Research also decided to offer specific services and infrastructure for these other parties (e.g. our cleanroom services, prototyping services and material analysis services). Simultaneously, the focus of the research and development in Philips began evolving from diversification towards specialization[49]. In 2015, Philips Research is a major division of Royal Philips headquartered in Eindhoven employing 1.700+ people globally (1.500+ in Eindhoven) and occupying several state-of-the-art buildings in HTCE.

In 2008, Philips decided to sell high tech campus to focus on their core businesses rather than real estate management. In the same year, Philips began a planning process with the Municipality of Eindhoven to set a definitive Zoning plan ('Bestemmingsplan' in Dutch), which became the control mechanism regulating the development of HTCE in the future. In January 2012, Philips established HTCE Site Management B.V., an independent liability company to manage the contracts, services, operations and marketing of the campus that will reinforce the concept of Open Innovation. In the same year, the campus is sold to a Dutch consortium of private investors and the name is officially changed to HTCE. The sale of the campus also included HTCE Site Management B.V., which was a Philips's organisation of about 20 employees. In 2014, the campus was part of the portfolio of Chalet Group, a private real estate company.

Recently, HTCE Site Management B.V. is the main stakeholder involved in campus decisions. Their acquisition strategy is aimed to reinforce the concept of Open Innovation Ecosystem. A framework labelled as 'Human Focused Innovation' is used to attract and select tenants companies in the fields of health; energy; and smart environments based on specific technology domains. Figure 5.2 illustrates how HTCE has evolved strategically.

49 In the 1960s and 1970s, Phillips reached 14 product divisions in a wide range of fields that covered 20 industries by 2000. Since 2005, Philips focuses on three main industries: Healthcare, Consumers Lifestyle and Lighting.

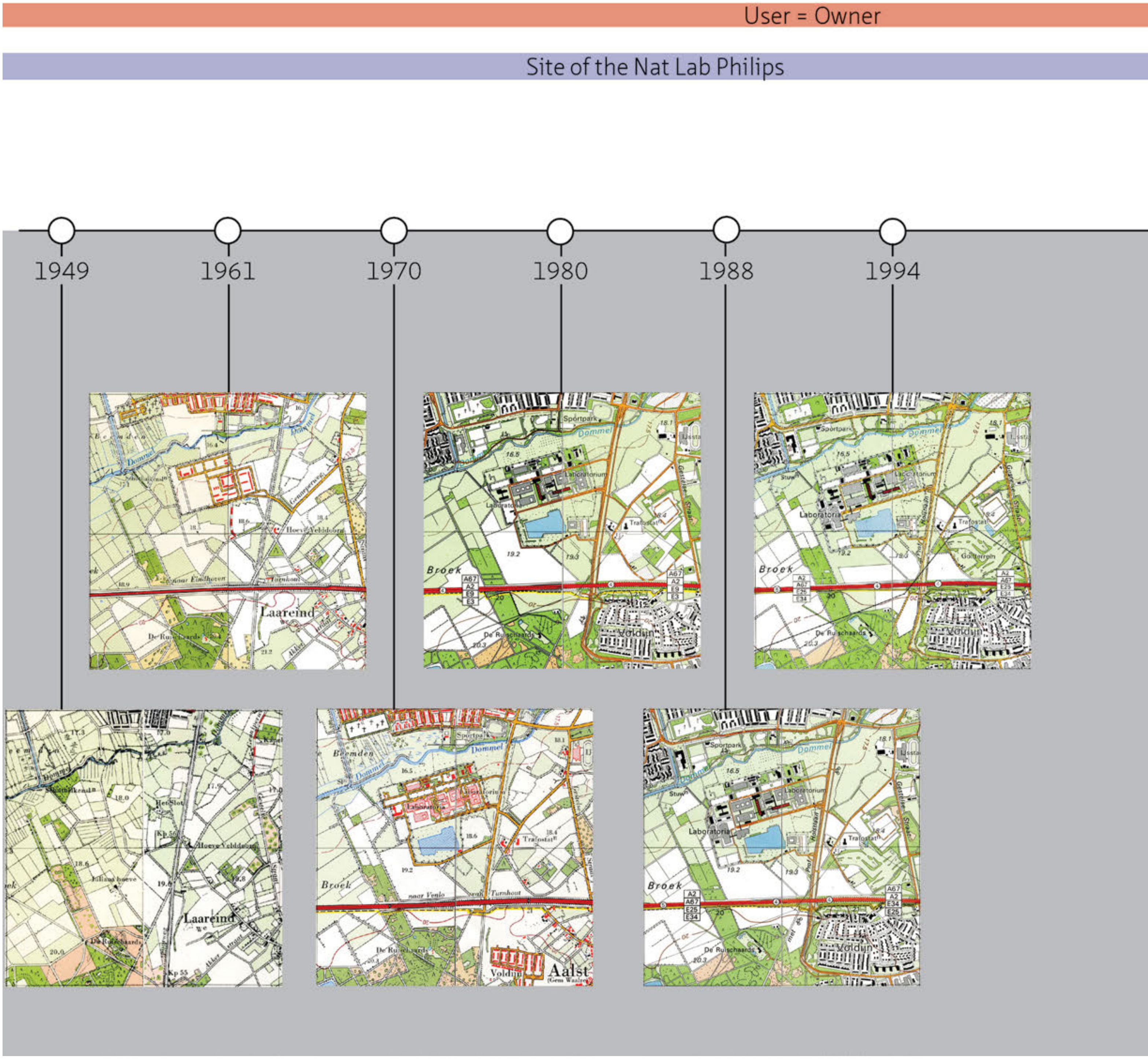
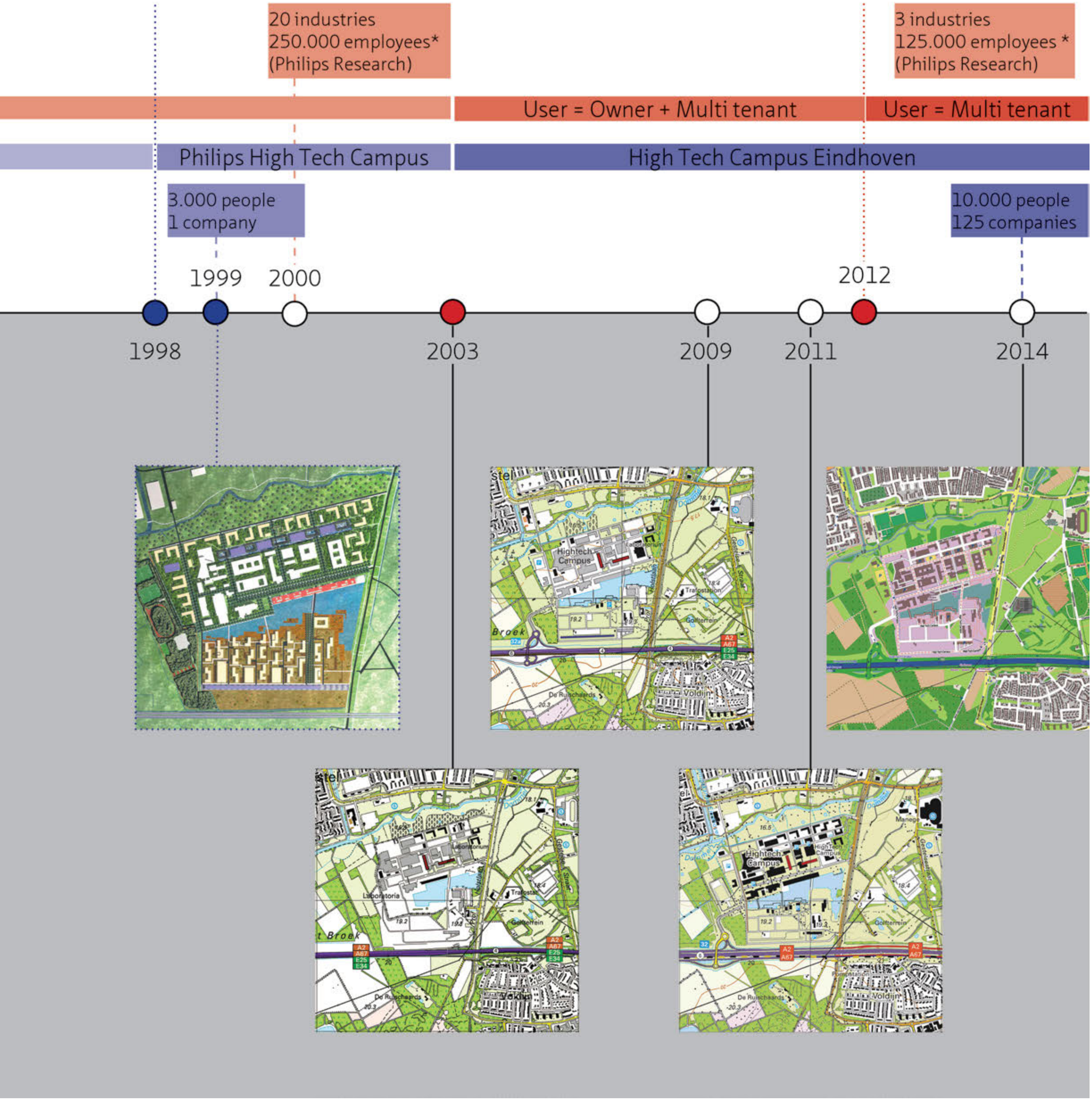


Figure 5.2 The strategic development of HTCE


20 industries
250.000 employees*
(Philips Research)
3 industries
125.000 employees *
(Philips Research)
User = Owner + Multi tenant
User = Multi tenant
Philips High Tech Campus
High Tech Campus Eindhoven
3.000 people
1 company
10.000 people
125 companies
1999
2000
2012
1998
2003
2009
2011
2014

The operational campus

By 2014, HTCE comprises 103 hectares of land owned by Chalet Group and operated by HTCE Site Management B.V. This property is located in the outskirts of the city of Eindhoven in the Netherlands. In 2014, this tech-campus accommodated over 10.000 people working for more than 125 organisations. It has a built area of 280.000 m^2 (GFA) distributed in R&D facilities and labs (45.000 m^2); services (10.000 m^2); office space (185.000 m^2); and vacant area available for start-ups (10.000 m^2). The campus has other 120.000 m^2 available for development expecting a population of 12.500~ people (around 200-250 companies) in the next 10 years.

The current tenants of HTCE are diverse and referred to as an ecosystem. There are 60~ start-ups, large companies including multinationals, five research institutes and service companies. Philips Research is still the largest organisation in campus with a workforce of 1.500+ employees. The Philips identity of the campus has been diminished even though large part of the tenant community is made up of eight Philips divisions[50] occupying 181.517m2 in 21 buildings in campus (2012). The presence of Philips is still essential in HTCE because it offers a wide range of services and facilities occupying 40.161m2 in campus, which are available for the entire ecosystem. These are technical services and facilities managed by Philips instead of HTCE-Site Management, because its operation demands specific expertise and capacity available in Philips. Besides this state-of-the-art laboratories, there are sports, leisure, shopping, restaurants, day-care and parking facilities to be shared among the different tenants of HTCE, aimed to attracting companies to establish in campus.

In an international survey of 39 technology campuses (Chapter 3), it has been observed that HTCE has an evident characteristic in relation to its hosting city referred to as 'Touches'. Physically, HTCE is distinguished as a separated area, which is located in the edge of the city of Eindhoven. HTCE is perceived as a group of self-standing buildings with its own internal structure, clearly differentiated from the city [See Figure 5.3].

This internal structure marks four main zones (north, south, centre and west), which have different functions and characters proposed in a Master plan of Philips High tech campus (Simons et al., 1999). The north zone is where most of the existing buildings of the former Philip's Nat.Lab where located. In this area, new buildings with lower density were built and a large part of the existing buildings were renovated to accommodate laboratory, office and parking space. In the centre, a main facility is proposed as the central place to be (the Strip) with shops, services, restaurants, wellness and conference centres. This is complemented by the creation of a central open space emphasizing the landscape features such as water and green. The south is a completely new development of smaller scale buildings accommodating office, lab and parking space, which still under development. And the west accommodates mainly sport facilities and fields, a day care facility and special space for office and laboratories. All these zones emphasize the design of open spaces and the green character of the surrounding landscape. An overview of this description can be observed in Figure 5.4.

50 These are Philips Research, Philips Design, Philips Lighting, Philips Consumer Lifestyles, Philips Healthcare, Philips Healthcare Incubator, Philips New Venture Integration & Corporate Investments, Philips Intellectual Property & Standards; Philips Innovation Services (Source: campus residents brochure, HTCE Site management B.V. 2014).

Figure 5.3 Aerial view of HTCE. Map image: Esri 2013

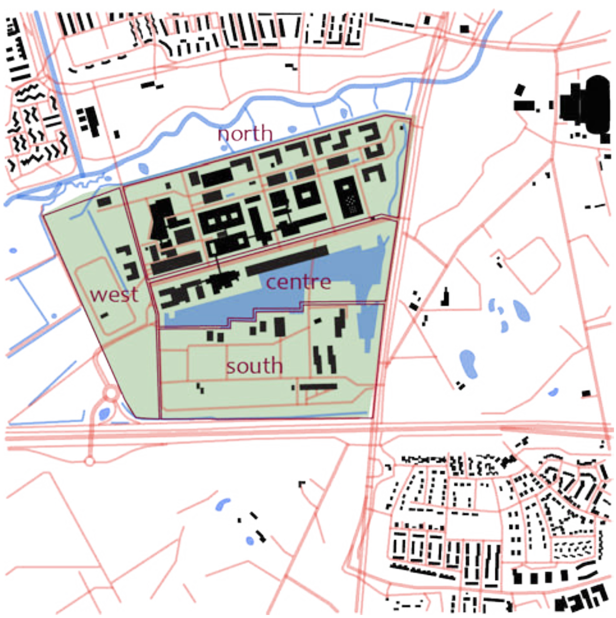


Figure 5.4 HTCE and its main development zones with a central facility indicated in red (Map: Flavia Curvelo Magdaniel, 2014. Data: Topografische Dienst Nederland, 2011, retrieved from the physical map collection in TU Delft Map Room; and Juurlink+Geluk B.V., 2014)

§ 5.1.4 The city of Eindhoven

Eindhoven is the largest city of North Brabant, which is a province of the Netherlands located in the Southeast of the country [See Figure 5.5]. This city of 219.000+ inhabitants (CBS, 2013) is the fifth largest city of the Netherlands. The Southeast Netherlands has grown to be the most important high-tech industrial cluster of the Netherlands and one the most competitive of Europe, which is branded as Brainport Eindhoven region[51]. On the one hand, its economic base is consolidated in the fields of mechatronics, the automotive industry and electronics, while industrial distribution, environmental-, medical- and information technologies are addressed as key emergent fields. On the other hand, its knowledge base is strong in the fields of engineering, applied sciences and design. For instance, Eindhoven is home of the Technology University of Eindhoven (TU/e) since 1956[52]. TU/e is one of the three technical universities of the Netherlands and a top global university[53]. Besides, Eindhoven is home of two other higher education institutions in applied sciences and design. This match between economic and knowledge bases is addressed as one of the strengths of this region.

It has been said that part of the success of Eindhoven relies on the role of the regional networks in developing a sharing vision of economic development. In fact, the region outlines the importance of its network excelling in these four aspects referred to as successful factors: trust, leadership, skills and focus. In the case of Eindhoven, the historical presence of Royal Philips determined the development of all these four factors with the involvement of the local government. For instance, when Philips was founded Eindhoven was not a city but a village. The company took responsibility in providing housing, education, facilities and amenities for their initial 20.000 employees because the government couldn't solve these issues at the time. Over the 20th century, Philips helped building the city and has attracted and spun off several high-tech firms to establish in the region, contributing as well to the economic development of Brainport. Philips has established a strong relationship with the local governments based on mutual benefit. Both stakeholders and the existing knowledge base -with strong orientation toward technology and design- contributed to revitalize the economy of Eindhoven after a period of industrial decline leading to a major high-tech node in the Netherlands. For instance, national and local governments encourage its potential for innovation through policy and spatial planning aiming at high-tech development since the 1990s. In 2015, the milestones of the regional vision include the expansion and improvement of specific physical infrastructure such as campuses. In fact, the word campus has become a concept to protect in Brainport region after several business locations all over the Netherlands began using it as a branding term popularised by the success of HTCE. Nowadays, it is recognised not only as a main node in the municipal and provincial innovation ecosystems but also as a campus of national importance.

Overall, the transformation of Eindhoven from an industrial town to a high-tech business location is not only the result of the presence of Philips and TU/e, but also specific conditions that have made the presence of these organisations essential for its socio-economic development. These conditions will be discussed in the next section.

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51 At national level, the National Spatial Policy or 'Nota Ruimte' in Dutch (Ministerie van VROM, 2004) states specific objectives among others the strengthening of the international competitive position of the Netherlands. The priority focuses on the connections between urban networks and the main economic areas so-called Airport Amsterdam, Seaport Rotterdam and Brainport Eindhoven.

52 In the Netherlands, the number of programmes favouring technology-based education grew after the WWII. In 1956, the government established the Technische Hogeschool Eindhoven, which was upgraded to Eindhoven University of Technology in 1986.

53 TU/e ranks 106 in the list of the Top 400 global universities (The Times Higher Education World University Rankings 2013-2014)

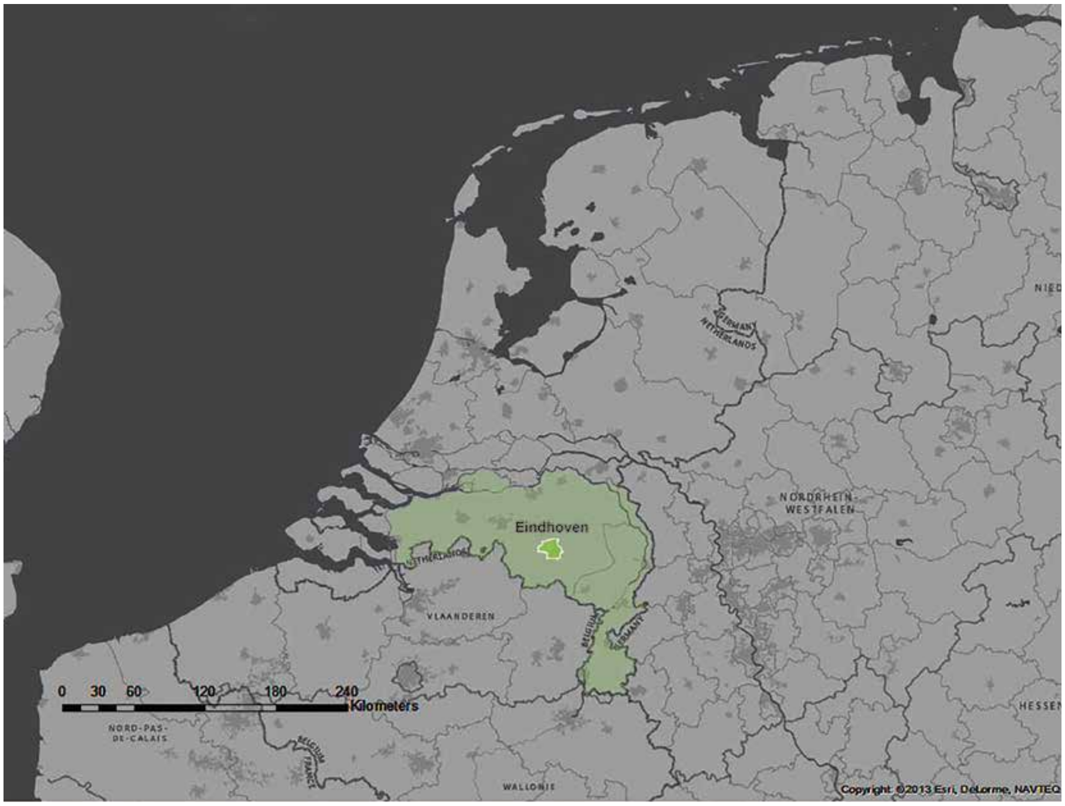
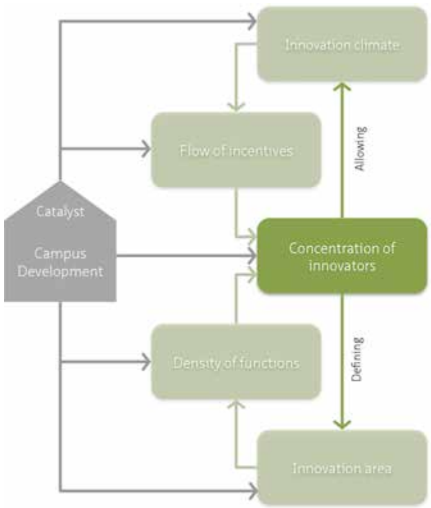


Figure 5.5 Location of Eindhoven in Southeast Netherlands. Base map: Esri 2013

§ 5.2 Conditions stimulating innovation in HTCE and Brainport-Eindhoven region

This section focuses on six aspects creating the conditions to accelerate the processes of knowledge creation and diffusion and its application in the development of technologies, which has been illustrated in Figure 5.1. As said before, each of them is a necessary but not a sufficient condition to stimulate innovation. Therefore, they are interdependent, but they also have different functions -including attracting and retaining knowledge workers- to enable such processes. The following paragraphs, illustrate with empirical data the conditions that have been facilitating innovation in HTCE and its hosting city-region from the case study perspective.

§ 5.2.1 Concentration of innovators: R&D as the engine of a high-tech industrial cluster



This indicator refers to the essential parts of the system in which technology-based knowledge is created and transferred into applications. The innovators are the organisations engaged on research activities in technology fields (basic research and R&D). These are universities, HEIs and research institutes advancing knowledge as well as firms transferring that knowledge into industrial products.

Eindhoven is home the Eindhoven University of Technology (TU/e) since 1956, which is one of the three technical universities of the Netherlands and a top global university. In addition, Eindhoven is home of two other higher education institutions focused on applied sciences and design[54]. In the Southeast Netherlands, there are two other research universities and three more universities of applied sciences. Together they offer a diverse education programme and research in the fields of management, economics, law, health care, sciences, engineering and technology.

There are eight top R&D institutes in this region focusing on high technologies[55]. Two of these locate in HTCE. In total HTCE, accommodates five research institutes that collaborate with governments, firms and increasingly with universities. For instance, the Holst Centre (established in 2005) was an initiative of Philips Research that became an independent open-innovation R&D centre set up by two research institutes: Imec (Flanders, Belgium) and TNO (The Netherlands) with support from the Dutch Ministry of Economic Affairs and the Government of Flanders. The Center for Translational Molecular Medicine (CTMM) is founded in 2007 with the financial contribution of the Dutch government, industry and academy. The most recent development of public private cooperation for research in HTCE is Solliance (initiated in 2010), which is cross-border cooperation between six research institutes from the Netherlands, Belgium and Germany, including the Eindhoven University of Technology.

These institutes have joined forces in solar research opening a large laboratory facility at HTCE in 2014. Figure 5.6 shows an overview of the research universities, higher education institutions and research institutes that concentrate in Southeast Netherlands.

HTCE has been home of R&D firms for more than 50 years. First, it was home of Philips' research activities and later, it has evolved at an R&D ecosystem of 125+ technology organisations focused on innovation. These include start-ups and large firms next to the research institutes already mentioned. These companies perform R&D activities in the fields of Health, Energy and Smart Environments. Indeed, this focus is a requirement for firms to settle in campus because they are supposed to collaborate and to enrich the Open Innovation concept. These three fields and the different companies' sizes provide a complementary diversity that might stimulate firms to engage in collaborative research projects. Correspondingly, TU/e has focused its research in the fields of Energy, Health and Smart mobility.

54 These are the Design Academy Eindhoven (founded in 1947) and the Fontys University of Applied sciences (founded in 1996)

55 These include TNO Industry; TNO Automotive; The Dutch Polymer Institute (DPI); the Embedded Systems Institute (ESI); The energy Research Centre (ECN); The Foundation for Fundamental Research (FOM); the Holst Centre; and TÜV Rheinland TNO Automotive International B.V. (TTAI)

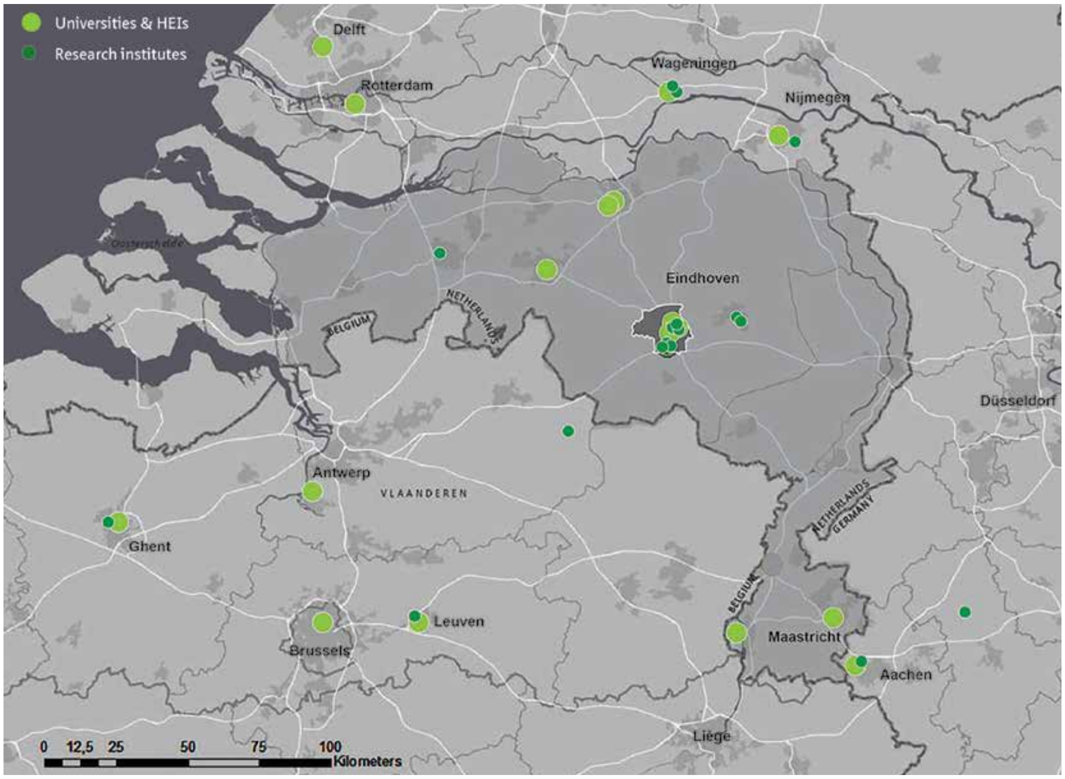


Figure 5.6 Concentration of universities and research institutes in Southeast Netherlands (Large dots in Light green: research universities and universities of applied sciences; Small dots in dark green: research institutes). Base map: Esri 2013

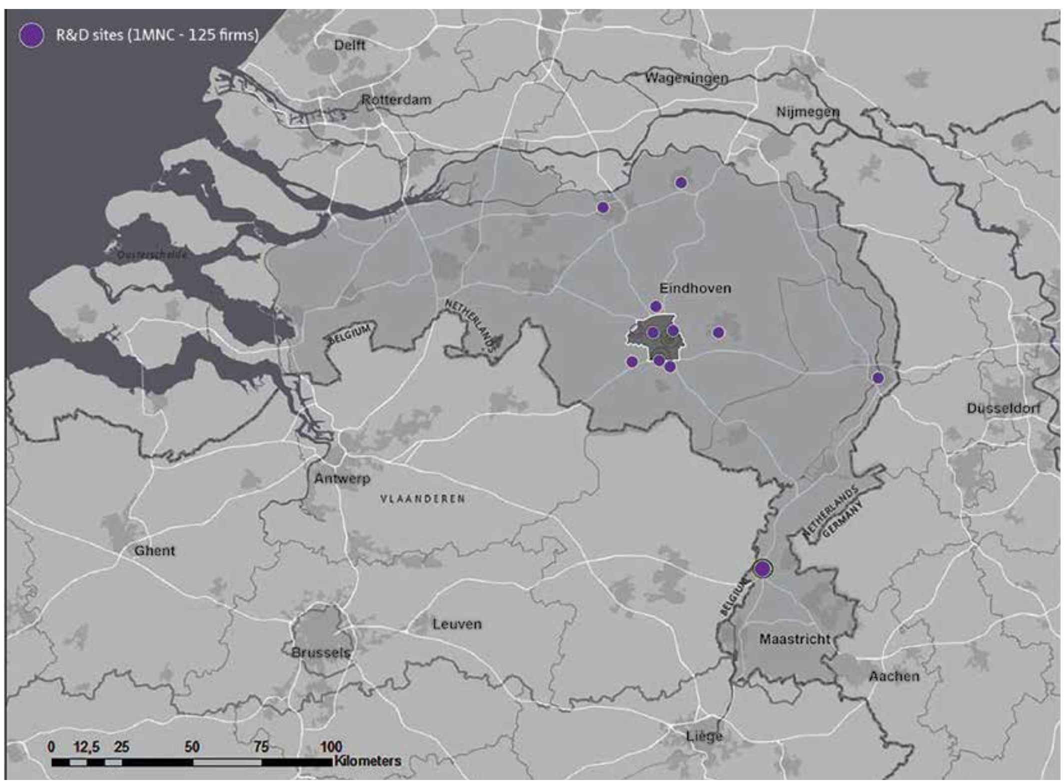
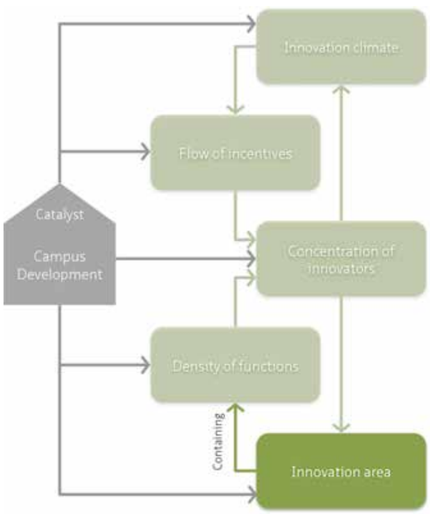


Figure 5.7 R&D corporations and campuses attracting firms to establish in Brainport Eindhoven region. Base map: Esri 2013

Next to HTCE, the region is home of several R&D world-class companies, including 5 of the Top 10 corporate R&D in the Netherlands. Indeed, the region is referred to as the Dutch R&D hotspot because of the high concentration of R&D investments, in which the private funds are significant[56]. The private R&D investment in Brainport Eindhoven region is very high compared with other regions in Europe. This is largely explained by the presence of multinational corporations focused on innovation such as Philips, ASML, DSM and NXP among others. These companies are anchors of interrelated supply chains in the region, which have consolidated in the high-tech industrial sectors including mechatronics, the automotive industry and electronics. Other emergent sectors include industrial distribution, environmental technology, medical technology and information technology. There is an infrastructure of specialised campuses in the region attracting companies to establish in these nodes. Campus development is a strategic instrument for implementation of Dutch economic policies to enhance competitiveness in the knowledge economy. Within the national spatial policy, HTCE is recognised not only as a main node in the municipal and provincial innovation ecosystems but also as a campus of national importance. Figure 5.7 illustrates the concentration of R&D companies and campuses or business locations in the Brainport Eindhoven region.

§ 5.2.2 Innovation area: HTCE campus at the heart of Brainport Eindhoven region



This indicator refers to the geographical area allowing contacts between the concentrated innovators. The innovation area is delineated by the positions of the innovators in a territory and by the physical characteristics of such territory allowing contacts and interactions between the innovators. Thus, scale and connectivity of these areas are important aspects of this indicator.

In the case of the HTCE, the innovation area takes shape at the scale of the region considering the innovators -outlined in the previous section- are concentrated around specific knowledge nodes located in the Brainport Eindhoven region. A location analysis of these innovators shows that the higher concentration of innovators (knowledge institutions, research institutes and R&D firms) is within a radius of 9 km from a central point of HTCE. This innovation area is designated in this research as the Brainport Eindhoven area and illustrated in Figure 5.8 and Figure 5.9 The identity of this area has shifted from an industrial region to a top technology region.

The Brainport Eindhoven area is connected to the region and the country by railway and motorway infrastructures, which constitute the most important transportation hubs for innovators in the area. HTCE is accessed by car- and bike-oriented infrastructure. Besides, only buses provide accessibility by means of public transportation. Nevertheless, there is a direct bus line between Eindhoven Centre and HTCE facilitating the connectivity of this area. Indeed, innovators in this area can be reached within 30-40 minutes with public transport and within 10 – 15 minutes by car[57]. In addition, this innovation area is connected worldwide through the Eindhoven International Airport accessed within 40-60 minutes from the R&D sites by using public transport.

56 In the year 2012, R&D investments in the region totalled 390 million euros of public funds and 2.1 billion of private funds (Brainport Eindhoven region, 2012)

57 Measure calculated using Google maps and www.ns.nl.

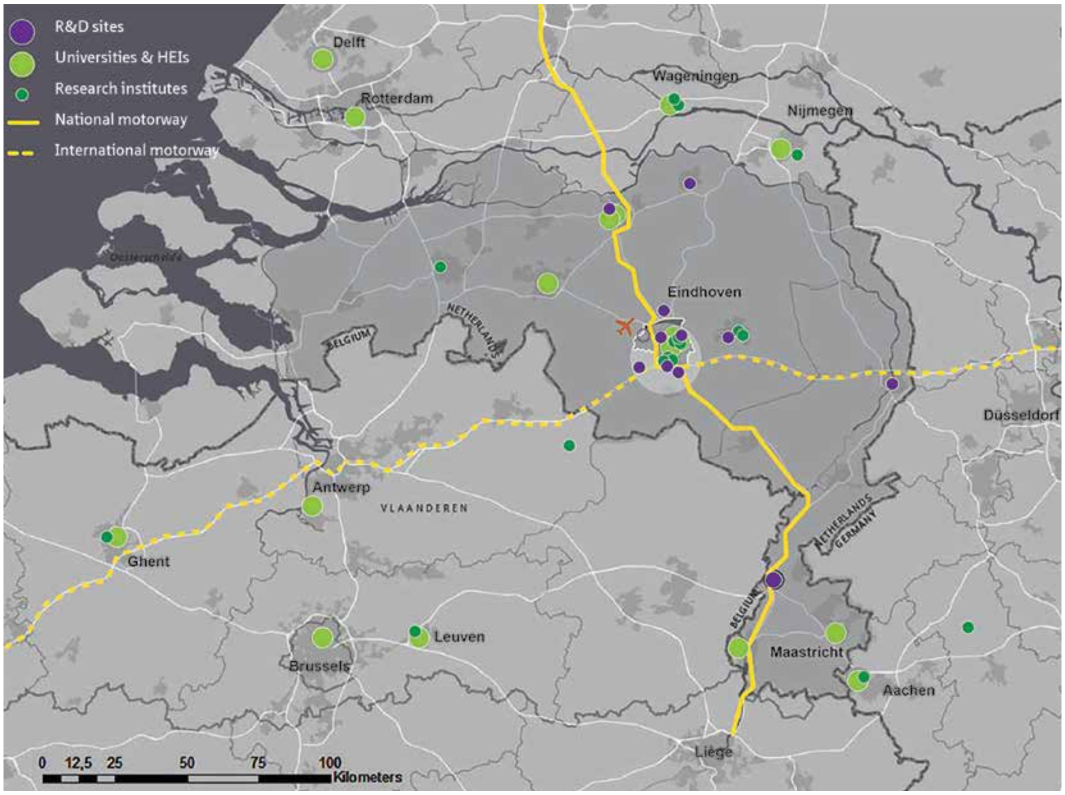


Figure 5.8 Innovation-area where HTCE locates in a regional context. Base map: Esri 2013

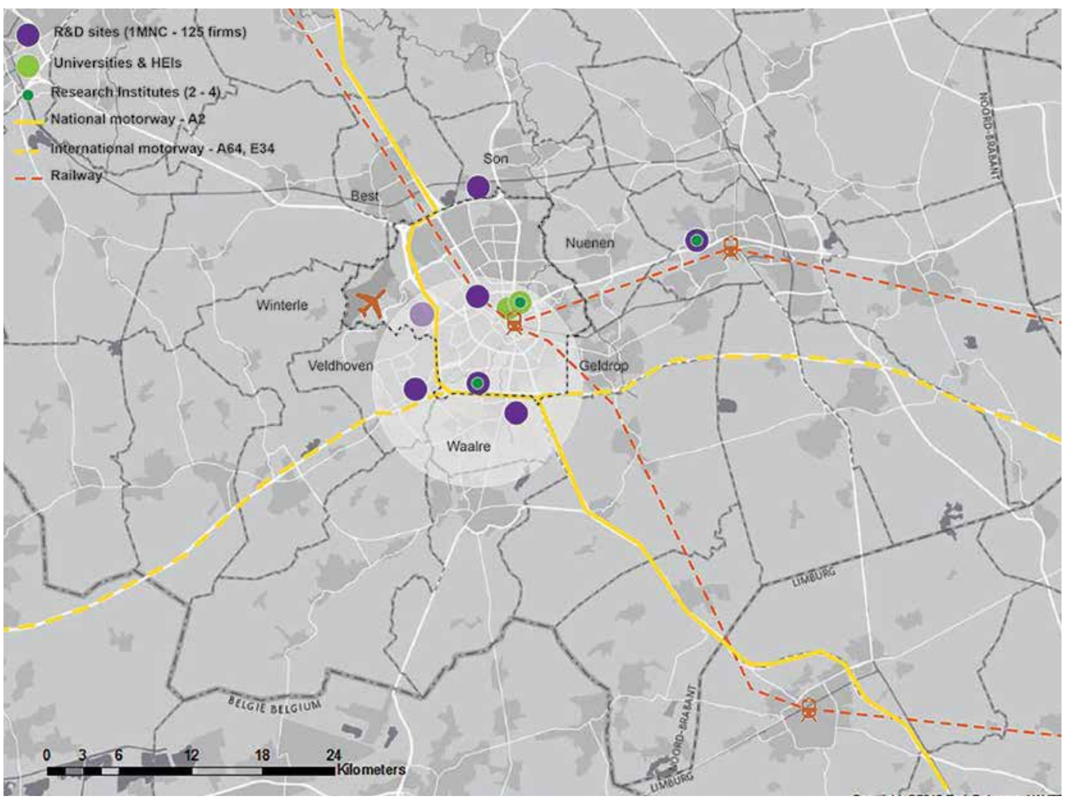
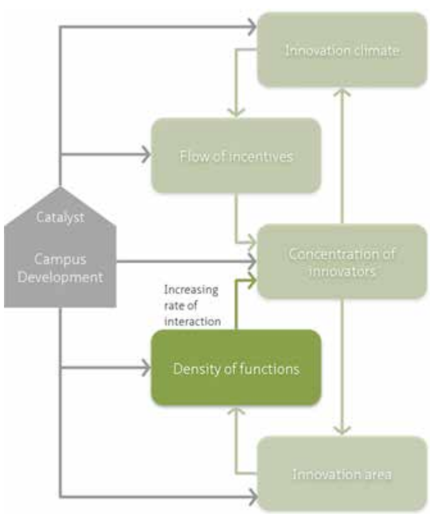


Figure 5.9 Brainport Eindhoven area and its main elements. Base map: Esri 2013

The Dutch spatial policy[58] focuses in the connections between urban networks and the three national economic areas including Brainport. For instance, the A2 motorway is an important connection for Brainport. This is one of the busiest highways in the Netherlands spanning from Northwest to Southeast. It connects Brainport with the other Dutch strategic economic areas and with other international axis in the southeast Netherlands[59]. Similarly, the A2 connects important nodes within Brainport (Eindhoven – Maastricht) and it is already so-called Brainport Avenue or knowledge axis where HTCE is located. For instance, Figure 5.9 illustrates how the A2 motorway is an important physical characteristic of this area, which separates (also administratively) the city of Eindhoven from its neighbouring towns. This physical separation strengthens the importance of the transportation system in allowing contacts between the innovators of this area while travelling short distances. In this moment, car is the most efficient transportation means of this area. The public transport system in this area consists of buses connecting the periphery of the city with the downtown's national railway. Not surprisingly, HTCE and other R&D site locate in Eindhoven's periphery. Given the existing physical conditions, the efficiency of the public transport system is critical in connecting the different innovation spots that are perceived as separated zones in the area.

§ 5.2.3 Density of functions: the HTCE community generating diversity



This indicator refers to the diversity/mix of activities in the innovation area ensuring frequency (or increasing the rate) of interaction between the innovators. These indicators have an important social component because knowledge sharing and idea generation are strongly tied to social interaction and trust developed among innovators through frequent interaction.

As described before, the innovators of Brainport Eindhoven area are R&D firms and universities, which locate in two main areas: the city centre and the southwest outskirts of Eindhoven. The share of researchers and young people is representative of the innovator's population in this area. For instance, there are 10.000 students at the research university (TU/e) and the design academy, while the Fontys University of applied sciences has 40.000 students in Eindhoven and two other locations in the Southeast Netherlands. The R&D sites employ over 10.000 skilled people. Both, universities and R&D sites want to attract international talent. The city and the region strive to be an attractive location for international firms and talent.

In the ealry 2000s, the city's knowledge-based policies promoted an international brand for the region. In 2013, there was an international community of 12.000 knowledge workers in the Southeast Netherlands. Indeed, the share of international population has become an important indicator of competiveness in cities, universities and business locations such as HTCE[60]. In this context, the

58 'Nota Ruimte' in Dutch

59 The A2 also intersects the A67 in the South of Eindhoven, which is a highway in the European road system (E34) connecting Belgium and Germany.

60 For instance, cities and regions use the number of foreign companies as an indicator for competitiveness. For instance, the number of foreign companies in Eindhoven is 204. Similarly, the Southeast Netherlands houses more than 1.300 foreign companies.

Netherlands is a country open and tolerant to different cultures, which makes it already an interesting location for foreigners. However, quality of the place to live and work is essential to attract international people in the region. For instance, the diversity of activities and amenities in Brainport has improved in the last years, but still weak compared with the offering of cities in the Randstad like Amsterdam or Rotterdam. Sufficient attractive facilities and entertainment for young workers, such as restaurants, pubs, concert halls and cultural events is key in retaining people to live, not only to work in the region.

The city of Eindhoven has been improving its international image to match its economic importance. For instance, since the 1980s the city has targeted efforts in urban renewal and building facilities in the city centre such as a large shopping mall and a concert hall, among others. Recently, the development the Strijp-S is an important example of this. The 27-hectare plot occupied by Philips has been released to the city of Eindhoven to redevelop into a mixed-use neighbourhood. The urban development plan includes different types of new housing and workspaces for creative firms in the former industrial buildings of Philips. In addition, a unique mix of lively functions is expected, including innovative retail concepts like boutiques, pop-up stores and industrial restaurants. Next to area development efforts, the city has created a new brand image promoting a vibrant and lively city thorough programs and events targeted to young workers. In addition, the city of Eindhoven runs a dedicated Expat centre to help international companies and individuals settle in fast. This centre offers expert and independent advice on (international) schooling, healthcare, housing and tax scheme advantages for foreigners. Correspondingly, an important achievement of the city in terms of internationalisation is the establishment of the International School Eindhoven (ISE), which officially began operation in 2009[61]. Overall, the growing mix and density of functions is concentrated in the city centre of Eindhoven, while the outskirts enjoy mostly the attractiveness of the landscape and outdoors activities.

In contrast, the targeted R&D locations of Brainport are located in these outskirts as separated nodes from the city. Their choice to create lively environments is either to connect efficiently with the city or to re-create their own diversity of functions, which is the case of HTCE. This tech-campus has its own 'central place' capturing the vitality of a city's downtown. Since 2003, a central facility called The Strip provides diverse restaurants, shops, cafes and other services for the campus community. Since the same year, HTCE has also made efforts to promote an international image when Philips decided to open the campus to other high-tech companies. Indeed, the diversity of people has increased on campus including researchers, service providers, managers, or students' intern of the different firms at HTCE. There is an indication of diversity of people in HTCE, estimating over 85 nationalities in campus. This is also reflected in the diversity of supplies in terms of amenities, which has grown in the campus over the last three years. The Strip is increasingly accommodating the diversity of services: Business oriented events, international restaurant and cafes including global franchises, dedicated shops, social events and food markets, a child care centre opened in 2007, among others are converting the campus in an enjoyable place able to attract not only beta-like workers [See Figure 5.10 and Figure 5.11].

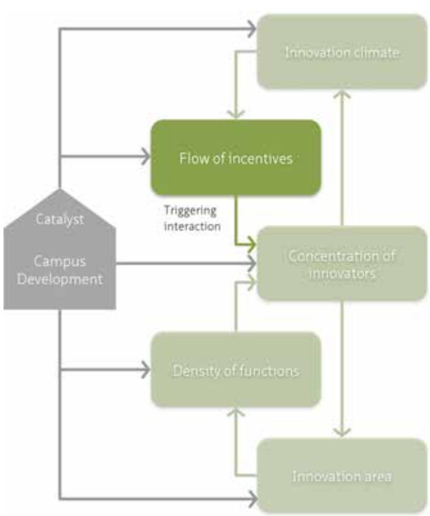
61 The origins of the International School Eindhoven traces back to 1966 with the foundation of the Philips International School, aimed to support international families working in Royal Philips.

Figure 5.10 Temporary amenities in central open space (2014)


Figure 5.11 Central building housing amenities (2013)

Besides the diversity of functions, other aspects as social security, working conditions and costs of living are essential in attracting knowledge workers in the region. For instance, social security system and the good working conditions are important aspects that make the Netherlands an attractive destination for Expats. However, the Dutch costs of living are high especially in Amsterdam and other cities in Randstad. In this respect, Eindhoven has an advantage to compensate for the lack of sufficient attractive facilities for young people. In addition, the introduction of special labour agreements is an important and unique initiative to improve the quality of life in the region. This will be discussed in the next section.

§ 5.2.4 Flow in incentives: the entrepreneurial tradition of the Triple Helix in Brainport



This indicator refers to the actions needed by the innovators to start and to carry on the processes of knowledge creation, diffusion and its application in the development of technologies. The role of the stakeholders in the Triple Helix is an important aspect of this indicator. For instance, the University-Industry-Government relationships determine the actions that will trigger interaction between the innovators. The quality of these relationships is crucial because each of these spheres has their own interests on innovation. Examples of these incentives are research expenditure, availability of working opportunities, institutional frameworks and policies, entrepreneurial activities, among others. These incentives or actions are can be strategically organised in close collaboration between these parties.

In the case of the HTCE in Brainport Eindhoven area there is a flow of incentives coming from the roles taken by each of these spheres (university-industry-government), bringing together resources that have triggered interactions between innovators to carry on the processes of knowledge creation, diffusion and its application in the development of technologies.

TOC

Leaders in each of these three spheres are part of Brainport Foundation (Stichting Brainport in Dutch), which is a body of representatives from the different parties involved in forming and developing the Brainport vision and strategy.

First, it is the leading role of industry investing in R&D and advancing economic development in the region. The Dutch-based multinational corporations in the area are important stakeholders in a regional network, which together have developed a shared vision of economic development. Philips has been recognised as a major leader and trustee of Eindhoven. This role comes from a long tradition tied to the history of Eindhoven and Philips. As said before, when Philips was founded, Eindhoven was a small village. Then, the company took responsibility in providing housing, education, facilities and amenities for their initial 20.000 employees because the government could not solve these issues at the time (De Vries, 2005). In addition, other important companies established in the area spun out from Philips such as NXP and ASML. Eindhoven grew up as a company town and a lot of people in the region have a bounded corporate history. They know each other for long, they have worked together and they speak a common language. But most important, they are local-based companies and culturally, they are willing to collaborate and invest in something that will benefit them directly. Indeed, Southeast Netherlands benefits from private investments in R&D, which totalled €2.1 billion in 2013.

This unique characteristic has been crucial strengthening the trust among public and private stakeholders in the regional network. The companies established in the area are involved in regional activities, including sponsoring, planning and decision-making[62]. The business of Brainport-based companies leads the competences of the region and the areas to focus. The governments and the universities have facilitated this leading role of industry, because of the trust developed by the private sector in fostering economic development acting beyond their own interests. For instance, TU/e recently announced a change in focus towards Energy, Health and Smart mobility, in line with the focus of R&D businesses in the region and in HTCE.

Second, it is the enabling role of the national and regional governments providing legal frameworks aimed to spur the region's economic development based on its knowledge and research strengths. One of the main concerns in Eindhoven has been the region's vulnerability to economic downturns because large companies have been the region's main employers. For instance, companies like Philips and DAF Trucks (a major truck manufacturing company) were hit during economic turndowns in the 1980s and the 1990s, which resulted in a major loss of jobs in the region. Since the early 1990s the local government has pursued a knowledge economy strategy to stimulate the region's economy, which is supported at national level.

Two major programmes aimed for technology-based economic revitalization: Stimulus in 1993 and Horizon in 2002. Recently, a new brand identity for the region 'Brainport' in 2010, framed within a National spatial policy[63] that recognises Brainport as one of the three cornerstones of the Dutch economy next to Airport in Amsterdam and Seaport in Rotterdam [See Figure 5.12]. Brainport 2020 is the strategic vision and implementation programme setting out the road map for the Southeast Netherlands. Several projects and initiatives from these programmes have resulted in important achievements for the region as follows:

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62 The CEO of Philips Benelux is the Chairman of Brainport Foundation and it is the only corporate stakeholder in a board composed mainly by the Majors of municipalities and representatives of universities in the region (Brainport Development, accessed on April 2015)

63 Nota Ruimte' in Dutch states specific objectives among others the strengthening of the international competitive position of the Netherlands (Ministerie van VROM, 2004)

- Attracting TNO Industry -a major research institute in the Netherlands- to Eindhoven in the 1997;
- Creating Venture Capital funds[64] meant to stimulate young firms in the manufacturing sectors and entrepreneurs; revitalising business parks;
- Creating new jobs (4.000 new jobs created at the end of 1999)
- Developing HTCE as a major site to attract international companies in R&D businesses.
- Establishing Brainport Foundation (Stichting Brainport in Dutch) and Brainport Development[65].
- Building facilities for start-ups with growing possibilities at R&D locations such as HTCE and Brain and TU/e Science Park[66].
- Strengthening collaboration among industry and knowledge institutions. Since 2013, the Municipality of Eindhoven and the largest trade union in the Netherlands (FNV Bondgenoten) have been pursuing a collective labour agreement (CAO in Dutch) to be applied in the entire Eindhoven region, which will make easier for workers to move from one to another company.

Figure 5.12 The three cornerstones of the Dutch economy of the national spatial policy (Brainport Development NV, 2012)

The local government has been active stimulating economic development through the collaboration with regional actors in industry and academia and the improvement of their existing competences. The previous list illustrates the most important of several initiatives showing the level of synergy for collaboration among different parties of the triple helix aimed at strengthening the competitiveness of the region.

64 In 2000, the Stimulus Venture capital Fund (SVCF) was initiated by NV REDE, which became Brainport Development NV in 2010. This fund developed further into a larger fund called the Eindhoven Venture Capital Fund founded in 2008.

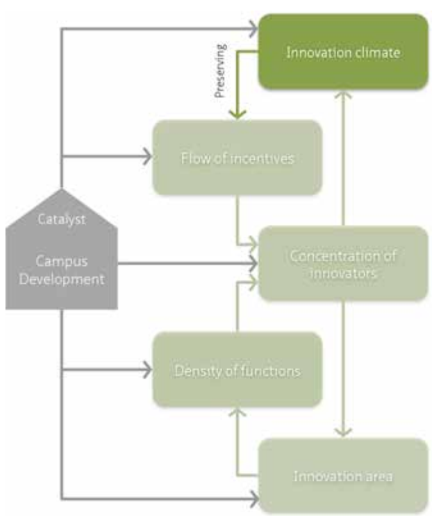
65 The first is a body of representatives from the different parties involved in forming and developing the Brainport 2020 strategy, while the second is the government agency that aims to enhance the prosperity and well-being of the region covering a wide range of activities in five sectors: strategy; projects and programmes; communication; business; and SME services (Brainport Development, accessed October 2014)

66 Brainport Development offers professional business accommodation with high quality facilities for small companies. Four so-called Business Centres built by Brainport Development locates at HTCE (Bèta Technology & Business Accelerator; Mu Technology & Business Accelerator) and TU/E Science Park (Twinning Center, Catalyst Technology) Source: Brainport Development, 2015

Last, it is the complementary role of the universities and research institutes providing the required knowledge to attract and prepare skilled knowledge workers. Indeed, over the years they have gradually become important stakeholders in attaining the region's shared vision of economic development. Since the end of the WWII, the provision of technically oriented education in the Netherlands is seen as a political intervention. Indeed, TU/e was founded as the 'Technische Hogeschool Eindhoven (THE)' by a law passed in 1956 and upgraded to university by an amendment to the law on 1 September 1986. Before that, the Academy for Industrial Design (AIVE, established in 1947 and nowadays the Design Academy), constituted Eindhoven's knowledge base. In 1996, this knowledge based expanded with the creation of the 'Fontys University of Applied Sciences' (or Fontys Hogeschool in Dutch). The region's universities are aware of their crucial role attaining the Brainport's knowledge-based strategy. Recently, the TU/e has focused its strategy not only on education and research, but also on knowledge valorisation. The university is envisioned as a major source of knowledge, technology and new business in knowledge economy. The new brand of its campus is TU/e Science Park Space, where space has been allocated for new young entrepreneurs in collaboration with the region. In addition, the university identifies cooperation with industry as an important strength to continue developing.

The three spheres of the triple helix (Universities-Industry-Government) shared a vision of economic development for the Brainport Eindhoven region. Actors in these sphere has formed a regional network that is bonded by trust, leadership and skills developed over the years. Indeed, the roles described above for each sphere show that these actors are committed to attain a shared goal for mutual benefit. Therefore, their actions go beyond their own exclusive goals.

§ 5.2.5 Innovation climate: Reinvention of Eindhoven based on its natural strengths



This indicator refers to the interrelated -social, economic and technological- developments in context preserving the flow of incentives or increasing the actions needed for innovators to carry on their processes.

Over the last century, Eindhoven has transformed from being a small town dominated by agricultural activities in the beginning of the 20th century and industrial activities until the late 1980s, to be the capital city of a high-tech and design region. This transformation resulted from different economic cycles, related to periods of technological developments leading to two waves of change and revitalisation of industrial processes in the region[67]. A number of new key technologies emerged in the Netherlands and in Eindhoven in the 1890s. According to De Vries (2005), electricity was brought to the entire country, cars and planes powered by combustion were invented and the telephone and a number of chemical industrial products became widespread. Scientific laboratories were set up because both the chemical and electrical industries were both knowledge-intensive sectors.

67 Revitalization and change refers to the interrelated social, economic and political processes of organising resources for the purpose of re-establishing industries. This definition is similar to the definition of reindustrialisation as understood by Castells (1996). These definitions differ on the origin of the process. In the case of reindustrialisation is the result of the need to reinvigorate national economies, while revitalisation and change is not necessarily an induced procedure but an evolutionary course emerging from the natural interrelation of social, economic and political processes. In this sense, revitalisation can be a result of reindustrialisation processes but is not always the case.

The foundation of Philips in 1891 as a chemical company marked a rapid growth of Eindhoven towards an industrial town. In 1914, Philips set up the Nat.Lab or physics laboratory, which was the company's industrial lab focused on fundamental research. The Nat.Lab constituted for many year the most important knowledge base of Eindhoven. After the WWII, Eindhoven progressively developed to be the most important industrial centre of the Netherlands.

During the post-war period was an important national focus on improving the technically oriented education that favoured the knowledge base of the city. However, in the late 1980s the city faced an economic and social decline because of the de-industrialisation processes creating great jobs losses. This decline marked an important period of revitalization (or in fact, reindustrialisation) in which local stakeholders joined forces to re-orientate the economic sectors based on the knowledge strengths of the region: technology and design. The government played an important role in setting various programmes strengthening the Eindhoven's knowledge economy strategy. The following paragraphs collect the most important of many factors shaping the innovation climate in Brainport-Eindhoven area and HTCE over the last 70 years[68]. Figure 5.13 illustrates the main events shaping the innovation climate at HTCE and Brainport Eindhoven area in relation to three periods of technological developments.

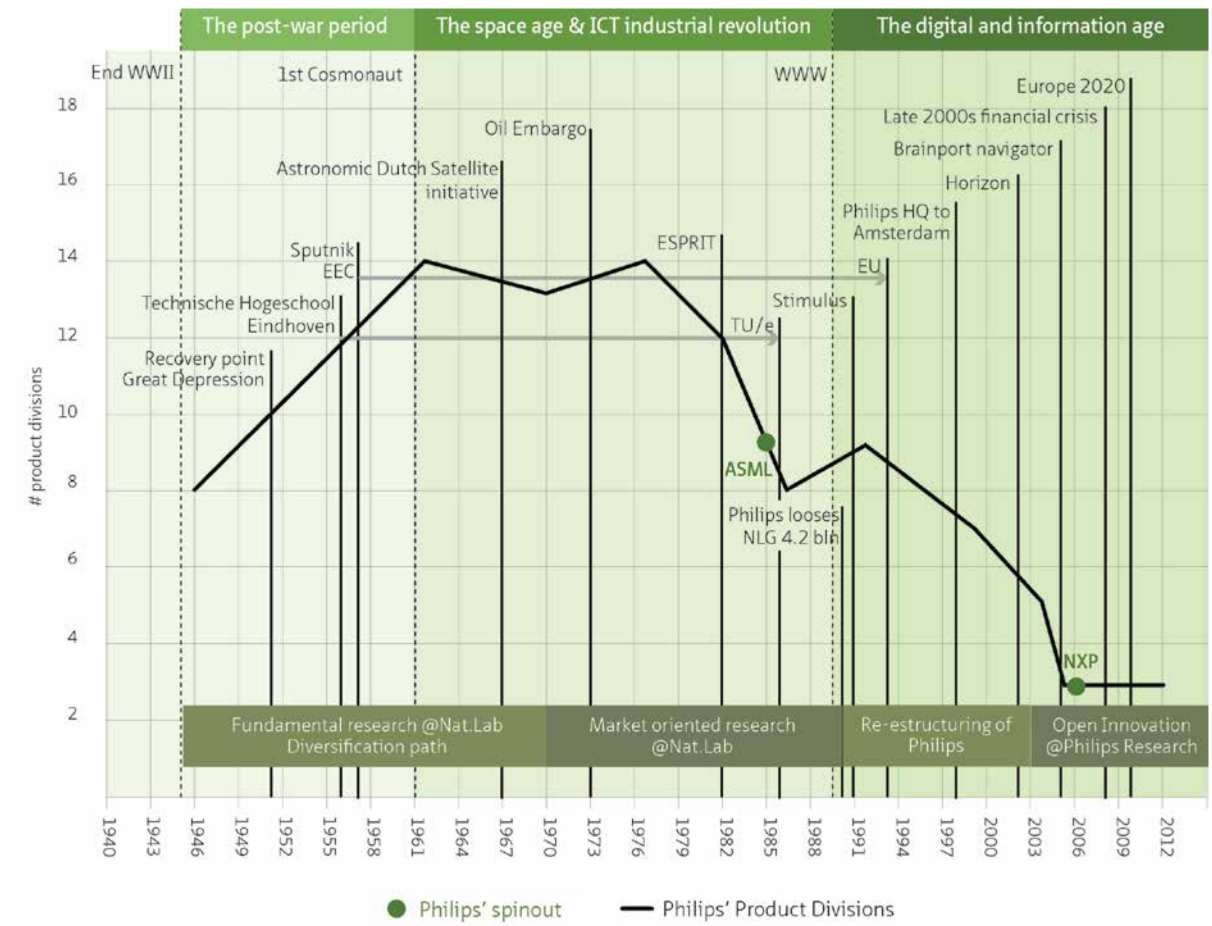


Figure 5.13 Interrelated developments shaping the innovation climate at HTCE and the Brainport-Eindhoven area

68 The information presented in this section relies primarily on published research (Baggen et al., 2010; De Vries, 2005; Fernández-Maldonado, 2010, 2012; Huang, 2013; Maldonado & Romein, 2009; Van Den Berg et al., 2005) and many official reports and online public data of HTCE and other institutions mentioned throughout the text.

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The post-war period

The first wave of change of industrial processes in the area began during a period of technological advancements referred in this research as the post-war period or atomic age: 1945-1960 (Chapter 3). Indeed, World War II constituted a decisive break in the course of the 20th century technologies, which grew significantly together with policies relating to technology and technological research. Developments in the United States involving massive government funding positioned the crucial role of scientific and technological research in the victory of the allied forces, affecting various government systems in Europe after the war. These developments coincide with a positive transition for the economy of industrialized countries, with the recovery of the Great depression in the 1950. In the Netherlands, the time was positive for the economy; the population grew as well as the number of programmes favouring technology education. In this context, the Dutch government emphasized the need of reflecting 'more brains' in Dutch products and industries and their role to play achieving this goal (Baggen et al., 2010). Accordingly, technical education experience a major growth in the Netherlands after 1945, when the number of technical schools tripled at the levels of schools for junior, intermediate and higher technical education. In Eindhoven, these trends were visible with an increase of the population and the establishment of the technically oriented knowledge base. In the research activities of Philips, this period is characterised by a focus on fundamental research within the Nat.Lab and a transition from physics to technological research.

During the WWII period (1939 – 1945), the Germans occupied the southern part of the Netherlands from 1940 to 1944. Before the war started, Philips had plans to move the activities of the Nat. Lab to Delft but the invasion took place so fast that it was impossible to execute all the plans (De Vries, 2005). Accordingly, during the occupation period the population of the Nat.Lab grew from 108 to 151 scientists. At the same time, the research programme was reduced in some topics because of the danger of being put to military use by the Germans. The city of Eindhoven was liberated in September of 1944; eight months before the northern part of the country did it in May 1945. Therefore, in 1944 a request was made to the government the set-up of a temporary academy (De Tijdelijke Academy in Dutch) in Eindhoven that could educate new scientists and engineers for the Nat.Lab. Lectures were given to student by staff of the Nat.Lab in a number of buildings in the Eindhoven region. This temporary academy ended by the end of 1945 when the other universities had resumed their programmes.

After the WWII, the population in the Netherlands grew steadily. The same trend was visible in Eindhoven, which grew from 129.000+ up to 181.000+ inhabitants. In 1946, the Nat.Lab became an organisation of 300 employees with a new area of focus besides physics and chemistry: electrical and mechanical engineering. The academic dimension of the lab culture was enhanced with seminars and international visits outlining the importance of fundamental research. There were no strings attached between the research programme of the lab and the product divisions of Philips. This independence was possible because of the favourable economic situation allowing innovation to take place. Indeed, some important innovations were developed by the lab's own initiative[69]. Simultaneously, Philips expanded its research activities opening Philips Research North America in Briarcliff, US. From the second half of the 1950s positive changes affected the research panorama in Eindhoven and in Philips. In 1956, the Technische Hogeschool Eindhoven is founded that later became TU/e. Also, by the same period, Philips Research enlarged in the Netherlands and abroad[70]. In this period, the Nat.Lab maintained that its main

69 During the period 1944 -1953 Philips registers 6 patents and 10 scientific publications.

70 Philips Research is established in Aachen in 1955 and in Hamburg in 1957

role for the company was to do research to support the product divisions in developing their product policy and in particular their long-term policy[71].

The space age and the ICT industrial revolution

The transformation of Eindhoven to an industrial town steadily developed along a period of technological change referred in this research as the space age and the ICT industrial revolution: 1961 - 1988 (See Chapter 3). An important seed for this wave was the launching of the first satellite –Sputnik- in 1957, which led to an important influx of research projects advancing technology worldwide. This period was characterized by advancements in microelectronics brought by competitive space programs between the US and the Soviet Union since 1961, when the Soviet Union put the 1st cosmonaut in orbit. Advancements from this period created fast-changing industries that moved from minicomputers to networks of computers, software, artificial intelligence and telecommunication technologies.

This technological change was visible in large multinationals like Philips. By 1962, Philips diversified its industrial focus from eight to fourteen product divisions adding Defense Systems to Telecommunications and a couple of new divisions such as Industrial Components and Materials; Radio Television & Record Playing; Domestics Appliances; and Computers among others. Important advancements of that period are the patent of Plumbicon[72] and the introduction of the Compact Audio Cassette, both in 1963. In the same year, an important research project known as Geldrop project introduced new fields of research including the Astronomic Dutch Satellite initiative added in 1967. This project made possible the extension of the Nat.Lab premises outside the Strijp, which was the lab's main location in the city centre. By 1965, the Nat.Lab reached a population of 2.130 people and has already started moving to a research facility known as Complex-W since 1963, situated in the village of Waalre southeast of Eindhoven. Likewise, in 1965 Eindhoven grew to a city of 181.609 inhabitants.

Simultaneously, the Asian companies entered the electronic market making it difficult for Philips because of the many competitors that emerged especially in Japan. In the late 1970s, there was an important state-funded research program in Japan that helped companies like Fujitsu, Hitachi, Mitsubishi, Nippon Electric and Toshiba to establish in the market. The R&D state funding increased during the 1980s and Japan became a serious competitor on the global market. This caused a growth in R&D efforts in the US as well as a growth in scientific cooperation between European countries, which have recently established the European Economic Community (EEC) in 1957. The EEC is renamed the European Community (EC) in the 1980s, indicating that the cooperation had begun to extend beyond economic agreements[73]. Joint scientific research became part of the whole agreement. In 1982, the EC launched the pilot phase in the European Strategic Programme for Research and Development in Information Technology (ESPRIT). ESPRIT was implemented trough integrated programmes and projects aimed at technology transfer. The programmes enabled universities to carry out research programmes in co-operation with industry. According to De Vries (2006), Philips took part in several projects set up within these programmes, which often involved the Nat.Lab. By that time, Eindhoven had the 'Technische Hogeschool Eindhoven', which was upgraded to University (TU/e) in 1986.

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71 In 1946 Philips formalises eight Product Divisions (Lighting, Electron Tubes, Apparatus, Allied Industries, X-ray & Medical equipment; Telecommunications; Industrial equipment; Electro-acoustics)

72 Plumbicon was a new type of camera tube that had a considerable attention in the television world (Philips technical Review, Volume 27, 1966, No.1)

73 In 1993, the EC received its current name of European Union (EU).

In 1973, the oil crisis had a worldwide impact in the economy of industrialised countries including the Netherlands. There was a need for adaptation with consequences for industry affecting Philips too. During the 1960s, there was a change of attitude in industry towards fundamental research triggered by authors that stressed the role of the marketplace in innovation[74]. In Philips, the goals of the Nat.Lab shifted towards the needs of the Product Divisions rather than seeking new ideas and developments as used to in the lab's culture. Thus, the research activities, new knowledge and patents gained focused to the needs of the Product Divisions application areas as the launching of the compact disc in 1983[75]. This focus had two main implications. First, the Product Divisions rather than the board of management became the funding source of the research budget in the lab, resulted from the introduction of the contract research in 1989. This was important boosting the company's existing body of knowledge because with the limited means, people from the lab –and their embodied knowledge- were transferred to the Product Divisions. Second, the structure of the lab expanded containing new functions relating to the Product Divisions' needs (e.g. coordinators). The Nat.Lab became an important knowledge centre for Philips in the fields of design and systems, aligning the research with the industrial and businesses activities of Philips that began its specialisation path[76].

In the urban context, the city of Eindhoven continued growing up to 192.562 inhabitants in 1975. However, in the period 1975 – 1985 the population of the city shrunk to 190.839 inhabitants.

The digital and information age

The second wave of change in the area has taken place during a period of technological change referred in this research as the Digital and Information age: 1989 - present (Chapter 3). This period began with the invention of the WWW allowing computers to connect anywhere on Earth. Global discoveries with an impact on society include the use of the GPS systems for commercial applications such as mobile devices, the first successful case of a cloned mammal and the first draft of the human genome. In the region, this period began with an economic crisis resulted from a decline of jobs in manufacturing. Likewise, Philips faced a dramatic reduction of the company, which nearly went bankrupt in the early 1990s, losing 4.2 billion guilders in 1990 (2,1 billion euro In 2015). Accordingly, the company was doing too many unconnected things and their main commodity businesses (light bulbs and television tubes) were under continuous pressure from manufacturers in South Korea and Taiwan.

Between 1996 and 1998, Philips sold off forty businesses, shrinking the workforce by 26,800 and bringing in 16.7 billion guilders. This was an incentive to focus the research activities on the needs of the product Divisions and to work with limited resources. This made crucial the role of the Nat.Lab in determining the company's product portfolio, which changed over the time acting as a knowledge centre. The combination of different types of research in Philips (from fundamental to product development oriented research) enabled the lab management adjusting the balance between the varieties of research work to the changing circumstances. In the period 1990-2013, Philips Research became a

74 Industry and Technical Progress, Carter and Williams (1966); Invention and economic growth, Schmookler (1966); and Successful Industrial Innovation, Myers and Marquis (1969) in De Vries (2006)

75 By 1977, Philips had 14 product divisions (Radio TV & Record and Industrial Equipment are divested -; and three new divisions are set -Audio, Video and Science & Industry). Between 1974 and 1983, Philips registered 12 patents and 10 scientific publications.

76 In 1986, Philips shrunk to 8 Product Divisions (Merges: Domestic Appliances with Personal Care and Telecommunications with Data Systems; Divested: Audio, Video, Electronics Components & Materials, Science & Industry; New: Components, Industrial & Electro Acoustics Systems). In the same period, Philips co-founded ASML; a joint venture with Advanced Semiconductor Materials International (ASMI).

front-end innovation organisation[77]. There was a reorientation on new fields of expertise and change in culture and competency profiles in the Research organisation. In this period, the activities of the Nat. Lab s merged in Philips Research. For 80 years, the Nat.Lab positioned Philips as worldwide innovative company fulfilling a continuous role as a source of inventions[78].

In this period, internal changes in the organisation of Philips led to the development of HTCE. In 1997, Philips decides to re-locate its Headquarters from Eindhoven to Amsterdam. This decision resulted from a strategic measure to save the company, which nearly went bankrupt in the early 1990s led by the 1996's, shift in general management. The new Philips' CEO -Cor Boonstra- was the first outsider in this management position and his measures include the reduction of businesses and employees in Philips reinforced by a successful campaign that served as brand for the company: 'Let's make things better'. It began with the re-location of Philips' HQ in Amsterdam. Accordingly, the birthplace of Philips did not match anymore the high ambitions of this strategy, which wanted to place Philips as strong player in the international market. The city of Eindhoven sought for an agreement to keep the most important business in the region. In 1997, Philips made the decision to concentrate all the research activities of Philips dispersed in Eindhoven in one location. That location was Complex-W. The board of Philips and the Municipality of Eindhoven made agreements to re-develop the site in close collaboration. Philips sells to the Municipality of Eindhoven the inner city properties that accommodated the R&D activities that will be relocated in Complex-W. The Complex-W needed not only expansion but also a new image that matches the new corporate brand. At the time, the existing Zoning Plan for this area did not specify neither the type of functions permitted nor the buildings regulations because the accommodation of R&D activities was a type of new development in the Netherlands. The municipality and Philips agreed to re-develop the site in close consultation and to set-up the regulations in the future according to the results of the development.

This restructuring of Philips as major employer of the region and the bankruptcy of DAF a major trucks manufacturing company, led to a process of revitalization of industrial activities in the area resulted from the need to reinvigorate the regional economy. Thus, since the early 1990s the local government launched two major programmes aimed for technology-based economic revitalization. In 1993, the EU and the city Region Eindhoven (SRE[79]) initiated the Stimulus Programme. This European program was set up to reduce unemployment, stimulate cooperation among regional actors and stimulate the joint development of products and technologies. Later in 2002, the SRE invited the local universities and the business community to formulate a common agenda and goals for the so-called Horizon Programme (Huang, 2013). This programme aimed to improve the technical labour supply according to the regional demands, increase the commercialisation of technologies and diversify the economic sectors and improving the international profile of the region. These programmes succeed to create new jobs, attract R&D investment and companies as well as research institutes to establish in the area [See § 5.2.4]. The cooperation model between industry, knowledge institutions and government was created in a period of crisis. This unique tradition of partnership is embedded in the regional networks driving the region forward.

77 In 2014, Philips is a leading innovation company that invests 8% of its sales revenues in R&D. By 2012, Philips registered a total of 1.500 patents applications part of the full intellectual property (IP) portfolio, which is composed of inventions generated in Philips Research, the Philips businesses and obtained by acquisition of IP or entire companies (retrieved from Philips, accessed in 2014).

78 Important inventions took also place –e.g. in 1997 Philips and Sony introduce the DVD.

79 'SRE is a regional organisation made up of the city of Eindhoven, the city of Helmond and another 19 surrounding municipalities' (Huang, 2013)

Simultaneously, important developments took place in the region and in Europe. For instance, the Centre for Industrial Research of the Netherlands Organisation for Applied Scientific Research (TNO) moved to Eindhoven in 1996. Eindhoven's Municipality, TU/e and the economic development organisation for the Eindhoven region in that moment (NV REDE) promoted this movement. Around the same period, knowledge started gaining global importance as a production factor. In 1996, the Organisation for Economic Co-operation and Development (OECD) released in Paris a global report called the 'Knowledge-based economy'. Correspondingly, the World Bank released 'Knowledge for Development' in 1998. Thus, stimulating innovation for economic growth and development became a mutual interest pursued by governments, industry and other institutions in many global regions including Europe. Indeed, the European Commission released the 'Innovation policy in a knowledge-based economy' in 2000. Since then, other knowledge economy policies have been released in the European context[80].

Brainport is considered a good example of the Triple Helix cooperation model given the success of the region in the knowledge economy because of its innovation achievements and the synergy of the local network (Fernández-Maldonado, 2010; Horlings, 2013; Van Den Berg et al., 2005). This reputation has attracted institutional attention and support at European level. In June of 2007, the European Commission approved a regional development programme aimed at strengthening regional competitiveness and employment. The so-called Operational programme South Netherlands was co-founded by the European Regional Development Fund (ERDF) for the period 2007-2013 focusing on actions in three flagships. The first flagship is 'knowledge economy, entrepreneurship and innovation', addressing collaboration between research institutes and enterprises, setting up R&D clusters and promoting innovative processes. The second flagship is the 'urban dimension', addressing inner city problems, the quality of the built environment and better quality sites for businesses. Last, the third flagship is 'attractive regions', targeting environment, culture, tourism, energy and access to ICT, considered as key elements that can improve the investment climate in the region providing enterprises and workers an attractive place to work and live.

In 2008 a global financial crisis, marked by the collapse of large financial institutions and the drop of the stock market, has led to a recession of economic activities in Europe and USA and reductions in growth in some developing countries as well (Te Velde, 2009). In response, governments have set up wide frameworks or small initiatives to help countries and a variety of firms to grow in the difficult economic landscape. In the global context, examples of those wide frameworks are the Innovation Strategy released by the OECD in 2010 or the Europe 2020 by the European Commission in the same year. In the Dutch context and especially in the Eindhoven region, an example of small initiatives is 'Syntens', an initiative of the Dutch Ministry of Economic Affairs established in the South of the Netherlands as a network to support entrepreneurs in SMEs through strategic advice free of charge.

Around this time, Philips has continued its internal restructuring closely related to its research activities. In 2005, a merger of several Philips departments creates Philips Applied Technologies group. A large part of the Applied Technologies organisation merged with Philips Research in 2011. In 2006, Philips sold 80% of their Semiconductors businesses to the newly created company NXP. This operation included the divestment of one quarter of Philips Research personnel, meaning that around 350 people began working for NXP settled in HTCE. In 2015, NXP became the second largest R&D Corporation of Eindhoven.

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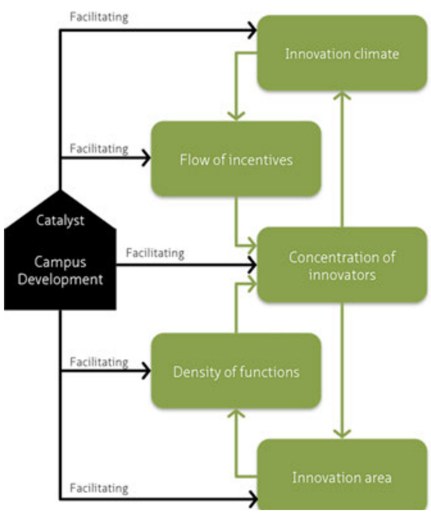
80 In 2009, the European Commission releases 'A knowledge intensive future for Europe'. In 2010, the OECD launches its 'Innovation strategy' and the same time the EC launches 'Europe 2020' where innovation is the central driver for socio-economic development.

Overall, the tech-identity of the region has grown with a lot of attention in the last years. Eindhoven is already considered a benchmark for innovation in different studies (The top seven intelligent communities of 2011, Creating Knowledge hotspots in the city, 2011; and European Cities in the Knowledge Economy, 2005). The indicators used to consider this region as a good example of innovation performance vary from study to study. A statistics report on economic performance of European regions (Brandmuller & Onnerfors, 2011) ranks the Eindhoven city-region as the highest region in Europe in terms of patents per population. Correspondingly, the population of Eindhoven grew from 207.331 up to 213.808 inhabitants between 2005 and 2010 (CBS, 2011). As to 2014, the Brainport region has been regarded as an Open innovation ecosystem. This one is defined as a network of research and knowledge-intensive companies, which are also engaged in production and quality manufacturing.

§ 5.2.6 The presence of a catalyst: the development of HTCE facilitating innovation



This indicator refers to a type of resource facilitating all the previous necessary conditions to stimulate innovation. In the review of the literature on innovation in the knowledge economy, the built environment is addressed as a resource-type of infrastructure facilitating this process. They are either referred to as part of science systems (e.g. laboratories and facilities for research), or places attracting talent. This position matches the traditional view of real estate management in which the built environment or real estate is the fifth resource in achieving organisational performance, next to people, technology, capital and information.

This research assumes this view of the built environment as a resource for stimulating innovation. However, it proposes a differentiation of this resource from the others. The built environment is a catalyst for innovation, which makes it a slightly different type of resource. That is, because the built environment –in contrast to capital for instance- is not exclusively targeted to stimulate innovation.

The built environment can be used simultaneously to support a different goal (e.g. sheltering people's activities and/or maximizing investments among others). In addition, the built environment can be re-used or adapted to changing goals over time (e.g. transforming manufacturing buildings into offices or housing). This proposition considers also the existence of inhibitors reducing the actions of the built environment as catalyst. These are the conflicts created by a lack of balance in the different perspectives of the stakeholders involved in the development of the built environment.

The analysis of the previous input indicators has allowed identifying five interventions in which the built environment has acted as catalyst for innovation in HTCE and in Brainport Eindhoven Region. Figure 5.14 illustrates each of them facilitating particular conditions for innovation. These campus interventions are:

- A. Intended accommodation strategy
- B. Representative facilities
- C. Shared facilities
- D. Flexible facilities
- E. Physical connectors

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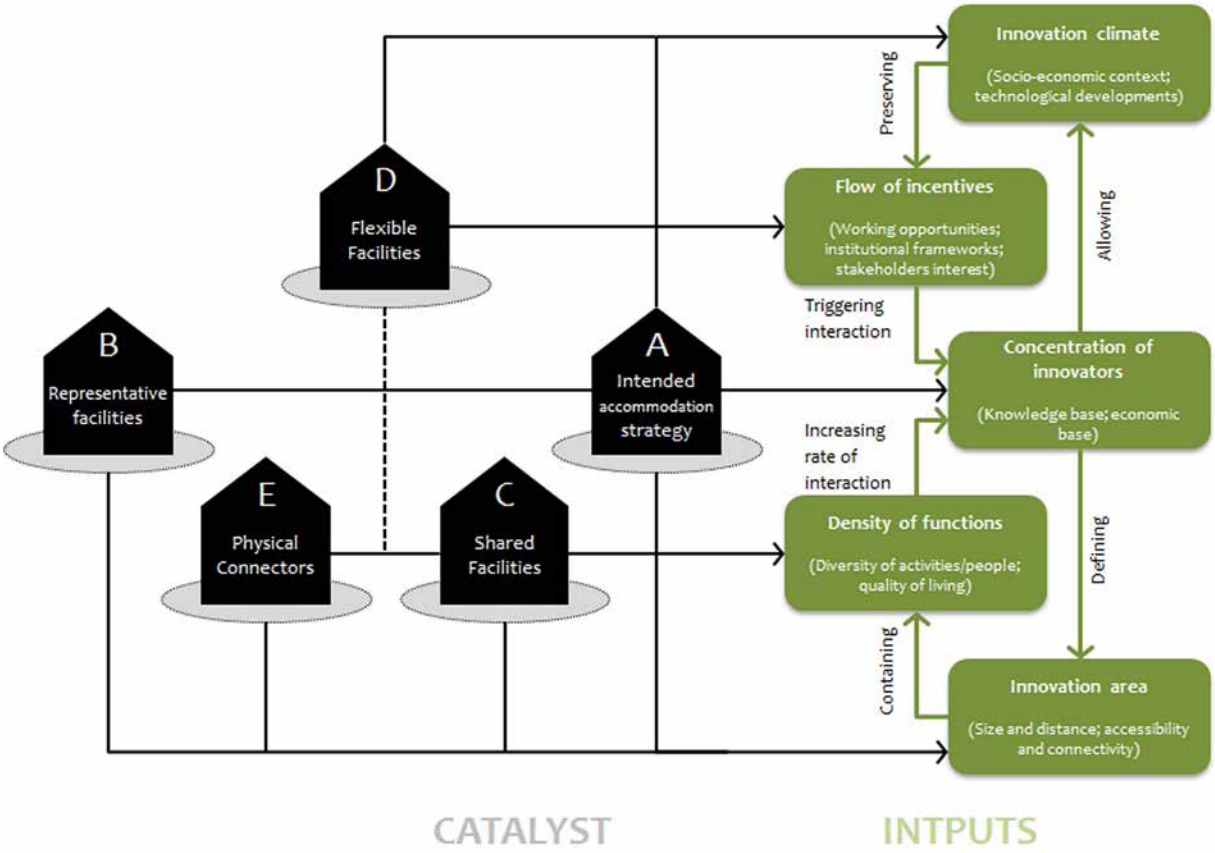


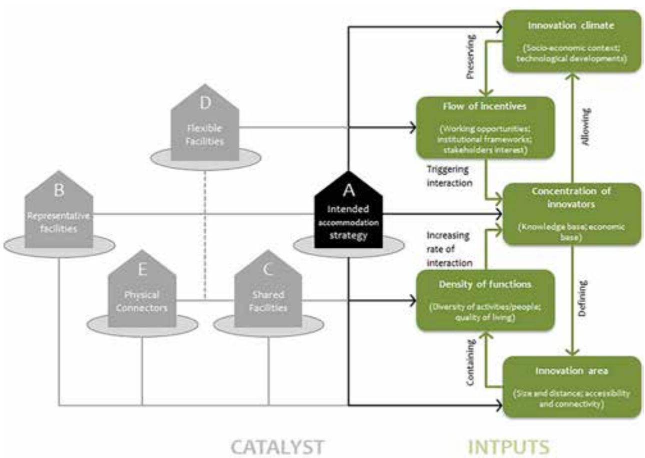
Figure 5.14 Five campus interventions of the built environment facilitating innovation in the case of HTCE

This chapter dedicates the following section to illustrate, with much empirical information as possible, the findings validating this proposition.

§ 5.3 The development of HTCE as catalyst for innovation

The following paragraphs collect the most important of many observations from empirical information and events related to the development of HTCE over time, validating the proposition of the built environment as catalyst for innovation[81]. Thus, the catalytic role of the built environment is documented in five types of interventions that were identified through the case analysis. The following paragraphs provides empirical information that help to understand how each of these campus interventions facilitated some condition for innovation at HTCE and the Brainport Eindhoven area.

§ 5.3.1 Campus intervention A: Intended accommodation strategy towards concentration



In the late 1990s, Philips concentrated its research activities in one location in Eindhoven. This intervention emerged as strategic action that will strengthen the collaboration among regional stakeholders. This intervention facilitated the concentration of innovators in one location, defining a strong identity for the innovation area on the one hand and allowing a positive innovation climate on the other hand. Similarly, this intervention favouring concentration triggered the national and international attention to preserving a flow of incentives in the area, as well as to improving the quality of living in the region. The following paragraphs outline with examples, how this single intervention facilitated all the conditions for innovation in the Brainport-Eindhoven region.

The development of HTCE is the result of a collaborative action between Philips and the municipality of Eindhoven in keeping their mutual interests during a period of crisis. In 1997, Philips decides to re-locate its Headquarter from Eindhoven to Amsterdam. This accommodation decision was part of a corporate strategy branded as 'Let's make things better'[82], which aimed at reducing costs and supporting image to recovery from an economic downturn. The birthplace of Philips did not match anymore the high ambitions of this strategy, which sought to place Philips as strong player in the international market. In reaction to this announcement, the municipality of Eindhoven sought for an agreement with Philips fearing to losing the main employer in the city. After negotiations and a deal that included the purchasing of Philips' inner city properties by the municipality, Philips decided to concentrate in one location all its research departments dispersed in Eindhoven. The location selected was an existing Philips' site located outside the city of Eindhoven in direction to the town of Waalre, which was referred to as Complex-W. This site was developed in the 1960s to accommodate the expansion of the Nat.Lab. Back then, it was an industrial site surrounded by farmland and still conserving its character as a built environment separated from the city.

81 The information presented in this section relies primarily on interviews with decisions makers on the built environment of HTCE in 2013 and 2014; maps retrieved from the physical map collection in TU Delft Map Room; and many official reports, plans and online public data of HTCE and other primary sources [See Appendix D].

82 Philips introduced this slogan in 1996 and it was used until 2004.

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The board of Philips and the Municipality of Eindhoven made agreements to redevelop the site in close collaboration. Philips sold to the Municipality of Eindhoven the inner city properties that accommodated the R&D activities that will be relocated in Complex-W. The Complex-W needed not only expansion but also a new image matching the new corporate brand. At the time, the existing Zoning Plan for this area did not specify the type of functions permitted, or the buildings regulations. The accommodation of R&D activities was a type of new development in the Netherlands. The municipality of Eindhoven and Philips agreed to redevelop the site in close consultation and to set up the regulations in the future according to the results of the development[83]. This agreement was a unique opportunity in the Netherlands to experiment in area development. The municipality provided flexibility to develop a land with very little restrictions, while Philips provided the means to create a state-of-the-art environment. In addition, this development strengthened the relationship between the city of Eindhoven and Philips based on trust and mutual benefit.

The deal was on and Philips established a Steering Committee to inventory the current supply and the future accommodation needs at that moment[84]. In the same year, this committee -composed by members of the Board of directors of the company[85] - invited three architecture and engineering firms to design the vision for a 'new campus'. The Committee set up the goals for concentrating these activities as 'synergy, greater efficiency and better returns on research and development', which were the leading elements for the design besides a limited budget to implement the design. In 1998, the steering committee selected three Dutch firms to design the masterplan for Philips High Tech Campus (PHTC).

The vision for PHTC was finalised together by the three architecture firms and one engineering firm in 1999. The vision included the design explaining the main concepts and a draft of its implementation in four phases [See Figure 5.15 and Figure 5.16]. The design emphasized four different concepts: 1) a central place to be; 2) a layout structure that create harmony with the existing elements; 3) independent parking buildings; and 4) four types of landscape design. Overall, because of the location characteristics of the site, the concentration of R&D activities included the concentration of other functions facilitating the needs and demands of end users on campus.

In 1999, the masterplan of Philips High Tech Campus began implementation. Philips decided to use preferred –and mostly local- partners as contractors for realising such ambitious project. The project manager set up a structure that brought together the interests of several internal and external stakeholders. Important stakeholders were the Philips Steering committee (nine members); The Exploitation Company PHTC (four members); the Project group (20 members from different organisations including diverse consultancy firms and the municipality); the Campus users' consultation (one member that collects the demands of users at campus and building level). These four management units covered - respectively and hierarchically- four perspectives of the built environment influencing the development of the campus: strategic, financial, physical and functional [See Figure 5.17].The implementation of the masterplan served as a collaboration platform between internal and external stakeholders.

83 For twelve years, this masterplan was updated and served as guideline for campus development until 2012 when the Zoning Plan (Bestemmingsplan in Dutch) is approved as regulatory framework.

84 In 1999, Complex-W had a gross floor area of 190.000 m^2 approx. and accommodated the Philips research Laboratories (then Nat. Lab), which was an organisation of about 3.000 people. The project was expected to take five years to complete starting in summer 1999. After the completion of the last phase, the total number of people employed on the campus will be more than 8.000 (Source: Philips archives, 1999).

85 According to interviews with architects invited to design the master plan in 1997 the steering committee was composed by three member including the CEO of Philips and the director if the Nat. Lab a t the time. Information retrieved from the project management concept in 2000 shows that this committee was composed by 8 members from different management structures in Philips (e.g. General management and Asset management)

Figure 5.15 Masterplan of Philips High tech campus presented in 1999 by the selected companies. Source: Simons et al. (1999)

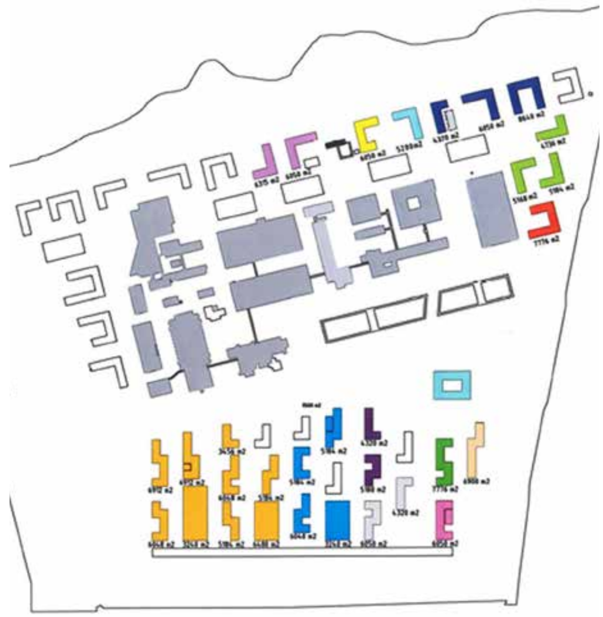

Figure 5.16 Proposal for functional programme of the campus. The existing buildings are in grey colour. A large part of the new program was meant to accommodate the former Centre for Industrial Technology (Philips CFT –in dark yellow colour). Source: Simons et al. (1999)

Up to 2003, Philips developed the campus according to the master plan until internal developments in the innovation climate of the Research organisation called for adjustments to such plan. In 2003, Philips adopted the Open Innovation Model[86] as new ways of working to carry out their R&D activities. Thus, Philips began co-operating with external parties to accelerate their innovation processes. In the same year, Philips decided to open the campus to other high-tech companies. This decision and the services offered by Philips began attracting other companies and research institutes to locating at the campus. Simultaneously, the city was in the process of revitalising its economic activities through policies strengthening knowledge-intensive activities. Thus, the presence of a campus attracting knowledge-intensive firms made perfect sense for the region. Philips modified the plan according to the changing demand starting with removing its name from the campus, which began to be called High Tech campus Eindhoven (HTCE).

In 2008, Philips decided to sell HTCE. The campus had evolved to a cluster of different R&D companies and research institutes. Thus, Philips decided to focus on their core businesses rather than on real estate management. Besides, the company saw the opportunity to profit from the sale of a campus that has become a valuable asset for the company and for the region. It was the time to develop the definitive Zoning Plan (Bestemmingsplan in Dutch) as part of the initial agreement between Philips and the Municipality of Eindhoven. The urban planning team of HTCE and the Municipality of Eindhoven began working in close collaboration to make a plan that will become the control mechanism regulating the development of HTCE in the future. The planning process went on from 2008 until 2011.

86 ‘Open innovation is a paradigm that assumes that firms can and should use external ideas as well as internal ideas and internal and external paths to market, as the firms look to advance their technology’ (Chesbrough, 2003)

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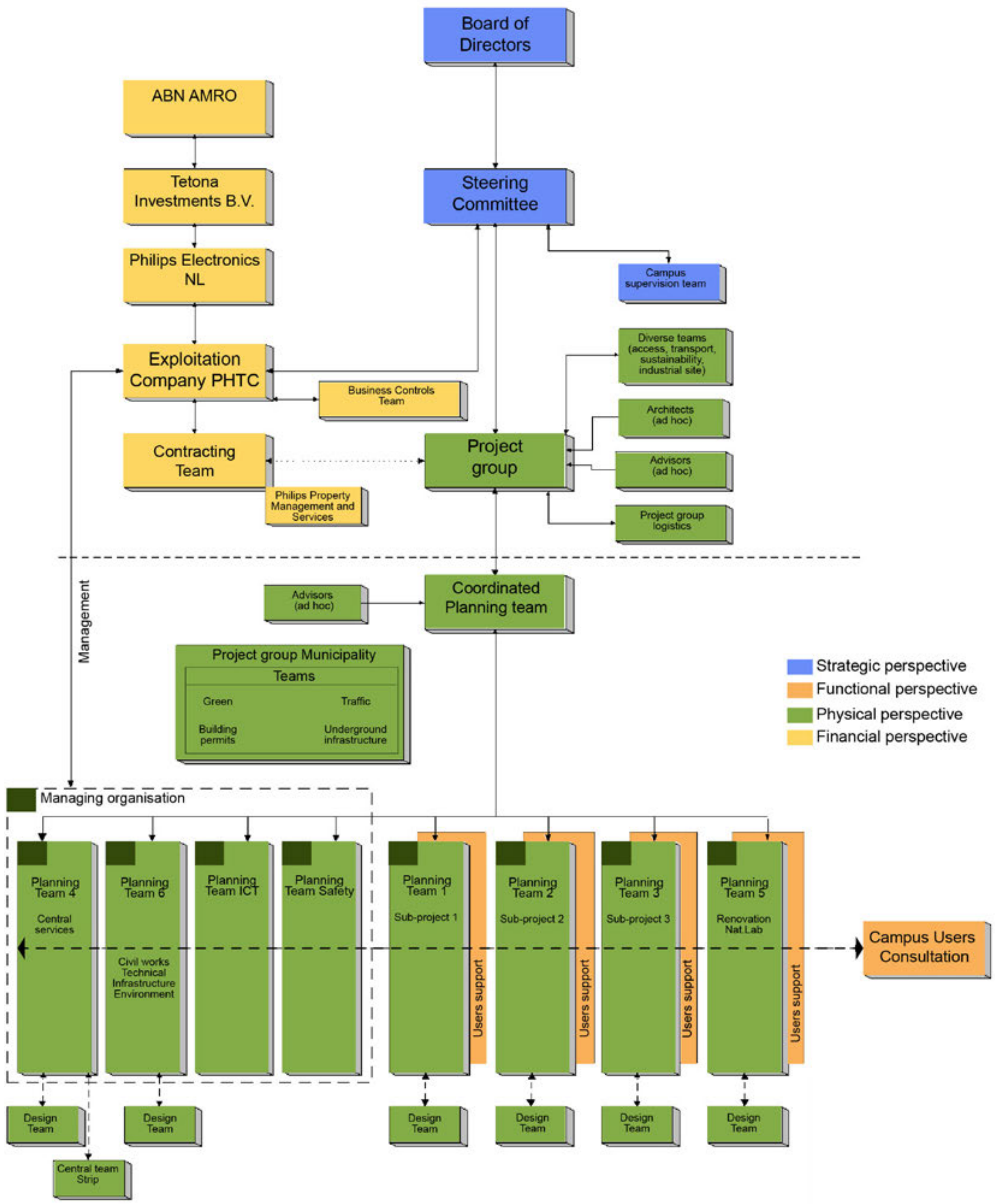


Figure 5.17 Project structure of PHTC including main managing stakeholders involved in realising the proposal. The different perspectives of the built environment connected to specific purpose in decision-making are outlined in colours. (Data: De Brink Groep, August 2000. Edited and translated to English)

In 2012 the definitive Zoning Plan 'HTCE – Klotputten' is being implemented by the Municipality of Eindhoven after an intensive process that involved several parties including Dutch legal officers, environmental advisors, urban designers and specialists from Philips. The name of the campus officially changed to High Tech Campus Eindhoven. The campus is incorporated as a crucial node in the national and regional spatial planning reinforcing the innovation identity of the area[87]. Indeed, HTCE is affected by spatial policies at three levels. At national level, the National Spatial Policy or 'Nota Ruimte' in Dutch (Ministerie van VROM, 2004) states specific objectives among others the strengthening of the international competitive position of the Netherlands. The priority focuses on the connections between urban networks and the main economic areas (Airport, Seaport and Brainport). An important connection in the Nota Ruimte is the A2-or knowledge axis connecting Brainport Eindhoven region with important zones of economic activity in the Netherlands, Germany and Belgium[88]. Another crucial aspect of strengthening the international competitiveness is the supply of attractive locations for companies and addressing traffic congestion. For instance, the knowledge clusters played an important role and the A2-zone -called by the SRE Brainport Avenue- is addressed as an important knowledge axis where HTCE is located [See Figure 5.18 and Figure 5.19].

Figure 5.18 Desired development direction for A2-Zone in Nota Ruimte (By SRE, retrieved from Bestemmingsplan HTCE – Klotputten, 2012)

Figure 5.19 Spatial quality of Brainport Avenue in 2016 (Map data: Google, DigitalGlobe).

87 'The expansion of the campus fits to strength the national, provincial and municipal ambition of Eindhoven as the most knowledge intensive region (Brainport) of the Netherlands'. (Translated from HTCE Bestemmingsplan) Gemeente-Eindhoven (2012, p. 7).

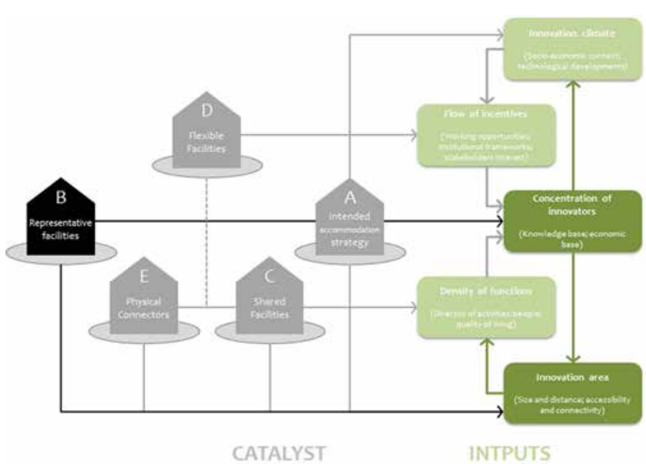
88 The A2 axis is as the most important growing zone of the Dutch economy. Along this axis lie urban areas with high densities of driving activities, international businesses services towards the north and advanced manufacturing industry towards the south in Brainport Eindhoven region. Thus, the A2 axis is the knowledge axis of the Netherlands and it is also an International axis at the southeast (Translated from Van Oort and Raspe (2005)

At provincial and regional level there is the spatial regulation called 'Structuurvisie Ruimtelijk Ordening' in Dutch set in 2011, which draws the spatial planning vision of the region. In this vision, the campus is addressed as a 'high-valued urban zone' located in an important urban intersection. Around the campus grounds the area named as Klotputten is indicated as an important 'green and blue cover' which is an area reserved for agricultural and environmental conservation. Accordingly, the extraordinary character of the campus concept as 'business site for R&D activities' makes it acceptable even though it deviated from the environmental category that the province gives to this area.

Lastly, the clustered accommodation strategy of Philips in the 1990s evolved at an important node to channel an important flow of incentives to the area. For instance, HTCE has positioned the concept of campus, which has become important in the Dutch spatial planning agenda. In 2009 and 2011, the Ministry of Economic Affairs, Agriculture and Innovation commissioned Buck Consultants International a study about campus development in the Netherlands. The purpose of the study was to establish an inventory and assessment of campus development in the country, to identify the potential campuses adding value to the national economy and to evaluate the economic value in stimulating such developments. The study identified four indicators that makes a campus relevant for the Dutch economy: a focus on R&D activities; a high quality environment with research facilities where multiple companies can use; the presence of an evident knowledge carrier, such as a university, college or a large research department; and an Open innovation environment (Bci, 2012). Based on these indicators, the Ministry of Economic Affairs, Agriculture and Innovation designated HTCE and other 24 campuses as of national importance, among 74 campuses developed at different stages in the country.

Overall, the Dutch national government has recognised the campus development as important instruments for the implementation of national economic policies enhancing its competitiveness in the global knowledge economy (Huang, 2013). Accordingly, providing subsidies and conducting infrastructure development is the main role of the government facilitating the development process of campuses. In HTCE, this is visible in improvements regarding the connectivity of the campus, the establishment of research institutes and the provision of space for start-ups, which are addressed further in this section.

§ 5.3.2 Campus intervention B: Representative facilities

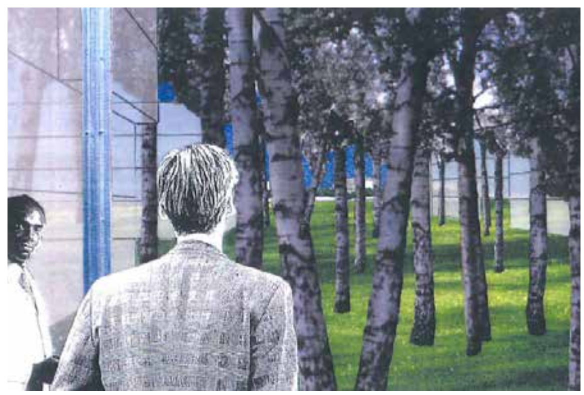


Since 1999, when Philips introduced the idea of the campus, decision makers of the built environment have directed efforts to create an atmosphere that matches the high-tech character of the site. This emphasis has resulted in a campus well known because of its state-of-the-art facilities, providing services and an environment that are highly valued by end-users. Indeed, Philips and later HTCE Site Management had established a brand image for the campus that has facilitated the concentration of innovators in HTCE. As well, the brand of HTCE has become a strong element in the identity of the innovation area. The following paragraphs will illustrate with examples, how building representative facilities has been a catalyst for these two necessary conditions for innovation.

High-tech and sustainability as image for the innovation area

As mentioned in the previous section, in 1998 a Steering Committee in Philips invited three architecture and engineering firms to design the vision for a 'new campus'. In the same year, the steering committee selected three Dutch firms to design the masterplan for Philips High Tech Campus (PHTC). The design finalised in 1999 pursued radical changes in terms of appearance. The proposal emphasized the green character of the surrounding landscape and at the same time created a high-tech atmosphere with state-of the art buildings. The architects proposed transparency, flexibility and sustainability as design concepts for the built environment. Their design preferences favoured the use of plain and natural materials selected on the basis of their sustainability aspects (e.g. metal, glass, wood and stone with their natural colours) stressing the quality of the existing landscape features [See Figure 5.20]. Another intervention that strengthened the desired image of the campus was the renovation of two important buildings of Philips Research, which are landmarks in the campus since the Complex-W was developed. The renovations of the former WY Building (HTCE 37) and WB Building (HTCE-34) were two separate interventions (25.000 m^2 each) including interior design, façade works and technical upgrading, which took several years to complete.

1 Designers' idea for the PHTC central area



2 Designers' idea for the PHTC north and south areas

3 Interior of campus building in HTCE central area in 2013

4 HTCE north area in 2013

Figure 5.20 Comparison between the desired image for the campus and the attained spatial quality (Collage *1* and *2*: Martine Nederend in Simons et. al., 1999).

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The landscape design has been an important element of the campus image accounting for sustainability and environmental responsibility, which are very valued in the area. As mentioned before, this campus is being planned in a site surrounded by an environmentally protected area. Therefore, the campus has been designed in close collaboration with the 'Brabantse Milieu Federatie (BMF)' –translated in English as the Brabant Federation for the Environment- making sustainability a permanent concern. The incorporation of sustainability is not only enhancing the image of the campus because of the use of green materials and the respect of the existing landscape structure [See Figure 5.21], but it is also illustrated in more specific interventions aimed at energy efficiency. For instance, the parking garages have solar cells that generate the electricity of the garages. In addition, there is a large system for cold and heat storage in the ground used to control the climate in the buildings and to save energy costs (up to 30%).

1 *Parking garage in campus north*

2 *Access to an office building in campus south*

Figure 5.21 Spatial quality of HTCE landscape design in 2013

An important design feature related to sustainability is the horizontal and permeable arrangement of the buildings. The 1999's master plan proposed a new building structure that allowed keeping woodlands and a transparent architecture enhancing interaction between the building and the landscape. An important building rule was keeping the height of the buildings up to 15 meters (four storeys height). One of the architects from the initial design team stated in an interview that this measure corresponded more or less to the height of the existing trees. Accordingly, the reasoning behind this measure is to avoid loosing eye contact with the ground floor and therefore inviting people to use the public space.

Brand identity presenting HTCE

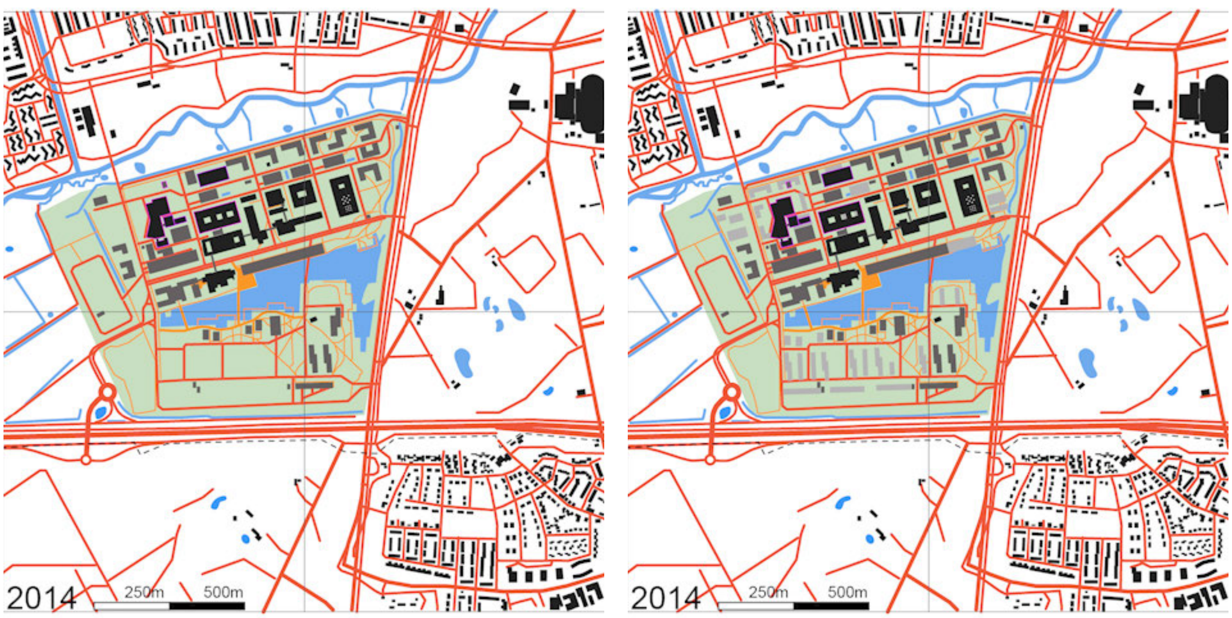
In the early years of the campus, the image of Philips was dominant. However, when the campus opened to other companies in 2003 the site adopted a new brand identity. HTCE became the new brand promoted with a communication and marketing strategy. This strategy included a new logo that is exposed in the entrances and the parking garages of the campus[89]. In addition, the Site Management organisation set-up strict guidelines on how to use the HTCE corporate image and how to expose the brand identity of each company on campus without hindering the HTCE brand and the high-tech style. This communication and marketing strategy helped building a neutral territory that attracted other companies, which began seeing as positive the less dominant role of Philips to establish on campus.

89 There is a special one along the A2 corridor exposing the logo of HTCE along an international motorway.

This strategy became the milestone of a strong internal and external identity for the campus. Externally, the campus became a regional asset carrying the name of Eindhoven. The previous section illustrated this with the inclusion of HTCE in national, provincial and municipal spatial planning agendas. Internally, the brand strengthened a sense of belonging among the tenant's community, who consider the campus as the place to be. The results of tenants' survey and previous research demonstrated this[90].

Branding the campus as the place to locate has become an important marketing tactic of HTCE-Site Management to succeed in their acquisition strategy. In 2014, HTCE-Site Management launched a campaign promoting a new brand story 'Turning technology into business' which portraits the campus as the place where paths cross, ideas meet actions and innovation accelerates. This campaign introduced a new logo and collects the users' experience on campus. They describe the high-tech, green and social characters of the built environment as inspiring and facilitating. The marketing and communication department of HTCE has directed efforts to enhance this image by using specific facilities as anchors for the acquisition strategy. An example of it is the Strip, a central facility portrayed in many brochures and presentations of the campus, which is addressed in the next section.

Attracting companies has not been a difficult task for HTCE Site management considering the campus has physically developed resulted from the demand of companies already established on campus, which is nearly fully developed, however, at a different pace than the expected [See Figure 5.22]. According to HTCE-SM, there is no vacancy registered in their portfolio up to 2014 but there is capacity to accommodate small companies in buildings of current (large) tenants such as Philips and Brainport Development, which are willing to make agreements with HTCE-SM when there is a possibility to provide accommodation in their leased space.



1 Situation of HTCE in 2014

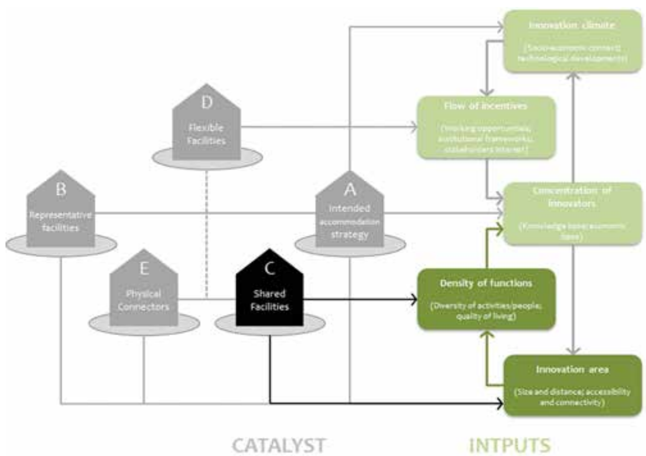
2 Expected situation of HTCE in 2025

Figure 5.22 Comparison of the urrent and future development of HTCE. The shade in green is the area occupied by HTCE in 2014. The buildings from Complex-W are in black. In dark grey are those built after the 1999's master plan and in light grey those to build in the future. The buildings to be demolished have a purple boundary. The red lines are main roads, the orange is the pedestrian network and the blue is water. (Map: Flavia Curvelo Magdaniel, 2014. Data: Topografische Dienst Nederland, 2011, retrieved from TU Delft Map Room and Juurlink+Geluk B.V., 2014)

90 The results from an online survey conducted by HTCE Site Management in 2012 showed that most of the participating companies find very important to be located in campus. Existing result empirical research confirms this finding (Van Der Borgh et al., 2012).

Overall, from 1997 to 2014 HTCE evolved from an industrial site of a single company to a sustainable campus of 125+ companies that perform R&D activities in high tech fields. Similarly, its population has grown from 3.000 approx. up to 10.000 engineers, technicians, researchers, managers and designers. These users have different preferences for working environments and the campus has developed a flexible brand image matching both, end-users' preferences and the regional spatial ambitions.

§ 5.3.3 Campus intervention C: Shared facilities



The development of shared facilities has been an important concept in HTCE since its 1999's master plan. This concept strengthened with the adoption of the Open Innovation model in 2003, which resulted in an updated of the master plan. Over the years, the development of shared facilities for both social and working activities has facilitated the density of functions and people in campus. In addition, it has contributed to enhance the identity of the innovation area. The following paragraphs illustrate with examples how this intervention has facilitated these two conditions for innovation.

This section focused on four types of shared facilities: the Strip, the laboratories, the Philips's cleanrooms, the Brainport Development's Business centres and the Parking garages. Each of them accommodates a different type of space that makes them distinctive but complementary at campus level since they unite the campus brief.

The Strip: a central place to be and meet

In 1999, the design proposed in the master plan for Philips High Tech Campus emphasised a central place to be as one of the four campus concepts. This place to be was translated into a major central facility facing a wide-open space that became representative of the campus: The Strip. In fact, the design team proposed a strip 36-meters wide and 360 meters long as a common facility to accommodate diverse activities of communal character. Initially, the facility was meant to bring together buildings of different forms and architecture under one single roof. The main concept was concentration of activities with enough room for inner gardens, terraces and spatial opening towards a large pond. The proposed functions to be accommodated in the Strip aimed at creating a lively and pleasant atmosphere that allow people to stay and promote informal contacts. These functions included restaurants, fitness, day-care, library, auditorium and conference rooms [See Figure 5.23]. Overall, the Strip was envisioned as a meeting place that soon became the most important social environment in campus.

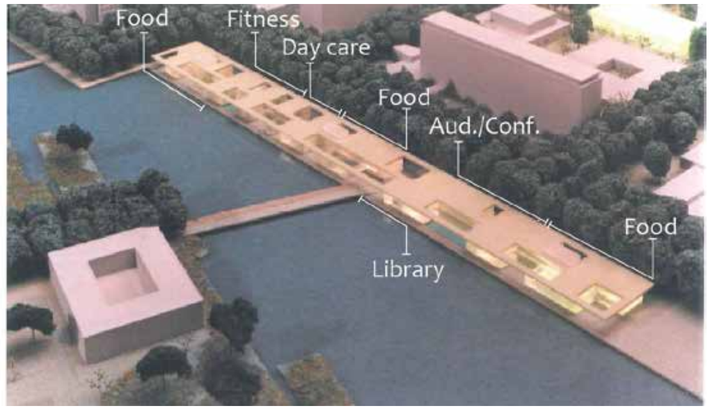


Figure 5.23 Vision for the Strip proposed for Philips High Tech Campus (Source: Simons et. al. 1999)

Although the original design and functional programs as been slightly modified[91], this shared facility is a major networking environment in campus that triggered other interventions on the built environment. For instance, developing the central facility in such a long building was costly and had to be built in phases[92]. Thus, to prevent people of not using it, the project team decided to close the canteens, restaurants, auditoriums or large meeting rooms in other buildings. Implementing this decision was not easy but the leading role of Philips facilitated its adoption as a corporate rule. Along with that, several bridges that connected the main buildings of the old Complex-W were gradually turned down between 2003 and 2011. Nonetheless, some of the bridges connecting Phillips departments were renovated and still in use [See Figure 5.24]. In turn, this favoured the consolidation and use of the public space and the pedestrian paths in campus.

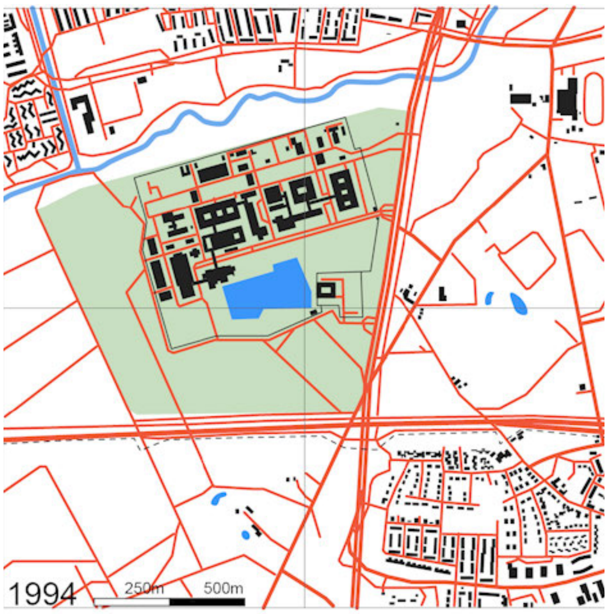
Over more than a decade, the Strip has succeeded as a place to be and meet, which is already referred to as the beating heart of the campus. Besides the diversity of functions accommodated in this facility[93], there are several networking events hosted every year at the Strip helping to building community among tenants and external stakeholders who visit the campus. As mentioned in §5.2.3 the location characteristics of the campus separated from the city explains also the success of this facility. Re-creating the diversity of functions of the city has been more effective that connecting with the city. The Strip captures the vitality of a city's downtown by concentrating functions in one place. This shared mixed-functions facility provides plenty opportunity to increase the density of people who are likely to meet -accidentally and/or intentionally- for relaxing, for working, for networking, for eating, for business, etc.

Since 2003, HTCE has also made efforts to promote an international image when Philips decided to open the campus to other high-tech companies. Indeed, the Strip has served as corporate icon to promote HTCE abroad [See Figure 5.25]. In 2014, HTCE has a diverse campus population representing over 85 nationalities and different type of knowledge workers including researchers, service providers, managers, or PhD and MSc students' interns of the different firms at HTCE. This diversity is also reflected in the diversity of supplies in terms of amenities, which has grown in the campus over the last three years.

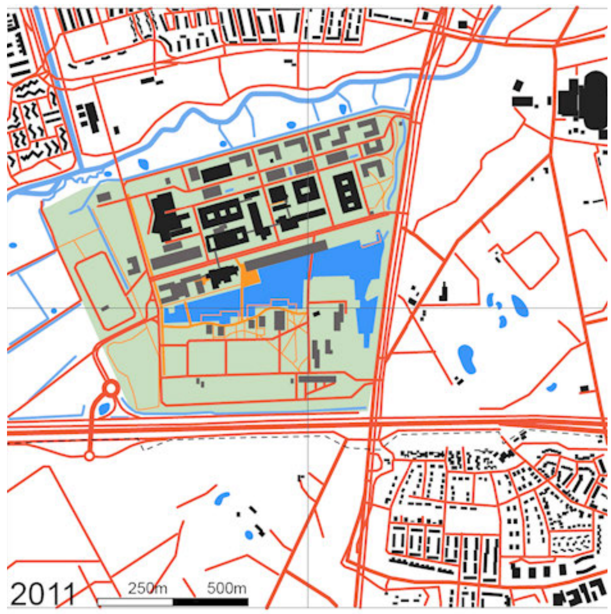
91 For instance, the library was not realised, the day-care is being developed as a separated facility in a different area and the permeable design with inner terraces allowing building 80% of the footprint has increased in built density.

92 Up today, only the first 250 metres length of the Strip has been built. The project is expected to be completed by 2025.

93 In 2014, the Strip accommodated a conference centre, eight diverse restaurants and cafés for different target groups, a wellness centre, six shops (including a supermarket, a hairdresser, a print shop, a computer store, a bank office and an insurance desk) and the central office of HTCE Site management.



1 *Situation of the complex in 1994*



2 *Situation of PHTC in 2011*

Figure 5.24 Comparison of the site before and after the PHTC Master plan. The shade in green is the area occupied by HTCE in 2014. Bridges connect the main buildings from the previous Complex-W in black. The central area where the Strip will locate is recognised by the existing pond, which is enlarged in the 1999's proposal. The new buildings including the Strip are in dark grey in the map on the right (Map: Flavia Curvelo Magdaniel, 2014. Data: Topografische Dienst Nederland, 1994 and 2011, retrieved from the physical map collection in TU Delft Map Room)

Figure 5.25 View of the Strip that is mainly used in corporate presentations and official website.

Philips' laboratories: collaborative laboratory space

In 2003 Philips adopted the Open Innovation Model to carry out their R&D activities. Accordingly, Philips began co-operating with external parties to accelerate their innovation processes. Philips selected to work with partners, who shared and complemented their expertise, knowledge and processes. In the same year, Philips decided to open the campus to other high-tech companies. Along that process, Philips Research also began to offer specific services and infrastructure for these other parties (e.g. cleanroom services, prototyping services and material analysis services). These services were blended and labelled as MiPlaza (Microelectronics Plaza). With this new brand, Philips Research offered their services to third parties. This meant other R&D companies could do, for example, their experiments in Philips's cleanrooms or they could order specific devices or material to be made in those cleanrooms. These services enabled small companies -e.g. start-ups that were not able to invest in such infrastructure themselves- to join campus and do their R&D activities in Philips facilities or using Philips services at the cots of flexible financial agreements.

Sharing facilities to collaborate in research has been facilitated by trust among a network of professionals strongly linked to Philips and the Eindhoven region. For instance, during its specialisation path, Philips divested several businesses by shrinking down to five its product divisions[94]. With the Open Innovation approach, Philips Research was able to attract medium and small enterprises as partners. At the same time, a lot of activities and technologies developed with these partners were divested because they were not fitting in the smaller portfolio of Philips. With the divestments of businesses people who were before employees in Philips began working for those new companies that came out of the divestments. Some established in HTCE, which means Philips began building a very good network of people that they knew in those other companies, making easier the co-operation in research because the relationships were built on trust. Among others, NXP an electronics company established in 2006 is one of the most important examples of this development happening in campus[95]. Philips divested their semiconductors businesses because its production activities were in other regions. This operation included one quarter of Philips Research personnel, which meant around 350 people began working for NXP a newly created company, which bought Philip's semiconductor businesses and settled in HTCE.

The dynamics derived from open innovation affected not only the innovation process in Philips but also affected the structure inside this and other organisations (people changing jobs, new companies created, companies merging, companies acquired, etc.) which accommodated their activities in HTCE[96]. An important reorganisation of activities took place in 2005 when a merger of several Philips departments created Philips Applied Technologies group. In 2011, Philips shifted in general management and launched a new corporate vision labelled 'Improving people's lives through meaningful innovation'. Healthcare became an important industry for Philips focusing on digital innovations. Internal restructuring in Philips continued following its evolutionary path to a specialised organisation. In this year, a large part of the Applied Technologies organisation merged with Philips Research and the services branded as MiPlaza were separated from Philips Research and merged with supplied technologies to form what is known as Philips Innovation Services (PINS). This entity operates also for external parties located outside HTCE.

94 In 2004, Philips' product divisions focused on medical systems; domestic appliances & personal care; consumer electronics; lighting; and semiconductors.

95 NXP has grown to a successful company headquartered in Eindhoven with research and development activities in several locations in Asia, Europe and USA. Its key innovation figures are: 3.000+ employees in R&D activities; $639 million investment in R&D; $4.8 billion revenue; and 8.000+ issued and pending patents (NXP, 2013).

96 Recently, Philips Research has spun out Sapiens and Intrinsic-ID, which locate at HTCE and collaborate in R&D activities with both, Philips Research and NXP.

By 2014, the high tech infrastructure of PINS comprised 25.000m2 of laboratory space & clean rooms and about 15.000 devices of electronic equipment. These facilities are almost unique in the Netherlands[97] and available for all tenant companies locating at HTCE. They are managed by Philips and not by HTCE Site Management. It does so, because Philips offers not only space but also a wide range of technical services and facilities, which demand specific expertise and capacity available in Philips. On the one hand, HTCE Site Management outsources Philips' services to provide the full range of services to other tenant companies interested on such services. For instance, new tenants in HTCE get two types of contracts with two organisations affiliated to Chalet Group: a Service Level Agreement (SLA) with HTCE Site Management and a Lease Contract with Calittum HTCE 2 CV[98] for rent and parking space. The first one overs three types of services: Collective obligatory services that are site related (e.g. Energy, ICT, infrastructure, etc.); Collective optional services if needed; and Optional services that are free choice and taken via HTCE Site Management. The use of PINS is part of the last type of services. On the other hand, Philips Real Estate manages the PINS' facilities and therefore, this organisation arranges the contracts with HTCE Site Management. However, there are special services that can be requested directly to PINS and managed within this organisation. Figure 5.26 illustrates how the PINS' operation is organised and managed to offer shared laboratories facilities to HTCE's tenants.

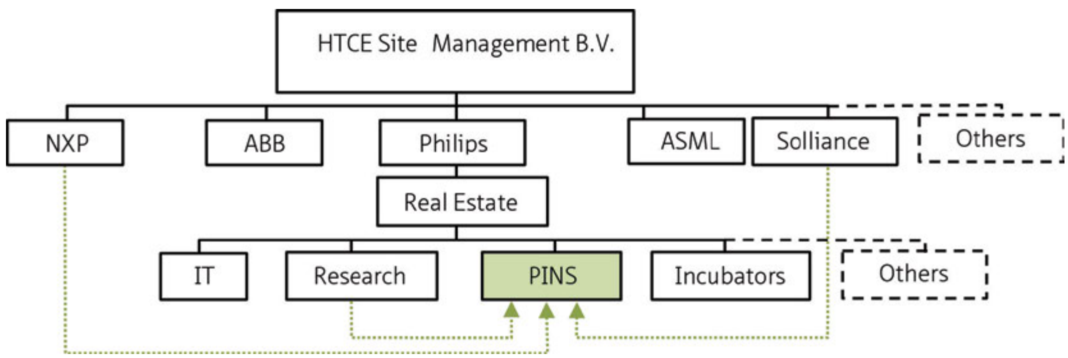


Figure 5.26 Involved organisations in the management and offering of PINS in HTCE. The dotted line represents the possible requests of rental space in technical facilities to PINS.

Overall, having these laboratory facilities and their availability to be used and shared are magnets attracting companies to establish on campus. Besides trust, the willingness to collaborate in R&D projects among residents on campus is driven by mutual benefits. In fact, the whole concept of Open innovation is having an effect in collaborating working patterns. The results from an online survey to HTCE's resident companies have shown that in 2012, about 82% of the respondent companies were working together with other resident companies. The same survey shows that collaboration among tenant companies has grown from 2009. On the contrary, the percentage of resident companies working together with research institutions and universities decreased from 2010 to 2012 (Blick-Marktonderzoek, 2012). This last issue is discussed further in section 5.4.

97 In a 2013's interview, an officer of Philips Innovation Services mentioned that some comparable facilities are found in Dutch Universities of Technology but of smaller size and with less functional variety. Standard laboratories facilities like these are large and costly. Accordingly, the broad focus on various technologies, the size and the flexibility are the aspects distinguishing PINS' facilities from others. This is the legacy of the diversification path of Philips in the past.

98 Calittum HTCE 1&2 is the legal entity at HTCE focusing on real estate properties (Land & Buildings). Next to it there is Chalet HTCE Development BV focusing on new real estate developments at HTCE.

Brainport Development Business Centres: shared facilities for start-ups

As mentioned before, Brainport Development N.V. is the government agency that aims to enhance the prosperity and well being of Brainport Eindhoven region. This agency covers a wide range of activities in five sectors: strategy; projects and programmes; communication; business; and SME services (Brainport development accessed October 2014). Indeed, developing physical infrastructure to support innovation -such as R&D facilities or business centres[99]- became part of Brainport Development's tasks. Brainport has considered three alternative locations for its R&D and business facilities: HTCE, Science Park TU/e and in the Automotive Campus in Helmond built in 2009. Brainport Eindhoven region considers these campuses as strategic locations when accommodating office space or lab facilities for SMEs and research institutes. Indeed, it is believed there are more opportunities for boosting collaboration among different organisation in these campuses because of the critical mass of researchers sharing spaces in these sites. This reason has led Brainport to strengthen and protect the concept of campus, which is increasingly used to market spatial development in Brainport region.

In 2007, Brainport Development built the first phase of ßeta Technology & Business accelerator in HTCE (HTC-9). It was the first development built and exploited by an external company in Philips' campus then. This facility accommodates shared business accommodation for start-up companies in high tech fields. The second phase of the building was completed in 2012, offering in total 10.500m2 (UFA) of office space, conference facilities and laboratory space for electrical engineering and physics. In 2013, Brainport Development built a new facility with office and lab space for SMEs focused on Life-tech and new energy technologies, Mµ Technology & Business Accelerator. The new building is the fourth of Brainport Development's business centres[100]. These two business centres of Brainport Development are two exceptional cases in HTCE development.

These facilities are the two only buildings in campus that are developed and managed by a different organisation rather than HTCE Site Management. Brainport Development, as a government agency, developed these facilities with subsidised funding bounded to certain restrictions. To strengthen Brainport Region as a common goal, HTCE Site Management (and previously Philips) has allowed Brainport Development to build and to manage these buildings independently. Accordingly, the tenant companies in these two buildings have direct contracts with Brainport Development instead of with HTCE Site Management. However, these two organisations have acquisition meetings to align their demands in attracting and accommodating companies in HTCE. In addition, Brainport Development has a service agreement with HTCE Site Management for the common services and a lease agreement with Calittum HTCE 2 for the parking spaces. In 2014, these two business centres were located next to each other [See Figure 5.27]. They are the only two offices and laboratory buildings in HTCE's West zone, which is characterised by the presence of the sports fields and the day-care centre.

99 The so-called business centres are facilities to accommodate the business activities of small companies to boost their success and quality. These business centres offer common standard services such as receptionist, secretarial services and meeting rooms. Brainport Development facilitates the provision of additional services or flexibility in rental agreements according to the demands of the new and young entrepreneurs. For instance, low investment costs at start-up, flexibility in the rentable space, rental period and notice and ready for immediate use. (Brainport Development, accessed in 2015)

100 The other two business centres locate at TU/e Science Park and are referred to as incubators.

1 ßeta Technology & Business accelerator

2 Mµ Technology & Business Accelerator.

Figure 5.27 Brainport Development Business Centres located in HTCE. (Photos: 2013)

The parking garages

The parking garages are one of the three types of shared facilities in HTCE. They are important because the garages' shared and non-exclusive use has strengthened the experience of the campus as a common place, rather than a collection of separate buildings assigned to different firms. Having centrally located garages in different zones has allowed more intense use of the public space and has strengthened the sustainability image of the campus and the area [See § 5.3.1]. In 2014, HTCE had 5.000 parking lots in three types of parking garages facilities located in different zones of the campus. These are distributed in four garages in campus north, one garage in the central avenue and two garages in campus south [See Figure 5.28].

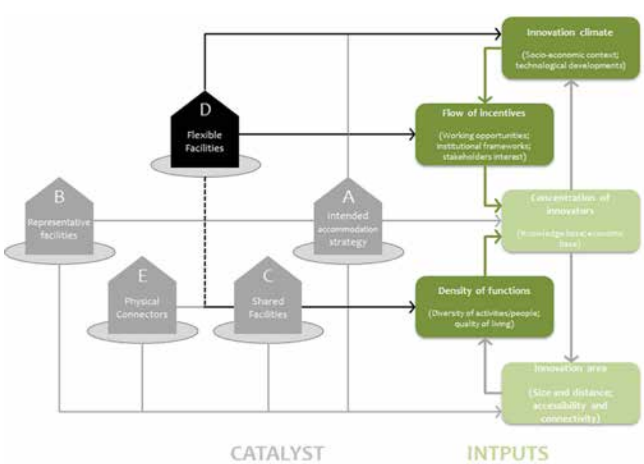
Figure 5.28 HTCE shared parking garages

Initially, the idea to provide centrally located multi-storey parking facilities resulted from the desire of attaining a green look, by minimising the amount of paved ground area. This idea was approved regardless the opinion of some users, who found this scheme inconvenient. In the 1999's master plan the design team proposed two types of parking facilities: five buildings in north that mostly remained as planned and a large building in south that was also an attractive high-tech billboard wall visible along the A2 highway. However, this last proposal was adjusted to four parking garages to be hidden from the highway with green slopes that act as noise barriers. This new proposal was financially more feasible. In addition, this solution offered more flexibility to be developed in different phases and it was friendlier with the desired green outlook for the campus.

Nevertheless, there have been other adjustments to the parking facilities proposal, which deviated completely from the initial plan and resulted from specific users' demands. For instance, the parking garage in the campus south by the pound and the one in the central avenue are examples on how users' needs and preferences influenced campus development. Indeed, the first one is remarkable because the change in the location of the parking facility came from a demand of Philip's semiconductor division, alleging that was more convenient for the end users to have this facility closer to their building. The project team saw accepting this change as a political decision, which was contradicting the campus design principles. Currently, these types of exceptions are not allowed anymore with the implementation of the Zoning Plan since 2012. Nevertheless, the role of enforcement and stakeholder's power in the development of HTCE will be discussed further in section 5.4.

Overall, these facilities are in fact a necessary infrastructure in campus, considering car is the most efficient transportation mean to access HTCE. However, it is remarkable how their concept design transformed them into special infrastructures that have strengthened the brand identity of the HTCE.

§ 5.3.4 Campus intervention D: Flexible facilities



Building flexible facilities has been an important catalyst for innovation in the long term. An important success factor of the Eindhoven region is being attributed to its capacity to reinvent itself according to the shifts of the technological paradigms affecting its economy over time [See § 5.2.5]. The same shifts affected the research activities in Philips calling for adaptation processes and restructuring of ways of working from fundamental research in the beginning of the 20th century, to market oriented research in the 1970s and to open innovation since the early 2000s. This adaptation of research activities has allowed Philips to positioning as a leading innovative company and to its hometown Eindhoven as a competitive region. Ultimately, these research activities were accommodated in specific facilities that enabled change for more than 50 years.

In HTCE, rational and functional buildings have facilitated the accommodation of the changing requirements of research activities and processes. The functional design principles were present in the Complex-W and inspired the second generation of buildings proposed in the 1999's master plan for HTCE. The following paragraphs illustrate with examples how building flexible facilities has been a catalyst for the density of function by allowing diversity of activities under one single roof; for the flow of incentives by channelling capital in a more efficient way; and for the innovation climate by accommodating the changing social and technological requirements of research activities over time.

The buildings of Complex-W

As mentioned before, in the 1960s Philips developed a set of buildings outside of Eindhoven to accommodate the rapid growth of the Nat.Lab's research activities, which expected a population of 3.000 people in the 1970s. From that moment until 1999, the site was known as Complex-W referring to Waalre, which is the village in the south of Eindhoven where the site located[101]. According to De Vries (2005), the actual move to the Complex-W started in 1963. The new group of buildings and the internal road network with two main access points determined the compact and straight layout structure of the campus up-to-date [See Figure 5.29]. The structure of the complex was based in a design and/or planning arrangement dictated by the functionalist reasoning of modern architecture, which was an appreciated architecture movement at the time[102]. The complex was dominated by large and straight-shaped buildings[103] connected by bridges, which configuration resulted from the necessity to concentrate and connect functions in the Nat.Lab. Likewise, the internal layout configuration of these buildings emphasized the use of central and double-loaded corridors for efficient circulation. This has been facilitated by the modular structure and light partitions that could be easily removed when needed. Regardless their tall or horizontal shape, these buildings were modest in appearance and made use of high ceilings and patio's configuration for obtaining a flow of window light in the functional areas.

These buildings accommodated various activities of Philips Research, including laboratory, office space and classrooms. The former Building WB (current HTC34) is an example of a building that accommodated several functions including a main library, an auditorium, classrooms and even its lobby was used several times to host congress or social events.

In 1999, the Masterplan of the Philips High Tech Campus proposed the renovation of several existing buildings of Complex-W, which Philips initially considered to demolish with the construction of the new campus. Instead, the designers outlined the benefits of keeping some of these buildings because of the implicit value of their physical characteristics meeting the goals of Philips' vision (synergy and efficiency in R&D activities). Between 2001 and 2014, around 70.000 m² of the existing buildings have been renovated. These buildings have accommodated Philips Research's activities and their changing processes for more than 50 years[104]. One of the latest and most remarkable renovations is the one of the

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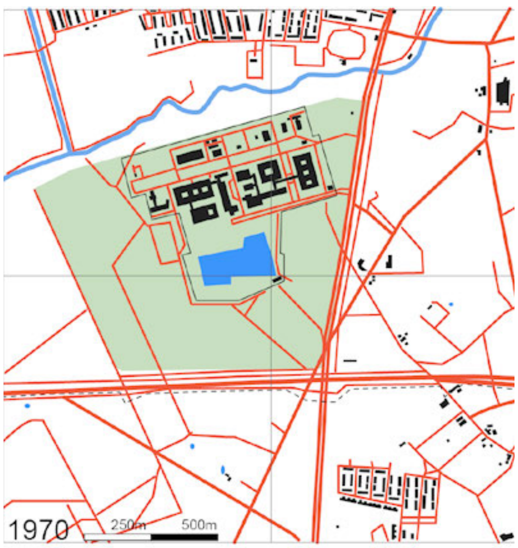
101 In 1972, a municipal rezoning brought the Complex-W back into Eindhoven's administrative boundary.

102 Functionalism or 'Nieuwe Bouwen' movement in the Netherlands dominated in the period 1920-1940 and concerned with light, air, hygiene and a functional use of materials and technology (Mattie et al., 1995). This movement was characterized by the combination of rationalism and functionalism. Thus, a distinction is made for both terms, 'so that rationalism here is taken to mean the striving after the most efficient realization of architecture as material structure, with the aid of the most economic and expedient materials, constructions and building methods and functionalism as the striving after the most efficient realization of a programme of requirements by means of the most economic and practical spatial forms and the most expedient amenities'(Van Woerkom et al., 1982).

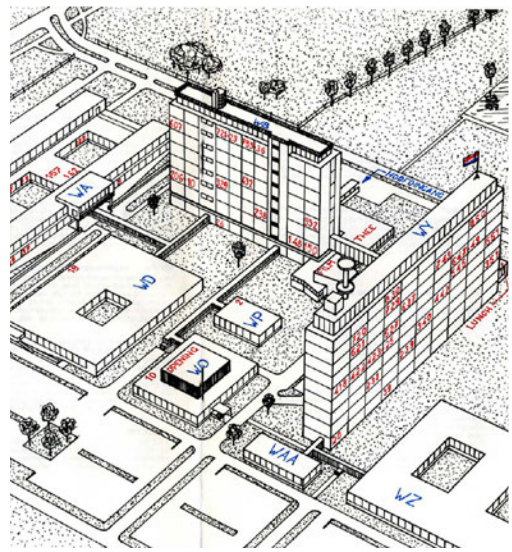
103 Two main shapes were identified: a) squared or wide rectangles, which were more horizontal buildings; and b) rectangular bars, which were buildings of 8+ storeys height – e.g. Buildings WB and WY built in 1968 with an approximate GFA of 25.000 m^2.

104 The renovation of two landmarks buildings of Philips Research strengthened the desired image of the campus. The former WY Building (HTC-37) and WB Building (HTC-34) were two separate interventions (25.000 m^2 each) including interior design, façade

former WD Building or HTC-33 completed in 2011. This building was still in the list to be demolished, but in 2006, Philips decided to keep it because it was chosen as the new location of Philips Design. This Philips' department was located in the city centre of Eindhoven but needed a new location in HTCE in line with the concentration strategy of Philips activities. This intervention marks a precedent for the research activities in campus since it will strengthen the role of design together with applied sciences and engineering in R&D. In this case, the end-users (mostly designers) made a preference for the renovation of an existing facility rather than building a new one. According to the architects, the renovation of this building was particular in the design process because it was based on the spatial preferences of the creative workers for flexible work places, high ceilings, openness and diversity and high-standards in interior design. For instance, the users choose to be in a spacious building dating from the 1961, which consisted of a single storey of over 5.000 m^2 with a patio in the middle. This building has a steel skeleton that was kept in sight strengthening the industrial look desired by the users and allowed the implementation of the Work Place Innovation concept (WPI), which is the Philips standard for flexible working. Indeed, the buildings of the former Complex-W have succeeded to adapt to these changes in Philips ways of working.



1 Situation of the Complex W in the 1970s



2 Perspective of the Complex from 1968

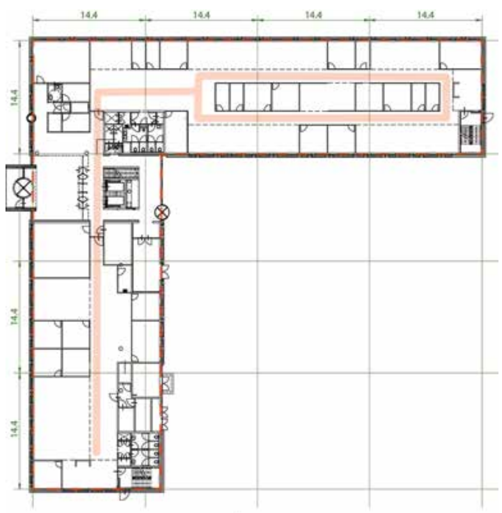
Figure 5.29 Group of buildings in Complex W. (Data map: Topografische Dienst Nederland, 1970 retrieved from the physical map collection in TU Delft Map Room). The perspective of the Complex (2) was used in the program for the opening of Building WY on September 18, 1968 (Source: N.V. Philips Gloeilampenfabriek retrieved from www.hagenbeuk.nl)

Overall, the quality obtained with the renovation of the buildings has been satisfactory for Philips, who is the main user of the existing facilities of the former Complex-W. This is demonstrated by its increased intention to renovate buildings that were subject to demolition in the HTCE's plan. Another example is the former Building WA (current HTC-48), which renovation has been completed in 2014 to concentrate the R&D activities of Philips Lighting. Up to 2014, there were still three important facilities to be demolished, including Building WAG (current HTC-4). This building accommodates important laboratory facilities (e.g. PINS' clean rooms), which relocation is costly and perhaps unnecessary considering this facility has been serving its purpose for more than five decades and it is recognised as one of the top research facilities of the Netherlands [See § 5.3.3].

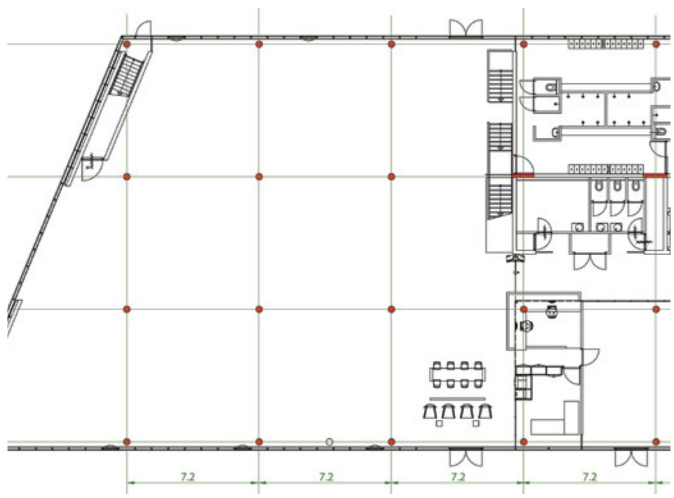
works and technical upgrading, which took several years to complete

The building grid of PHTC

In the 1999's master plan of PHTC, the designers created a building structure allowing the integration of the existing and new buildings in the campus proposal. Thus, the new buildings assimilated the rectangular bar-shape of some of the existing buildings and their orthogonal arrangement, which served to set a new building grid. This grid has a dimension of 14.4m x 14.4m determining both, the urban arrangement and the structure of the individual buildings. This dimension follows a logical scheme facilitating the use of modular structures. The grid has allowed spatial flexibility in the buildings. It allows to have specialised functions (e.g. laboratories) or general functions (e.g. office) within the same defined pattern. For instance, the internal layout configuration of the new buildings emphasized the use of central and double-loaded corridors for efficient circulation in office buildings and free spaces in specialised buildings including facilities such as the Strip, which is a remarkable example of the flexibility of the grid accommodating different functions under one single roof [See Figure 5.30].



1 *Floorplan of office building with a structure of load-bearing inner cavity sheets (in red)*

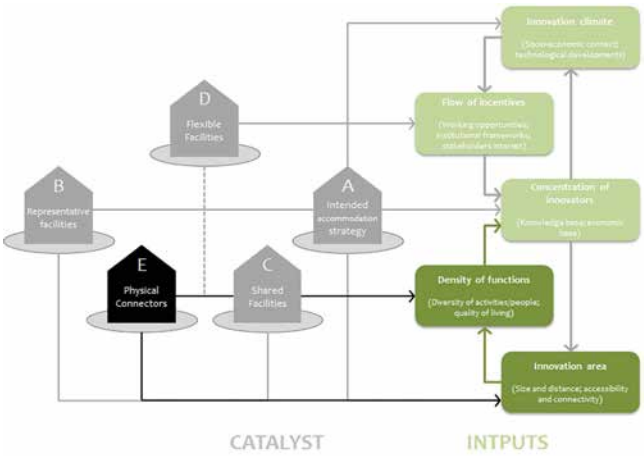


2 *Floorplan section of the Strip (wellness centre) outlining the skeleton structure (in red)*

Figure 5.30 Examples of new buildings on HTCE using the building grid. Florplans courtesy: HTCE Site Management B.V.

Overall, this building grid has allowed accommodating different organisations and their distinctive activities in flexible arrangements. Similarly, such flexibility allows having multitenant office buildings (e.g. ßeta and Mμ Technology & Business accelerators) and different users in one building such as the case of the common central facility, which uses the same building grid. In addition, this flexible grid has allowed having different types of buildings in HTCE (L- or U-shaped buildings defining an enclosed space, landscape pavilions and linear buildings), that increases the diversity in the supply required by different types of organisations. Beyond attaining flexibility, this grid has played an important role strengthening the use of the public space in HTCE, which is illustrated in the following section.

§ 5.3.5 Campus intervention E: Physical connectors



There are different types of physical connectors in HTCE enhancing physical proximity among innovators and therefore, facilitating their chances for encounters and interactions. Those types depend on the different scales in which the interactions between members of the HTCE's community and other communities happen in the innovation area.

At the campus' scale, the public space and the system of pedestrian and bike paths, are crucial physical connectors reinforcing the concept of a central place to be and the common shared facilities in HTCE. This physical infrastructure acted as catalyst shortening the distance between the different users of the campus and improving the accessibility to different functions when using the shared facilities, as well as giving cohesion to the campus as innovation area.

At the neighbourhood's scale, the landscape design and the continuity of the pedestrian oriented system, improve the accessibility and integration of the campus with its immediate surroundings. And at regional scale, the car-oriented infrastructure constitute the main connector shortening the distance between innovators in the Brainport Eindhoven area and facilitating the national and international accessibility to the campus. The following paragraphs illustrate with three examples at those three different scales, the important role of physical connectors facilitating the chances for encounter and interactions between innovators and therefore, acting as catalyst for the innovation area and the density of functions in HTCE.

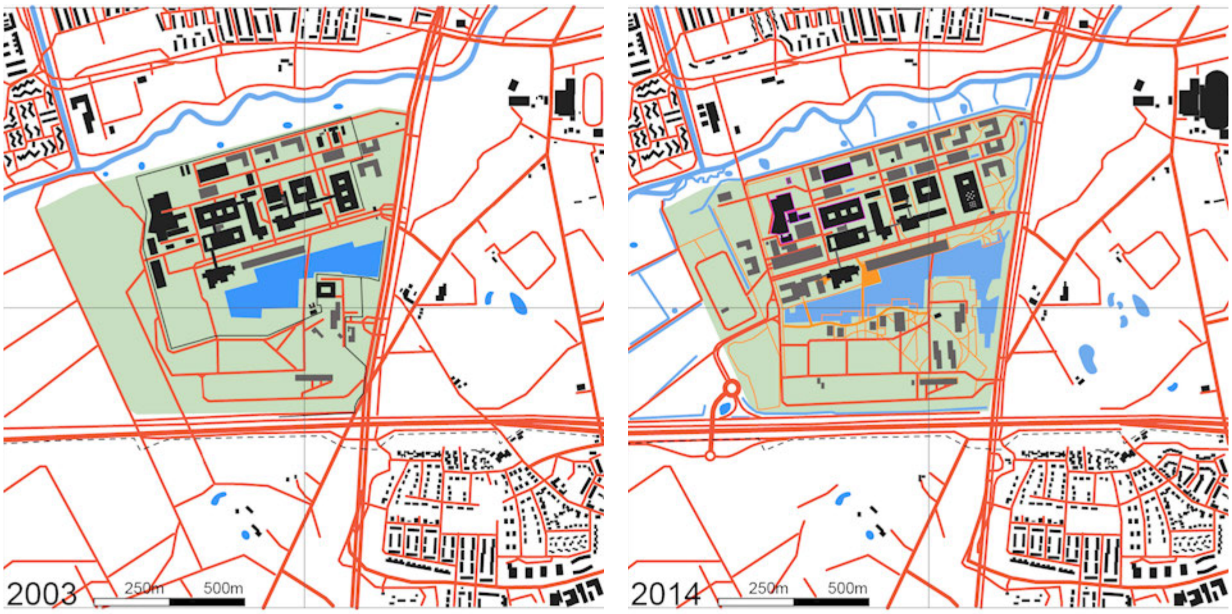
The public space at the campus' scale

The interventions in the public space of HTCE marked an important difference between the former Complex-W and the idea of the campus introduced in 1999. Since the early 1960s until the late 1990s, self-standing buildings connected by bridges dominated the arrangement of the site. Thus, a road network and parking lots to access these buildings occupied a large area of the ground floor. The main landscape feature in the industrial complex was the existing pond at the south, which was valued by the site's users because of its leisure function[105]. The 1999's master plan for Philips High Tech Campus emphasized the landscape strengths in the campus atmosphere. First, the design had the ambition to preserve the ecological quality of the area, by giving meaning to the existing landscape features. Second, it wanted to create a strong scenic landscape for high-tech architecture, by freeing the centre of the campus from car-traffic.

For instance, the proposed building grid helped facilitating these ambitions. Its constrained arrangement set up relations between the length and height of the buildings, which became smaller than the existing ones. Accordingly, the standard building height is between 4 up to 6 storeys and the maximum building

105 Having the time for walking around the pond during lunch is stressed as an important functional demand claimed by the employees of the Nat.Lab in the 1960s (De Vries, 2005)

length became five modules of 14.4 meters. In this sense, the design proposed the occupation of the land with a lower built density, which emphasized the horizontality and spatial openness of the design to integrate with the landscape. As a result, the road network became simpler by implementing a traffic route concept in the perimeter and a quiet campus heart for pedestrian and cyclists, who share paths. This logic has given importance to walkability, where a pedestrian network of paths became noticeable in the last years reassuring the orientation of the design towards the use of open spaces [See Figure 5.31].



1 Situation of HTCE in 2003

2 Situation of HTCE in 2003

Figure 5.31 Comparison of HTCE development from 2003 to 2014. Buildings from Complex-W connected by bridges are in black. Red: road infrastructure. Orange: pedestrian and bike paths and squares. Blue: water.(Map: Flavia Curvelo Magdaniel, 2014. Data: Topografische Dienst Nederland, 2011, retrieved from the physical map collection in TU Delft Map Room and Juurlink+Geluk B.V., 2014)

This system of physical connectors responded to the functional necessity to improve the access from the office buildings to the common facilities (e.g. parking garages and the Strip). For example, developing a large building as central facility was costly and to prevent residents of not using it, Philips made a decision to close the canteens, restaurants, auditoriums or large meeting rooms in the existing buildings. Along with that, several bridges that connected the main buildings of the old Complex-W were turned down, which in turn favoured the use of the public space and the pedestrian paths.

As can be illustrated in Figure 5.31, the pond extended in surface emphasizing the central feeling in campus as the place to be (and enjoy) and the environmentally friendly image of the campus. In addition, there has been an increased attention to use the open spaces for diverse activities, which help building community in HTCE. For instance, HTCE Site Management stimulates a number of initiatives for tenants in open spaces such as gardening, food fairs, social events, open cinema for families, etc. The concept of central place has succeeded in gathering people in informal or formal settings, whereas the open space plays a complementary role to increase the density of functions and people [See Figure 5.32]. Another complementary initiative to increase the use of open space is a bike-sharing system inside the campus. Accordingly, residents can borrow and return Campus bikes at the desks of several buildings in campus.

1 *Food fair at lunchtime during 2014's summer season*

2 *Ice skating at lunchtime in the winter season (Photo: Michael Murdoch retrieved from Bits & Chips, 2012)*

Figure 5.32 Different functions of open space at HTCE's central place.

Landscape design at the neighbourhood's scale

An area called the Klotputten surrounds HTCE. The province indicates this area as an important 'green and blue cover' which is reserved for agricultural and environmental conservation. Indeed, within a radius of 1km from HTCE's central place, there are only outdoors and few residential areas. The research organisations located at HTCE are the only innovators in the neighbourhood. Thus, the physical connectivity at this scale is in fact strengthening the image of the campus as one of the Eindhoven's outdoors to enjoy for the neighbouring communities. An important intervention facilitated HTCE's physical integration with its surrounding neighbourhood.

Until 2006, the campus was a gated site separated from its (sub) urban context. In that year, parts of the gates of the campus were removed when the campus fully occupied the available area for development (103 hectares) so-called 'the smartest square kilometre of the Netherlands'. The campus evolved from having one single and 24/7 controlled access to having three entrances, which were open to the public and without control in daytime during working days. This intervention allowed the continuity of the existing internal networks of physical connectors in campus towards the city. For example, a bike bridge was built on the northwest side over the Dommel in 2007. This will improve the accessibility of the campus with the city of Eindhoven and the neighbouring areas, especially for the campus' residents who commute to work using bicycle. Overall, the integration at neighbourhood level pushed the improvement of the HTCE's accessibility by means of public transportation, which is outlined at a regional scale as follows.

The road infrastructure at the Brainport-Eindhoven region's scale

In the early 1960s when the Nat. Lab moved to Waalre, the site chosen for its location was already defined by the presence of a highway to the south. This highway known as A67 motorway in the Netherlands is a European route connecting Belgium and Germany (E34) through the Netherlands. The delineation of this route would not only set up a limit for expansion of the campus but would also determine the relationship of the campus with the city and its accessibility at wide regional, national and international scales. As mentioned in § 5.2.2 this motorway intersects the A2 motorway or Knowledge axis, which is an important connection for Brainport Eindhoven region with other two economic areas in the Netherlands [See Figure 5.33]

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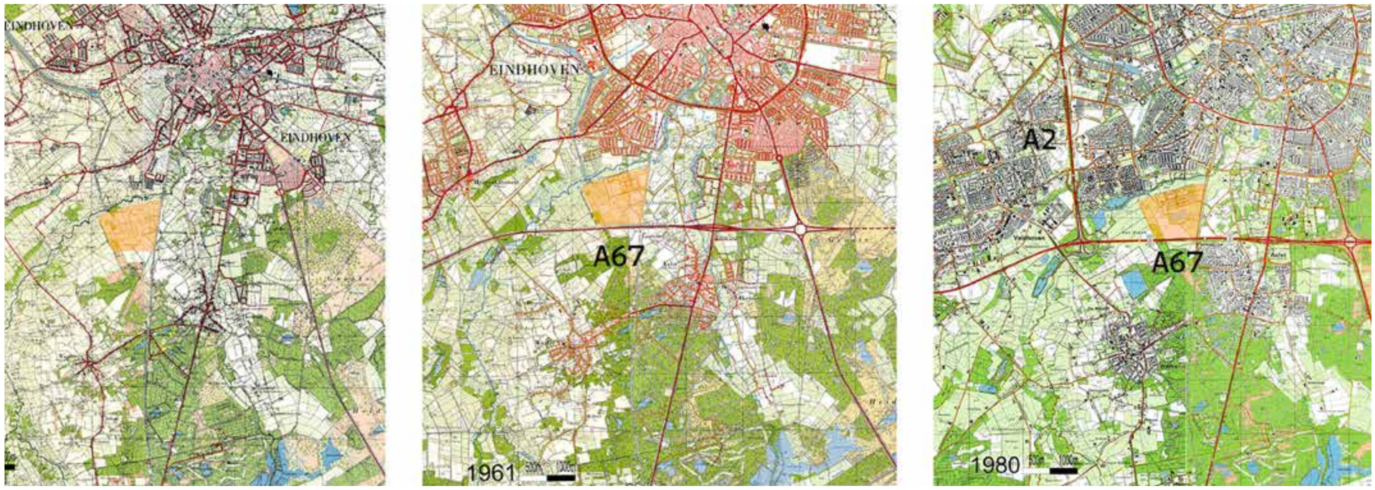


Figure 5.33 Location of HTCE's site (indicated in yellow) and the development of the regional road system from 1949 to 1980

Since 1972, this highway has defined the administrative boundary between Eindhoven and Waalre after a municipal rezoning, which also brought the campus' site back into Eindhoven. For several years, this highway was just a border limiting the expansion of the campus to the south until a functional need to improve the accessibility of the campus came to place. Since 2001, Philips pursued the construction of an additional access point to the campus directly from the highway. This unplanned intervention became a unique development in the Netherlands, since it involved granting permission to a private company at national level[106]. In fact, the permission was granted after Philips announced the campus will open for external parties and the access will serve multiple purposes. Otherwise, it could have been seen as a state aid to a private company because of the national character of this road. Philips assumed all financial cost of the project including the bridge and the roundabout.

With the new access through the highway, the location of the campus took a different dimension. Indeed, the access improved the accessibility of the campus at regional level (national and international) rather than at urban level (city). Furthermore, this access point allowed connecting the campus with Eindhoven Airport within 15 minutes by car[107]. The same intervention generated high traffic in the West of the campus because soon it became the main access point to the campus, especially for the personnel living in (and visitors coming from-) cities or villages different than Eindhoven. In that regard, HTCE Site Management has raised some concerns about the capacity of the parking infrastructure to be considered in the future developments in campus. In addition, the management organisation encourages the use of carpooling initiatives among campus residents. For that, HTCE site management started using a pilot initiative allowing people who work on the Campus, but also visitors, to easily and flexibly share car rides through a special app (HTCE Site management). This initiative resulted from a functional and sustainable ambition, but has also strengthened the concept of open innovation allowing contacts among the residents of HTCE.

106 The A67 is a Dutch national motorway (Rijsweg in Dutch) under the scope of Rijkswaterstaat, which is an 'agency part of the Dutch Ministry of Infrastructure and the Environment responsible for the design, construction, management and maintenance of the main infrastructure facilities in the Netherlands' (Rijkswaterstaat Leefomgeving - Dutch websites on waste and environment).

107 Eindhoven Airport is The Netherlands' second largest airport with direct connections to over 70 European destinations including London, Berlin and Dublin (HTCE, 2015).

Regardless the importance given to car-oriented infrastructure in HTCE's development, there has been an increasing attention to improve the accessibility of the campus in relation the city of Eindhoven in terms of transportation means. This is important because the Eindhoven's Railway Station is the major interchange for fast inter-city train services to Amsterdam (Schiphol Airport), Rotterdam and other neighbouring cities in Belgium & Germany. Thus, the Municipality of Eindhoven and Philips pushed through the creation of a direct bus line between Eindhoven Centre and HTCE (Hermes Line 407). This collaborative initiative was possible to implement after the Philips removed part of the campus' gates in 2006, which opened the existing internal road network in campus to the city. Up to 2014, the Hermes Line run directly from Eindhoven's city centre to HTCE. The bus' route passes through five stops distributed along the campus boundary. The line runs every 15 minutes in peak hours and every 30 minutes off peak hours. Additionally, there is another bus line (17) connecting Eindhoven with Waalre that stops at HTCE. Overall, the location of the campus outside the city has determined its car-oriented accessibility, which is nowadays an issue to improve in campus development.

§ 5.4 Discussion

In the previous sections, the development of HTCE has been studied as a historical phenomenon linked to a specific context in which innovation has been successfully stimulated. This study has used an analytical framework to validate the proposition that built environment can be a catalyst for innovation. For instance, it has been illustrated with examples how five type of interventions on HTCE have facilitated specific conditions, which altogether have supported the processes leading to innovation in HTCE and the Brainport-Eindhoven area. Similarly, few issues related to these interventions have been found through the analysis. They deserve special attention because these issues can hinder the role of the built environment as catalyst for innovation. Thus, this section will discuss these findings based on the available empirical information and the research proposition above.

§ 5.4.1 Relationships between the campus interventions as catalysts for innovation

This study suggested that the built environment as a catalyst for innovation has taken place by means of specific interventions, which appear to be related in the case of HTCE. For instance, two relationships are distinguished because of the nature of each intervention facilitating the conditions for innovation.

The first relationship is defined by interventions of strategic nature, which outline the role of management and planning in campus development. These are intended accommodation strategy and representative facilities. These interventions were directed to support the strategic visions of Philips and the Municipality of Eindhoven in the long-term, which turned out to have unexpected impacts for the region. Over the years of HTCE's development, both organisations made agreements securing each other's interests. For instance, these interventions have helped to establishing and maintaining a collaborative relationship between Philips and the city of Eindhoven in fostering the economic development of the city. That relationship based in trust is passed to the current campus' management organisation, which was a former Philips' organisation. In first place, these interventions have facilitated the concentration of innovators in the Brainport-Eindhoven area, which is the basic condition for innovation. In second place, these interventions together have been crucial in defining the innovation area and building its identity [See § 5.3.1 and § 5.3.2].

The second relationship is defined by interventions of operational nature, which outline the role of planning and design in campus development. These are shared facilities, flexible facilities and physical connectors. These interventions were alternative responses in solving the accommodation needs of Philips core businesses in campus: research & development. Simultaneously, these interventions have shaped the social and working environments in HTCE. For instance, translating Philips' research principles into an accommodation solution that was meticulously planned, allowed Philips building flexible facilities. Correspondingly, these facilities accommodated different types of activities and people, who shared spaces under one single roof, while creating the opportunities to meet and communicate thorough physical connectors [See § 5.3.3, § 5.3.4 and § 5.3.5]. These interventions have facilitated mainly the density of functions, activities and people, considered to accelerate the process of technology transfer as part of Philips' Open Innovation model.

The nature of these campus interventions not only defines the relationships among them, but also the involvement of various stakeholders in campus development [See Figure 5.34]. These stakeholders have different perspectives on campus interventions as catalyst for innovation. Such differences have raised a number of issues that can inhibit the catalytic action of these interventions. These issues will be discussed in the following section.

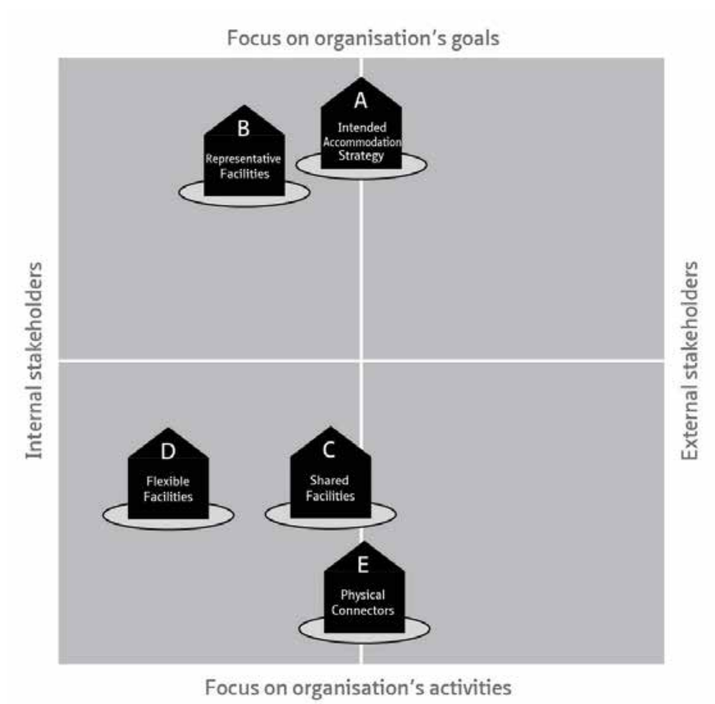


Figure 5.34 Relationships between the campus interventions according to their strategic or operational nature.

§ 5.4.2 Stakeholder's perspectives on campus interventions as catalysts for innovation

Section 5.3 slightly mentioned some issues related to each campus intervention, which can inhibit their function as catalyst for innovation. These issues are not exclusive to a single intervention and that is the reason they are addressed in this section. Rather, these issues are associated to the stakeholders' perspectives on campus interventions as catalyst for innovation. This means stakeholders perceive innovation in different ways according to their ambitions and perspectives on the built environment.

Therefore, some issues arise when the incompatibility of their ambitions generate a lack of balance in campus interventions. These situations can reduce the action of the built environment as catalyst for innovation and in the long term, they could hinder the innovation processes in the area. The following paragraphs address conflicts between specific stakeholders in different campus interventions and how they become issues that can inhibit the function of the built environment as catalyst for innovation.

The campus in the city vs. the campus as the city

In the late 1990s, Philips selected a location at the southwest border of Eindhoven to concentrate its research activities as part of its corporate accommodation strategy. This location is isolated from the city's urban amenities, which are concentrated in the city centre. Indeed, the natural and physical borders around HTCE have defined its permanent isolated condition since the site was established (e.g. the Dommel stream, the Klotputten and the A67 motorway). Recently, its connectivity with the city of Eindhoven is raising the attention of different stakeholders, whose perspectives on the built environment as catalyst for innovation are aligned but somehow contradictory. For instance, HTCE's stakeholders recognised the necessity to improve the campus' accessibility to the city centre to attract talent and innovators to the campus. Simultaneously, these stakeholders are recreating the functional vitality of a city's downtown on campus' grounds, which strengthen its isolated condition and independence from the city. This paradox is discussed as follows.

For more than a decade, HTCE Site Management has been pursuing the improvement of the accessibility and connectivity of the campus to main urban areas such as Eindhoven, Amsterdam and other neighbouring cities in Germany and Belgium. Indeed, there have been improvements in collaboration with municipal, regional and national governments, which have facilitated such improvements[108]. In turn, these improvements have established the road transport as the most efficient accessibility means on campus, contradicting also the region's environmental goals and creating some internal traffic issues. In the 2012 residents survey, the users have address providing enough parking spaces as the major area for improvement in HTCE. All in all, their long-term efforts are still insufficient to position HTCE as a competitive location to attract high-tech companies (and their young and talented personnel) compared to other urban areas in the Netherlands.

Correspondingly, HTCE Site Management has targeted its efforts towards making the campus' grounds an attractive location on its own. In the last decade, the campus has increased its functional program to compensate the lack of amenities in their surroundings. Up to 2014, HTCE provided enough facilities and amenities to keep their residents satisfied and attached to campus, regardless its poor connectivity with the city. Undoubtedly, this strategy has worked to make HTCE an attractive location for high tech firms. However, this strategy contradicts the vision of integrating the campus with the urban areas nearby, which makes its sustainability uncertain. It does so, because providing almost everything on campus is making campus' connectivity trivial. The main reason residents leave the campus is because there is no housing on the grounds. This function is not allowed on campus and neither on the environmentally protected surroundings, although residents find it an important priority to improve on campus[109].

108 As mentioned through § 5.3, examples of these improvements are: 1) the provision of permits allowing building campus infrastructure (e.g. HTCE's access point from the A67 motorway); 2) the inclusion of HTCE within a national spatial planning policy targeted to improve connectivity of the Dutch economic zones (e.g. the plan for A2-Zone so-called Knowledge axis or Brainport Avenue); and 3) the provision of dedicated transport infrastructure to access the campus from Eindhoven (e.g. the Hermes Bus Line 407).

109 In a residents survey report (Blick, 2012) 'Building a Hotel' scores 9/10 as a priority to improve on campus as an aspect for improvement. The users mentioned that a hotel facility would help to foster the city atmosphere.

Conversely, this factor keeps a balance between the in- and out-campus's functions making sense of the need to improve campus' connectivity. In this regard, it is essential improving HTCE's accessibility from the city of Eindhoven because given the efficiency of the car-oriented infrastructure connecting at regional level; it is likely that some HTCE's residents prefer to live in other areas outside Eindhoven and the Brainport region.

Overall, the location characteristic of HTCE is the source of this paradox, which makes difficult the integration of the campus and the city. This paradox inhibits the roles of the intended accommodation strategy, the physical connectors and the shared facilities as catalyst for innovation. Perhaps, a sounded balance of attractive functions both in campus and the city help the focus on urban connectivity and accessibility rather than an impossible urban integration.

Autonomy vs. Dependency in strategy implementation

The development of HTCE has been strongly influenced by the willpower of Philips' stakeholders attaining their goals. As a private development, the campus was envisioned to support a corporate accommodation strategy and translated to a master plan. The lack of municipal regulations for such development at that time, gave Philips the freedom to experiment in this area. Thus, the 1999's master plan was implemented rationally and deliberately to support Philips' corporate goals. As a result, the campus projects were executed following a hierarchical structure, in which decisions were made following a top-down approach. This approach worked very well when Philips was the campus' owner and single end-user. Thanks to the strict delineation of Philips' objectives and the provision of resources, it was possible to implement many of the projects proposed in the PHTC's master plan.

The development of the Strip is a good example of this. As mentioned in § 5.3.3, Philips closed all the existing canteens, restaurants and large auditoriums in the existing buildings in attaining its goal of creating a central place to meet. Although, the announcement of this intervention had opponents inside the organisation, this and other decisions were made at strategic level and adopted by the employees as a corporate rule. Indeed, most of the changes made to the initial plan for the campus occurred when the general management shifted in Philips. With the change in power within the organisation, some interests on campus changed as well. These were translated into specific interventions that deviated from the plan but were imposed from the top because the master plan was still a flexible planning instrument serving a corporate purpose. According to the architects, who were part of the initial team and have accompanied the campus development up to date, it was difficult to safeguard the campus concepts in every shift of the administration and partly became their role.

Nevertheless, things started changing in the campus' management approach when Philips opened the campus to external companies. To make Open Innovation a successful model for their research activities, Philips needed to adapt also their accommodation strategy in favour of this model. Although, there were established rules on campus, the need to incorporate the demands of the users became visible with the increase of diverse functions in the central area and the flexible agreements for tenant firms. Since 2003, there has been a transition from a top-down approach towards a bottom-up development in campus management and planning. This approach valued the external demands of the potential tenant firms benefiting the internal corporate strategy. In addition, his approach valued the ambition of Brainport Eindhoven, which became very interested in protecting the concept of the campus supporting their economic development goals. Overall, in the changing context of technology development Philips had the autonomy to adapt their accommodation strategy in favour of their core research activities.

In this transition, the selling of HTCE became imminent because its management deviated from Philips' core business. However, to preserve the concept of the campus and the control of its future growth and development a top-down policy was enforced from the municipality but delineated in collaboration with Philips. Since 2012, the HTCE's Zoning Plan (Bestemmingsplan) is setting up the guidelines for HTCE development. This plan is framed within the common spatial planning vision of the municipal, provincial and national governments. For first time in more than a decade, there is a strict regulation limiting the autonomy in campus development. Accordingly, there is no room for emergent change of plans or spontaneous interventions in campus. On the one hand, this instrument regulates campus development favouring the goals of both internal and external stakeholders interested on HTCE's development. But on the other hand, it reduces the campus' flexibility in adapting unexpected changes in the demand for accommodating research activities. Overall, it is difficult to estimate the impact of this policy since it has been implemented recently. However, its efficiency and sustainability is uncertain because it proposes a different dynamic, contrasting with the autonomy that made HTCE a successful development model. In the long term, it can inhibit the role of the intended accommodation strategy as catalyst for innovation.

Arranged vs. spontaneous collaboration dynamics in R&D activities

Attracting high-tech companies to establish on campus and the region is a shared goal of HTCE Site Management and Brainport Development. These two organisations call both the campus and the region, innovation ecosystems. According to both, the richness of these ecosystems is partly based in the diversity of its components (e.g. Multinational corporations, medium size firms, SMEs, research institutes and universities in complementary fields).

At campus level, HTCE Site Management arranges its acquisition strategy aimed to reinforce the concept of Open Innovation Ecosystem. A framework labelled as 'Human Focused Innovation' is used to attract and select tenants companies in the fields of health; energy; and smart environments based on specific technology domains. This acquisition strategy is measured by tracking the number of companies per segments and R&D projects in an annual review. In 2014, HTCE grew to an ecosystem of 125+ companies of different types[110] employing around 10.000 people working.

As mentioned in §5.3.3, the provision of shared laboratory facilities supporting the Open Innovation concept is a magnet to attract R&D organisations to locate at HTCE. Indeed, HTCE's residents enjoy the availability of specific equipment and services in these facilities and the possibility to collaborate in research projects with interested parties. Regardless the seducing factor of these facilities for R&D companies, HTCE Site management is aware that the isolated condition of the campus diminishes its attractiveness in comparison with other business locations in urban areas. Therefore, HTCE Site Management looks beyond attracting but also retaining residents through an approach that it may work better for specific types of organisations.

On the one hand, arranging the diversity of the ecosystem via defined selection mechanisms can be an effective tactic to stimulate the collaboration but only among certain types of organisations. For instance, HTCE Site Management carries an annual online survey to assess residents' satisfaction. Accordingly, the overall satisfaction of the companies with HTCE has increased in the last four years (Blick, Residents survey report 2012). Though, the results of this survey vary per type of organisation in campus and

110 These types include High tech manufacturing businesses; High tech businesses (only R&D); Research Institute; service companies; and others (e.g. knowledge management company, clinical R&D; Employers association; sales & technical support, among others)

aspects assessed[111]. For instance, in these results research institutes were less satisfied with the mix of companies at HTCE. Correspondingly, the percentage of resident companies that were working together with research institutions and universities decreased between 2010 and 2012. In fact, several residents addressed the presence of university students and people from social sciences as a major priority to improve in campus. These figures give an indication of the narrowed business orientation of the Open Innovation model, making explicit the difference between the logics of non- and for-profit sectors in sharing knowledge and transferring technologies. Generally, locating in one place a mix of R&D organisations working in complementary sectors does not guarantee their willingness to collaborate in research projects. Indeed, the 'fitting-into-the-selection-mechanism' tactic is helping to generate an exclusive environment that might be neglecting the relevance of other potential organisations enriching the ecosystem.

On the other hand, HTCE Site Management promotes building community and creating sense of belonging as an essential factor enhancing the collaborative environment at HTCE. For instance, HTCE Site Management stimulates a number of initiatives that strengthen the sense of belonging to a HTCE's community (e.g. gardening, networking and social events targeting businesses and family groups, sports tournaments targeting international communities, etc.). Section 5.3.3 and 5.3.2 illustrate the facilitating role of the HTCE's common facilities and open spaces in fostering campus community. In 2014, HTCE Site Management developed a website to bring these initiatives together in an online High Tech Campus community (https://mytechcampus.nl/), which works as a private social network where members of the community can post and are informed about the activities and the interests they share.

These types of tactics reflect the interest of HTCE Site Management to stimulate social proximity besides intellectual proximity, believed to boosting the effectiveness of the ecosystem. So far, there is no evidence supporting or refuting the efficiency of this type of tactics either strengthening the collaborative model or retaining organisations at HTCE. Perhaps, the synergy of the existing network in the Brainport Eindhoven region is a good example to replicate at campus level. However, as shown in §5.2.5 it takes time and resources to build such network based on trust, while the demands of organisations are in constant change. Indeed, neglecting the dynamic demands of end users can inhibit the role of shared facilities and physical connectors as catalyst for innovation.

§ 5.4.3 Final remarks and case recommendations

The observations discussed in the previous paragraphs illustrate the relationships between campus interventions as catalysts for innovation involving different stakeholders (e.g. campus managers, campus planners, campus developers, local and regional governments and users). In addition, it has been illustrated how these stakeholders have different perspectives on campus interventions, which can in turn, inhibit the actions of these interventions as catalysts for innovation.

Undoubtedly, there is an alignment among most stakeholders involved in HTCE's development to stimulate innovation as means for economic development. However, there are different layers in which innovation is perceived and promoted by these stakeholders. Likewise, these perceptions have changed over time, making evolutionary the role of some built environment's interventions as catalyst for innovation.

111 Most of the respondents of this survey worked for service companies and high-tech manufacturing businesses and only 5% of the respondents worked for a research institute.

HTCE's end-users tend to perceive innovation in two ways. In first place, innovation is seen as a process driven by the exchange of ideas because campus development is a solution to accommodate their research activities. Therefore, they seek facilitating their changing research activities through the built environment. For example, in the 1990s, concentrating all the activities in one location was a means for Philips to increase the synergy of its R&D activities dispersed in different locations. In the 2000s, developing shared facilities to attract external users was used also by Philips to stimulate their transition to open innovation. Today, renting space at a representative built environment is a means for SMEs and other residents companies to access high quality services and a network of potential partners to boost their R&D activities. Therefore, the concentration of R&D firms on HTCE is perceived by end-users as an opportunity to be part of a diverse environment that will boost the processes of knowledge creation, diffusion and its application in developing technologies promoted by the concept of open innovation.

In second place, most end-users also perceive innovation as a market for exchange of capital because of the for-profit orientation of their R&D activities. Thus, they seek to maximise their investments through the built environment. For example, Philips benefited from renting space to external parties in the 2000s and later from the sale of the campus to a consortium of private investors in 2012. Similarly, the current residents are willing to pay high rents at HTCE in exchange for brand, access to networks and services that will increase their returns on R&D activities. Correspondingly, other stakeholders who focus on HTCE as an asset resource (e.g. campus owners, developers, regional and local governments) stress this view on innovation as a market driven by the exchange of capital. For example, the Ministry of Economic Affairs, Agriculture and Innovation has considered HTCE as a campus of national importance because of its potential adding value to the Dutch economy. Thus, attracting firms to locate at HTCE has become a shared ambition of stakeholders who promote the stimulating innovation as a source of economic development on the one hand and as an opportunity to encourage real estate development the other hand.

The three conflicts from the stakeholders' perspectives discussed before in section 5.4.2 can be seen as three examples in which the perception of innovation as a market driven by the exchange of capital has been dominant in HTCE's development:

- Investing resources to developing a campus as a city because of its isolated location characteristic, while paradoxically improving its accessibility to urban areas as an urgent resource because of its lack of attractiveness as a business location;
- Giving private parties autonomy for strategy implementation at the scale of area development; and
- Arranging collaboration instead of giving room for spontaneous dynamics in collaboration patterns.

Nevertheless, as stressed in the previous section, the trade-off for this perception can also inhibit the role of the built environment as catalyst for innovation at HTCE. Therefore, the following are important points of attention to tackle these issues:

- There is no formula in attracting and retaining R&D firms at a location. As demonstrated by the analysis of the innovation climate, the research activities in industry are changing according to market trends and technology developments. For ***campus and city managers***, it is essential paying attention to the changing demand of campus users and being flexible to adapt to their changing accommodation requirements. Especially now, when there is an evident transition in the way the campus strategy is implemented (from autonomy to dependency in planning) and in the type of users (more international, young and diverse knowledge workers) whose preferences are pushing towards different needs.
- Having an aligned vision of spatial planning, in which HTCE is an important element at national, regional and municipal scales is not enough to improve the isolated characteristic of the site and its vulnerability as an attractive business location. It takes stakeholder's consensus and commitment in delineating not

only a plan but also strategic actions converging to the same goal. For ***campus and city planners***, the main challenge is prioritising a set of concerted actions to convert the site into an attractive location, while keeping satisfied the campus' end-users on the long term. For instance, offering more efficient and diverse infrastructure that will improve the connectivity and accessibility to HTCE is an important aspect to focus the attention.

- Protecting and giving continuity to the design principles of the campus over the years has enabled to create an inspiring and representing built environment that is highly valued among the campus residents. For ***campus & urban designers***, the most important point of attention is preserving in the campus brief the functional roles of shared facilities, physical connectors and flexible facilities.

§ 5.5 Conclusions

This chapter studied the development of the HTCE to gain and provide understanding of the roles of the built environment in stimulating innovation in Brainport Eindhoven region. The guiding questions of this chapter, providing such understanding, will be answered as follows.

How has the HTCE been developed?

This chapter illustrated that HTCE has been developed through specific decisions and interventions over two important periods of technological developments worldwide. It started in the 1960s as an industrial site to accommodate the growing research activities of the Philip's Nat.Lab, which was referred to as Complex-W. Later, in the 1990s the redevelopment of the site was branded as a campus intended to concentrate all research activities of Philips dispersed in Eindhoven. A so-called high-tech campus became the solution to support both, a corporate accommodation strategy and the regional ambition to keep Philips as major source of economic activity and employment in the area. Over the last decade, this campus has evolved into an ecosystem of over 120 organisations working and supporting R&D and high-tech sectors.

Within these periods, important decisions and interventions defined the way HTCE has been developed. First, it was the selection of a location at the southwest outskirts of Eindhoven to concentrate Philips' R&D activities, which has defined HTCE's accessibility, functional brief and rural image over a long period. Second, it was a given autonomy to explore design, planning and area development concepts, which defined the physical and functional features according to the internal preferences, making the campus a unique R&D site in the Netherlands at the time. And third, it was the political and financial power of Philips to implement and influence the plan based on the changing demands of their research activities, which evolved from fundamental research to market oriented research and Open innovation.

Since the 1990s until today, HTCE has been serving its secondary purpose as a preconceived area supporting an economic development vision for the future of Eindhoven. In the last decade, there has been an increasing alignment in the spatial planning policies at municipal, regional and national scales, in which HTCE is recognised as an important element in their joint knowledge economy vision. Nevertheless, HTCE is facing a transitional stage in its development. With the purchase of the campus by a consortium of private investors, there has been a change in the structure of campus decision makers, whose main concern is not boosting the efficiency of research activities but obtaining returns on their real estate investments. In addition, the autonomy enjoyed by the early campus developers in planning and design limited to the adoption of the HTCE Zoning Plan since 2012. Although, this was an important tactic of Philips and the municipality of Eindhoven to ensure the continuity of the design principles in the remaining area to be developed by the new campus owners, it is uncertain how the dynamics of the research activities will evolve and how flexible the already set campus will be to accommodate future change.

Why is the overlapping characteristic of the HTCE in relation with the city evident?

In an international survey of 39 technology campuses [See Chapter 3], it has been observed that HTCE has an evident characteristic in relation to its hosting city regarded as 'Touches'. Accordingly, the city 'Touches' the campus – i.e. HTCE is perceived as a separate area that is located at the southwest border of the city of Eindhoven.

Indeed, the 'Touches' characteristic of HTCE in relation to the city of Eindhoven is the result of different conditions (intended and existent), in which the campus and the city evolved to be isolated. First, the site where Philips decided to concentrate its research activities in the 1990s was a former industrial complex developed in the 1960s to accommodate the growing activities of the Nat Lab outside the city centre of Eindhoven. The site was located in the neighbouring town of Waalre until a municipal rezoning brought the Philips' site back to Eindhoven in the 1970s. Second, the area was surrounded by two main barriers, which have hindered its integration either with Eindhoven or with the neighbouring towns. Since the 1960s, the site was already enclosed by the A67 to the south, which constituted a major infrastructure-type of barrier limiting the campus expansion and any spatial connection to the south. Furthermore, the site has been surrounded by farmland covered by green and water surfaces, which the Province designated as an area of environmental protection. Indeed, a stream called the Dommel flanks HTCE to the north, which constitutes a major ecological-type of barrier limiting the integration of the campus with the existing urban fabric of Eindhoven on the other side of the Dommel stream.

These conditions limited the designers' choice to create a campus with its own spatial and functional logic and structure. However, it was a management choice to select this site, as it was later, the imperative decision to improve its accessibility at regional and municipal scales. As discussed before, this 'Touches' characteristic between HTCE and the city of Eindhoven has simultaneously enhanced and inhibited the role of the built environment as catalyst for innovation. For instance, the isolated condition of HTCE location creates the paradox of developing 'the campus as a city vs. wanting the campus in the city' because of the increasing need to improve the accessibility of the site, which is lagging behind the attractive urban areas as business locations. This relationship between HTCE and the city of Eindhoven will remain in the future unless the connectivity of the area will be significantly improved or political action will be required to adjust the existing zoning plan. The fact that housing has not been allowed as a function in the zoning plan shows the municipal ambition to integrate the campus with the city in the near future. And most important, it has impeded HTCE to become a city on its own.

To what extent has HTCE developed influenced by theoretical discourses of stimulating innovation? Is this influence explicit or accidental? Is it possible that the dynamics accommodated on HTCE have indirectly helped supporting such discourse?

As explained in Chapter 4, the proposition of the built environment as catalyst for innovation is based in a collection of theoretical concepts of innovation from economic geography. The empirical information analysed in this case points out that there is a link between theory and practice in the development of HTCE. The discourse of stimulating innovation through the concepts of synergy, physical proximity and diversity people, are at the core of HTCE development. For instance, designers, planners, managers, controllers, developers and policy makers involved in the development of HTCE adhere to the idea that these three concepts are essential for 1) sharing ideas that create new knowledge by means of the social interactions among interdisciplinary knowledge networks and 2) boosting the entrepreneurial environment by means of the trust developed by face-to-face contact.

While it is difficult to generalize the explicit or accidental influence of these theoretical concepts in practice, the study of HTCE's development uncovers some indications linking theory and practice over time. In 1998, when Philips -in collaboration with the municipality of Eindhoven- decided to concentrate all its research activities in one location, the concepts of 'geographical concentration' had already gained importance in an international context. As discussed in Chapter 2, agglommeration economies has been trying to explain the advantages of geographic concentration in organisation's location choices thrugh the concept of knowledge spillovers.

On the one hand, it is known that Philips' accommodation strategy was aimed to support a broad corporate strategy that sought minimising costs, supporting image and increasing productivity of Philips' R&D functions. Similarly, agglomeration economies have identified varied sources favouring the clustering of functions across geographical areas as cost saving to the firms. Among others, infrastructure sharing, inputs sharing and knowledge spillovers aligned with the reasoning behind Philips' accommodation strategy.This is explicitly addressed in the Philip's vision for the campus as 'Synergy, greater efficiency and better returns on research and development' (Simmons et. al., 1999).

This vision was determinant for the planners to incorporate an important design principle or the central place to be aimed at creating a lively and pleasant atmosphere that allow people to stay and promote informal contacts. This design principle aligns with the socio-cultural dimension of innovation discussed through the concep of proximity in the evolutionary school of thought of economic geography. Accordingly, the concept of proximity is extended from its geographical form to other forms (i.e. cognitive, social, organisational and institutional). Formal and informal contacts are stressed as relevant for the exchange of information and expertise that can lead to knowledge spillovers. This is also discussed in urban studies adressing diversity of people and ideas as major source of innovation. Overall, it is difficult to assert whether or not these theoretical concepts applied at the wide scale of the region were explicitly or accidentally translated to the scale of the area in HTCE design and planning. At management level there is an explicit influence of these concepts. For instance, HTCE Site Management actively promotes social interaction by organising different types of events in HTCE's central facility aimed at strengthening the campus' networks.

On the other hand, the concentration of Philips' R&D functions was one of the milestones aimed at supporting the economic revitalisation strategy of the Eindhoven region, which sought to re-orientate its economic sectors based on the knowledge strengths of the region: technology and design. In theory, this view aligned with Porter's view (1990) in which local competition favour growth and the transmission of knowledge in specialised geographically concentrated industries (e.g. traditional manufacturing; service; or high-tech). Accordingly, large firms are constituent parts of a cluster and Eindhoven could not afford loosing Philips as the most important firm in a downstream industry they have chosen to focus. Overall, as theory suggests and practice illustrates, the concerted development of HTCE is an example that the cluster thinking was assumed in both company strategy and economic policy. In 2015, the Brainport Eindhoven region is promoted as competitive cluster that specialises in High Tech systems, Smart materials & Chemistry and Food. Accordingly, the constituents of this cluster are interrelated multinational companies (including Philips), specialised supply companies and small and medium sized enterprises surrounded by world-class universities, hospitals and research institutes.

Recently the influence of theoretical discourses of stimulating innovation on HTCE's development became more explicit. In 2003, when Philips adopted the Open Innovation Model to carry out its R&D activities, it was explicitly adopting a theoretical approach that incorporated changes in its accommodation strategy. According to Chesbrough (2003), 'Open innovation is a paradigm that assumes that firms can and should use external ideas as well as internal ideas and internal and external paths to market, as the firms look to advance their technology'. This business model is based on inter-firm collaboration creating opportunities for firms (especially in R&D firms) to enter new markets while advancing technologies on their own markets. The model has been successfully implemented at HTCE allowing the campus to attract over 125 firms that cooperate in a so-called Open Innovation ecosystem. This success has had an echo outside HTCE since Brainport Eindhoven region promotes Open Innovation as a standard cooperation system among firms based in the area. Accordingly, open innovation results from collaboration, exchange of multidisciplinary knowledge and close proximity. These and the trust developed among the existing networks are constantly outlined as unique strengths of the Southeast Netherlands to attract new R&D institutes and companies.

What campus interventions have facilitated the conditions leading to innovation in HTCE and in the Brainport Eindhoven area and how?

Based on its research proposition this study has identified five types of intervention of HTCE's development in which the built environment has been a catalyst for innovation. Section 5.3 of this chapter has illustrated with many examples how each of these interventions facilitates specific conditions, which altogether are necessary to stimulate innovation. An overview of the five types of interventions at HTCE as catalyst for innovation is illustrated in Table 5.1.

The chosen approach of this study to investigate HTCE development as a historical phenomenon does not provide causal evidence of these interventions on the processes leading to innovation. Rather, it has chosen to provide understanding on the multiple events shaping these processes, in which the built environment -as many others- is a necessary but not a sufficient condition to stimulate innovation.

Based on the empirical findings, this chapter builds upon a model of the built environment as catalyst for innovation. It is targeted to campus decision makers, which can help to stimulate design, planning and management decisions aiming for a more efficient use of resources and thus, better built environments [See Figure 5.35]. The model outlines the following interventions as catalyst for innovation:

- Intended accommodation strategy seeking to concentrate R&D activities
- Representative facilities building a new identity for the area
- Flexible facilities adapting the changing users and their activities over time
- Shared facilities accommodating diverse functions and users with common agendas
- Physical connectors making efficient the contacts and interactions between users

Similarly, this model illustrates the relationships between each intervention, which can be used to detect potential zones of alignments and conflicts among stakeholders when making decisions. In addition, the model outlined the main challenges encountered in this case, which can inhibit the actions of the previous built environment interventions as catalyst for innovation.

TOC

CONDITIONS / INTERVENTIONS	Concentration of Innovators	Innovation area	Density of Functions	Flow of incentives	Innovation climate
Intended accommodation strategy	Concentration of Philips research activities in one location retaining Philips as major innovator in the regional economic base	The location of the Philips High Tech Campus at the south of Eindhoven was conceived and planned in collaboration with the municipality creating a new identity for the area.	Philips High Tech Campus master plan proposed a central place to be in its design concept increasing the diversity of functions and activities in the area.	Concentration of Philips research activities in one location to preserve working opportunities and support policy frameworks.	Concentration of Philips research activities in one location as concerted strategy to reinvigorate the city's economy, and the synergy of Philips' R&D activities.
Representative facilities	Brand identity attracting R&D firms	High-tech and sustainability campus' image building the identity of the area			
Shared facilities	The shared lab' s facilities and its services attracting SMEs to locate at HTCE	The shared facilities (lab, garages, central area) giving cohesion the campus as a unity rather than a collection of buildings	The Strip housing diverse activities and people under one roof. The Brainport Development business centres accommodating diverse R&D firms in one building.		
Flexible facilities			The building grid of PHTC master plan allowed having flexible buildings that can accommodate different functions, and created a smaller grain size giving importance to the need to increase the use of the public space.	The functional buildings of the former Complex W allowed channelling R&D capital o other targets rather than building new infrastructure.	The functional buildings of the former Complex W allowing to accommodate the changing accommodation demands resulted from shifts in the socio-economic and technological developments.
Physical connectors		The emphasis on landscape design strengthened the sustainable image of the campus at area level and increased its integration at neighbourhood level as a potential outdoor area for the city.	The pedestrian oriented infrastructure improved the connectivity between functions at campus scale. The road infrastructure improved the connectivity and accessibility of the campus at regional and national scales.		

TABLE 5.1 Summary of HTCE's interventions as catalyst for innovation conditions.

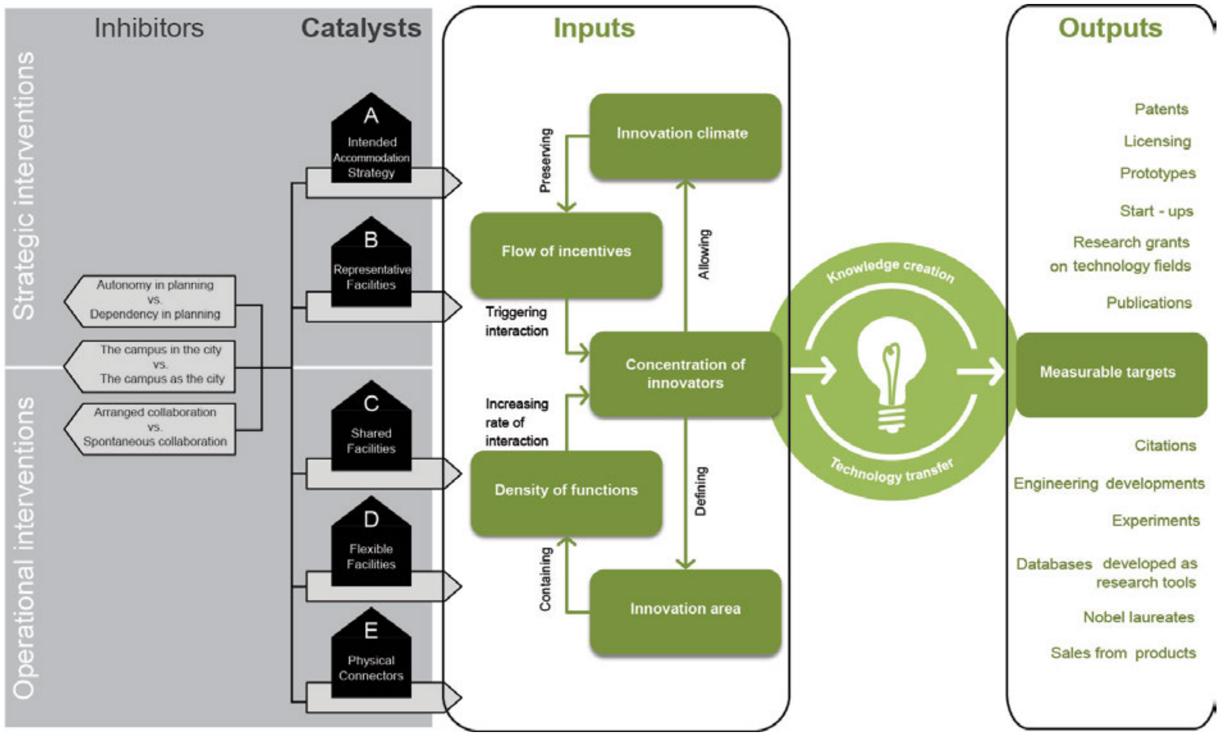
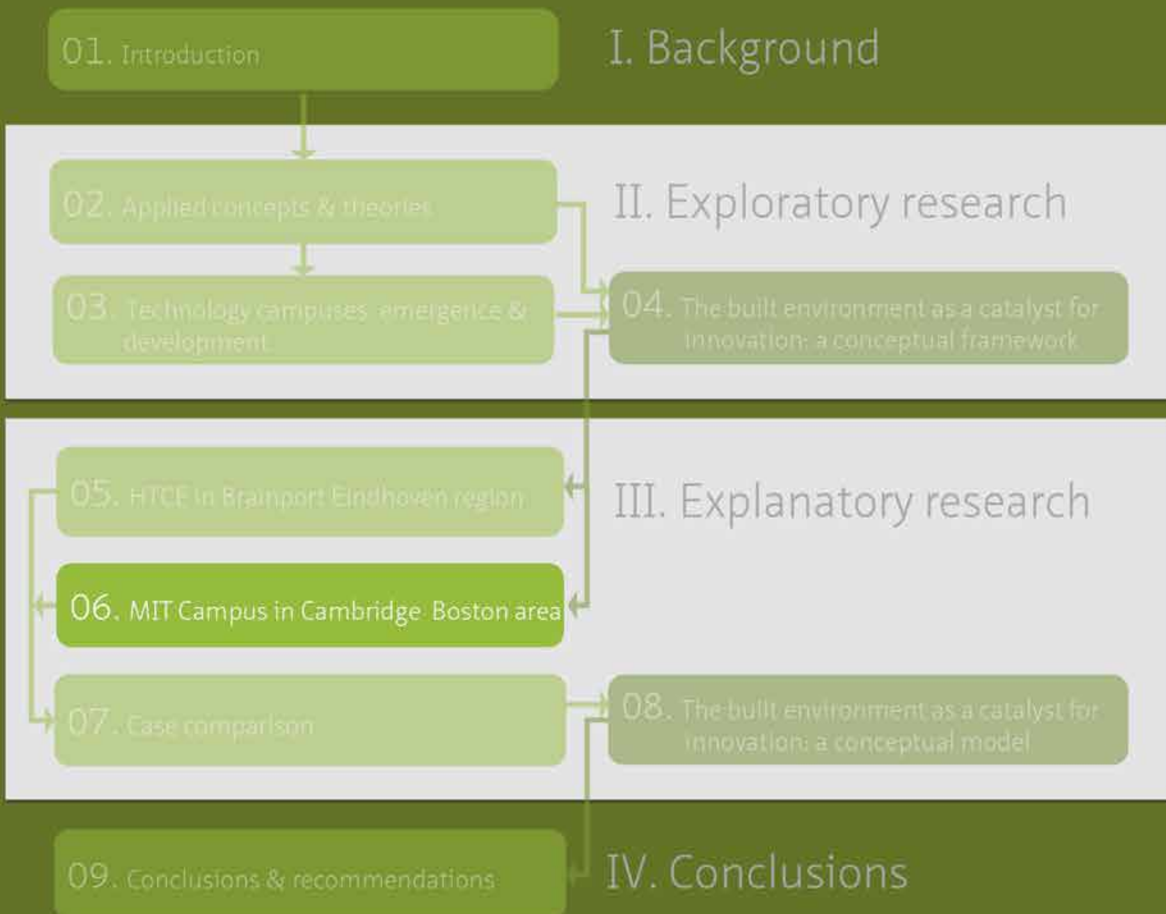


Figure 5.35 Preliminary model of the built environment as catalyst for innovation aimed to improve campus decisions. Version 1 of the model based on the case of HTCE.

Chapter 6. The MIT Campus in Cambridge – Boston area.



Chapter 4 proposed a conceptual framework as an analytical tool developed to match empirical information to the research proposition of this dissertation. The previous chapter assessed the usefulness of this framework with the first case study. This research considers a second case study because the comparison of the two will help to understand the similarities and differences in the research outcomes provided by the framework. In this way, if finding common phenomena in different contexts, the practical and scientific results of this study can have a wider impact. This chapter presents, therefore, the analysis of the second case study using the proposed conceptual framework. This case is the campus of the Massachusetts Institute of Technology (MIT), whose in-depth study contributes to answering the question: ***What campus interventions have facilitated the conditions leading to innovation in the MIT campus and in Cambridge-Boston area and how?***

This chapter presents an in-depth study of MIT campus' development, with the aim to uncover patterns of the built environment as a catalyst for innovation in Cambridge-Boston area. Thus, Section 6.1 begins introducing the logic of the case and the subject of study. Section 6.2 presents the aspects determining the context and relevance of the subject of study. Section 6.3 documents with empirical information how the built environment in MIT campus has served as a catalyst for innovation in Cambridge-Boston area. Section 6.4 discusses the findings of the case study. Last, Section 6.5 draws the conclusions of this chapter and how its findings can be used to answer further the central question of this research

6 The MIT Campus in Cambridge – Boston area

§ 6.1 Introduction

§ 6.1.1 Chapter aim and question

This chapter aims to gain and provide an understanding of the roles of the built environment in stimulating innovation in a particular context, in which this goal has been successfully attained as perceived in this research. The context selected in this case is the Cambridge-Boston area, a well-known science and technology cluster of companies and universities in the U.S. The campus of the Massachusetts Institute of Technology (MIT campus) in Cambridge-Boston is presented as the subject of study or unit of analysis. The MIT campus is defined as the land and buildings owned and used by the Massachusetts Institute of Technology (MIT) in the city of Cambridge to fulfil the mission of advancing knowledge and educating students for the benefit of society.

This chapter, therefore, asks ***'What campus interventions have facilitated the conditions leading to innovation in the MIT campus and in Cambridge-Boston area and how?'*** Next to it, the following set of sub-questions guided this case study research:

- How has the MIT campus developed? Why is the 'Overlaps' characteristic of the MIT campus in relation with the city evident?
- To what extent has MIT campus development been influenced by theoretical discourses of stimulating innovation? Is this influence explicit or accidental? Is it possible that the dynamics accommodated on MIT campus have indirectly helped supporting such discourse?
- What campus interventions have facilitated the conditions leading to innovation in MIT and in Cambridge-Boston area and how?

§ 6.1.2 Approach and methods

The built environment as a catalyst for innovation is the object of study or analytical frame in which the study is conducted. A basic assumption of this study is that stimulating innovation is a goal which successful achievement can be explained in two ways: 1) by measuring targeted outputs derived from the processes of knowledge creation, diffusion and its application and 2) by understanding inputs conditions allowing such processes. These insights derived from a central proposition developed in the exploratory research that the built environment is not a direct input of these processes but it can be a catalyst for the inputs of innovation. Thus, the built environment might facilitate some conditions that altogether enable the processes crucial to attain the goal of stimulating innovation.

The campus is the built environment unit, through which this assumption will be investigated. For instance, the study focuses on the development of technology campuses as an evolutionary process linked to specific and interrelated developments of the context in which innovation takes place (e.g. social, economic and technological developments). The study of the campus development is observed as a historical phenomenon linked to a spatial and temporal context.

Gaining and providing understanding of this phenomenon in context can help to stimulate design, planning and management decisions, aiming for an efficient use of resources and thus, better built environments. In this way, in case of finding common phenomenon in different contexts, the practical and scientific result of this study can have a wider impact.

Conceptual framework

HTCE and the Brainport-Eindhoven region explicitly address 'Stimulating innovation' as a goal in their strategic visions. According to the review of the literature (Chapter 2), innovation in the knowledge economy is measured by means of different inputs and outputs regarding the processes of knowledge creation, diffusion and its further application to develop technologies. These indicators provide evidence on how this goal has been successfully attained in these places [See Appendix G]. In addition, they constitute the reasons why he MIT campus is considered an exemplar case uncovering the role of the built environment in the innovation process from a survey of 39 campuses (Chapter 3).

This chapter uses the conceptual framework developed during the exploratory research (Chapter 4). This framework organises key concepts and relationships embedded in the proposition [See Figure 6.1]. Accordingly, the framework is used as an analytical tool developed to match the empirical information to be observed in the case, to the research propositions of this study.

According to this model, the input indicators focus on the aspects creating the conditions required for the processes of knowledge creation and diffusion. The built environment is positioned in this model as one of the input conditions, which are interdependent. Each of them has a particular function supporting these processes by complementing each other's functions. Therefore, each of them is a necessary but not a sufficient condition to stimulate innovation.

The output indicators of innovation focus on the measurable targets delivered through the processes of knowledge creation, diffusion and its application in the development of technologies. In the knowledge economy, these outputs are set as measurable goals by different organisations that want to remain competitive in such context These organisations correspond to three different spheres of the Triple Helix: universities, industry and governments. As shown in Chapter 2, each of these organisations measures innovation according to their different core businesses and aspirations. In explaining its proposition, this chapter emphasises on the input indicators or the necessary conditions facilitating innovation[112].

112 An overview of the output indicators of this case study can be found in Appendix G.

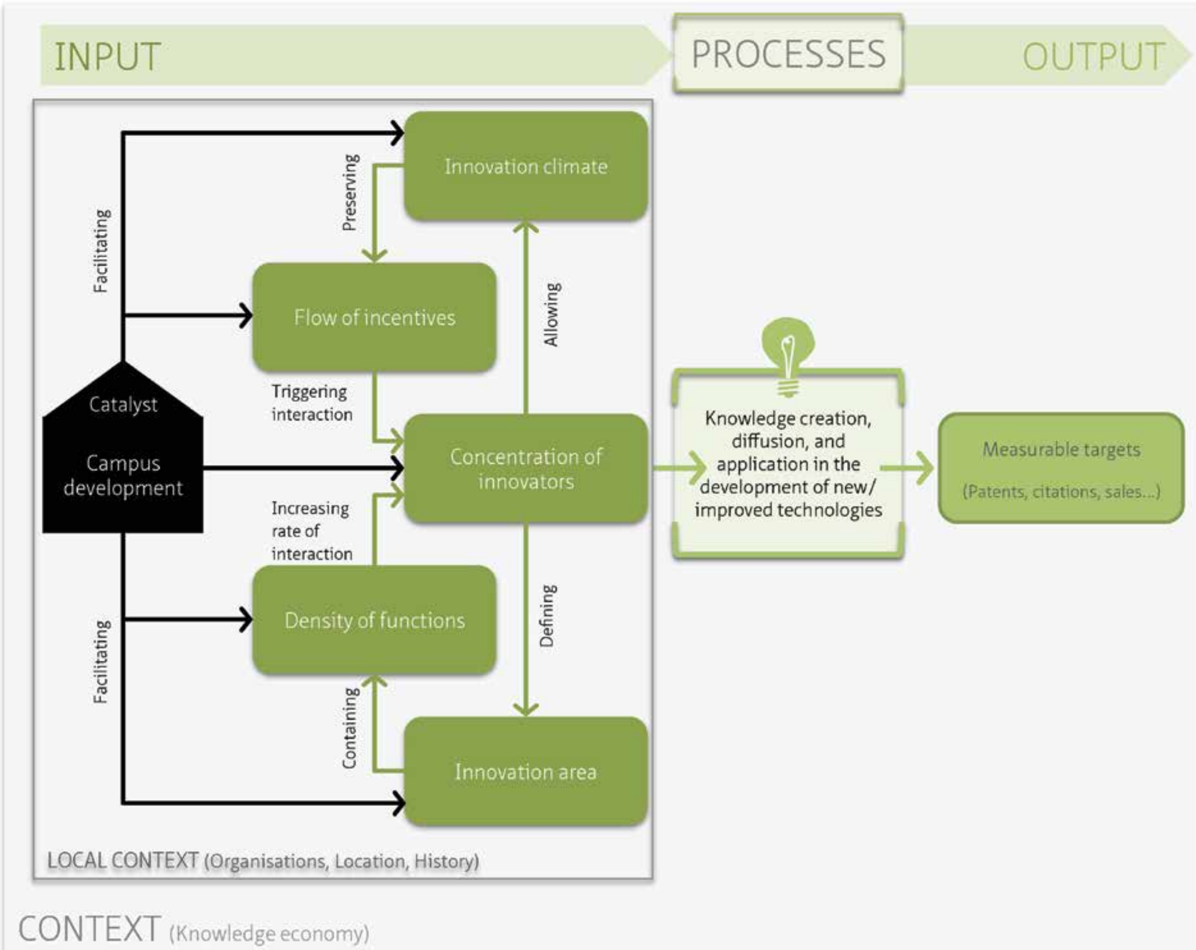


Figure 6.1 Conceptual framework representing the measurement of innovation in the knowledge economy. It distinguishes input- and output indicators.

The framework is the vehicle for analysis using replication logic. This procedure will facilitate a further comparison of the cases. The combined insights of this and the next chapter will be used to revise this conceptual framework and develop a hypothesis emerging from the empirical evidence.

Data collection

The information analysed and presented in this chapter relies on data collected by means of open interviews, observations in site, web search, attendance of seminars, review of documents and relevant readings. The data collection procedures and more detailed information about the case are described in the Case Study Protocol in Appendix F. The following paragraphs introduce the unit of analysis in context: the campus in its hosting the city.

§ 6.1.3 The MIT campus

The campus studied in this chapter is home of the Massachusetts Institute of Technology (MIT), which is one of the most prestigious research universities of the world. In addition, there are over 200 companies located in properties of MIT. The location of this tech-campus is the Boston – Cambridge area, where more than 60 campuses of universities and colleges locate. This concentration of higher education institutions is well known for its scientific excellence in research and technological advancements, which has positively influenced the transformation of this region in one of the most prosperous of the world. This transformation is a process has evolved along with interrelated developments in education, technology and economy in which universities such as MIT have played a crucial role.

The strategic campus

The MIT campus opened in Cambridge in 1916 resulted from a need to expand the academic plant of the Institute and support its mission. MIT was founded in Boston in 1861 as a School of Industrial Science by Law Act of the Massachusetts legislature and envisioned as a new educational model fostered by the intellectual and cultural elite of New England. Since its foundation, MIT has been a private non-profit institution whose mission is 'to advancing knowledge and educating students in science, technology and other areas of scholarship' that will best serve society. The discovery and application of knowledge for the benefit of society are values at the heart of MIT's educational mission that since its foundation emphasizes the 'learning by doing' model, which was inspired in the typical education of the Polytechnic universities (or 'Ecole Polytechniques') that emerged in Europe at the end of the 18th century. Today, MIT is well known as a leading research institution with a campus community of 22.000+ members (11.000 students, 1.000 professors and 10.000 staff members approx.).

MIT has become a role model of an entrepreneurial research university, which has built educational and research collaborations with universities, governments and companies all over the world. The many gifts and revenues from research and investment have increased the financial assets of this university up to US$17 billion in endowment, benefit funds and working capital[113].

The Institute has an administrative organisation led by the president and the senior academic and administrative officers[114]. The academic departments and divisions of the Institute are organised within the five schools[115]. The MIT Faculty is the body determining the Institute's educational policy but governing body of the MIT is the board of trustees known as the Corporation. The members of the Corporation include distinguished leaders in science, engineering, industry, education and public serve and specified institutional officers[116]. The Corporation and the senior leadership are the stakeholders

113 Data retrieved from a 2013's presentation of the MIT Investment Management Company (MITIMCo). This organisation manages the financial assets of the MIT.

114 Including the provost, chancellor, executive vice president, deans of the schools, vice presidents, deans for graduate education, undergraduate education, digital learning and student life, director of the MIT Libraries and the MIT community among others.

115 These are School of Architecture and Planning, School of Engineering, School of Humanities, Arts and Social Sciences, Sloan School of Management and School of Science.

116 The four specified institutional officers of the MIT Corporation are the chairman, president, executive vice president and treasurer and Vice president and secretary. In addition, there are two bodies reporting to institutional officers of the Corporation: the MIT alumni association and the MIT Investment management company.

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involved in campus decisions. The Institute wants to looks at the future through a vision based on 'Innovation and Collaboration'[117].

The operational campus

MIT campus comprises 104~ hectares of land owned (and partly leased[118]) by MIT in Cambridge, which distinguishes two types of properties: the academic plant and MIT commercial real estate property. The main difference between the two types is that the first type accommodates only academic-related activities and therefore is tax-exempt property (1,2 million m^2 of GFA and 68 hectares of surface[119]). The second type is considered as a group of assets owned by the institute to generate income, which adds to its financial resources (650.300~ m^2 of GFA and 36 hectares of surface[120]). In this property, other activities beside academic-related activities are accommodated including retail, business. Both types of properties constitute the MIT campus located at the south of the city of Cambridge by the Charles River since 1916.

In an international comparison of 39 technology campuses (Chapter 3), it has been observed that MIT campus has an evident characteristic in relation to its hosting city regarded as 'Overlaps'. Physically, the campus is not distinguished as a separated area as many campuses do. Instead, MIT campus is perceived as a group of buildings located in different areas integrated with the urban fabric of Cambridge [See Figure 6.2].

Figure 6.2 Aerial view of MIT campus. Map image: Esri 2013

117 MIT Framework 2030, retrieved in 2014.

118 MIT leases 493.801 sq. feet in 8 locations for institutional use (Source: Higher Education Population and Real Estate Statistics: 2010 (Cambridge Population and Facilities Only. CDD, 2011)

119 Converted from sq. foot and acres (MIT facts, 2015)

120 Converted from sq. foot and acres (MITIMCo, 2013)

These areas share common points with the city and some are distinguished as planning zones (e.g. the Main campus, the West campus, the East campus, the North campus, the North West campus and the North East campus) or as area development (e.g. University Park @MIT, Technology Square and Kendall Square) which distinct functional identity. For example, the West Campus is marked by the housing, sport and cultural functions supporting the student life, while the North East zones of the campus are transforming into a mixed use dominated by academic, business and retail functions. However, some of these areas or zones do not have a boundary that clearly limits where the campus or the city begins or ends. Likewise, there are several properties located in areas, which are not specifically developed or planned within those zones. An overview of this description can be observed in Figure 6.3.

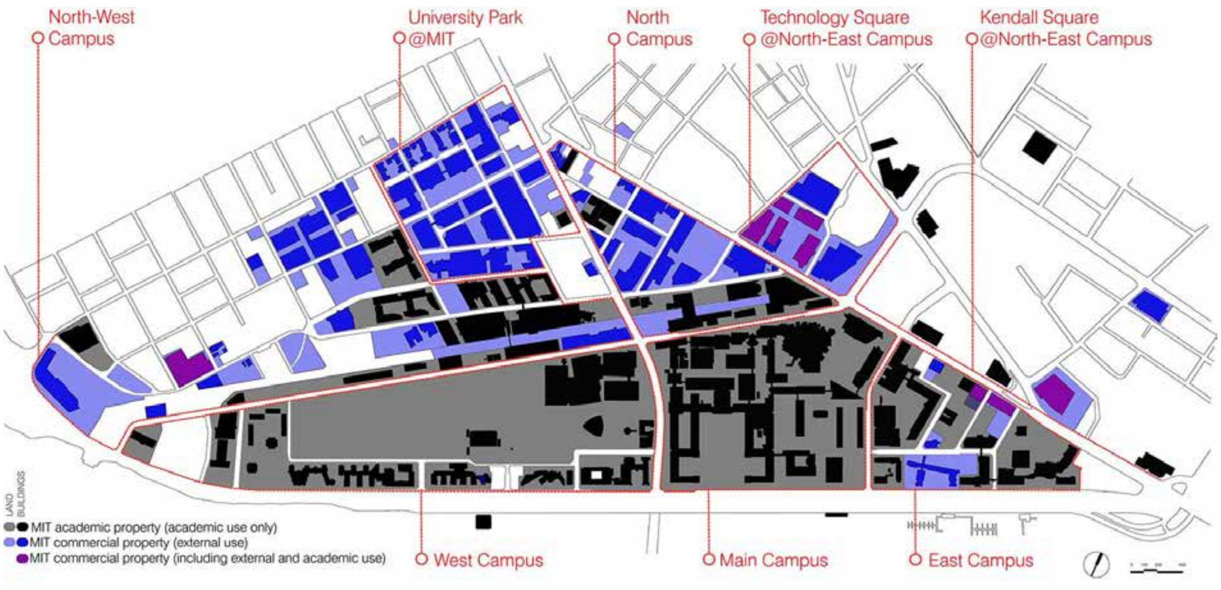


Figure 6.3 MIT Campus in two types of properties and seven main development or planning zones recognized over the years. Map: Flavia Curvelo Magdaniel, 2015. Data: MIT Facilities (2014), MITIMCo (2013), Simha (2001) and site visits in2014.

§ 6.1.4 The city of Cambridge

Cambridge is a city of the state of Massachusetts in the US. It is directly situated at the north of Boston, which is the capital of the state, across the Charles River [See Figure 6.4]. This city is officially promoted as 'Cambridge - The heart of innovation!'[121]. This motto or slogan reflects the ambition of this city to remain competitive as a place to live, work and do businesses in a national context where the capacity to grow and to compete depends upon the capacity to innovate ('A strategy for American innovation. Securing Our Economic Growth and Prosperity,' 2011). This city of 106.471 inhabitants (USCB, 2012) is one of the most densely populated areas of the US – i.e. 6.361 inh./km2.

121 Motto of the city of Cambridge (www.cambridgema.gov) since 2007 approx. Today is the brand for Economic Development used by the Community Development Department (http://www.cambridgema.gov/CDD/econdev/why_cambridge.aspx)

Figure 6.4 Location of Cambridge at the north of Boston and MIT campus in the south of Cambridge by the Charles River. Base map Data: Esri 2014

Since its foundation[122], Cambridge has enjoyed the historic profile of a 'college town' because of the early presence of Harvard University (since 1636), which is the oldest higher education institution of the US. In the late 19th century and the early 20th century, manufacturing was an important economic activity in New England during the industrialization period of the US. Cambridge became one of the main industrial cities of the region because of the presence of manufacturers and the settlement of several factories (e.g. the Carter's Ink Company in 1910, the Kennedy Biscuit Factory in 1875, the New England Confectionary Company in 1847, the Kendall Boiler and Tank Company in 1880). Many of them, located in East Cambridge and the area known today as Kendall Square, very near to MIT campus. During the Great Depression and after the WWII the industrial base of the city declined and soon the intellectual image of Cambridge began to shine again. This traces back to two important events contributing to enhance this status. First, it was the establishment of the Radcliffe College for female students in 1879, which is today part of Harvard University. And second, it was the move of MIT from Boston to Cambridge in 1916.

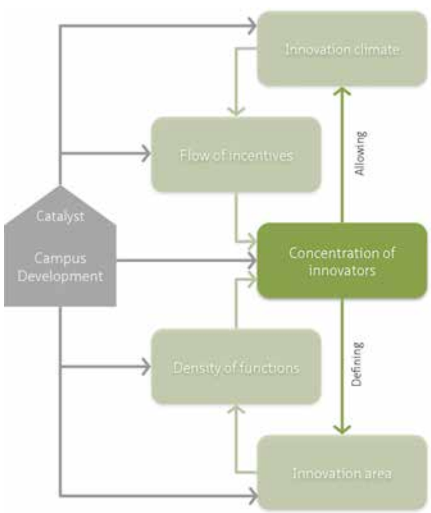
In the late 20th century, the establishment of high-tech companies brought different companies and economic activities to Cambridge. Today, the image of the city is changing to a dense tech-business location also because of the presence of these two research universities, which are playing a prominent role attracting R&D companies to establish in their surroundings. These companies and the universities form a science and technology cluster in the fields of Life Sciences and Technology businesses, which constitute the most important sectors in the economic base of the city. For instance, the city of Cambridge has an employment of 59.018, from which Biotechnology is the sector that provides more jobs and both research universities (Harvard University and MIT) are the top employers of the city. The transformation of Cambridge from a college town to a bio-tech business location is not only the result of the presence of the universities but also specific conditions that have made the presence of these universities essential for its socio-economic development. These conditions will be discussed in §6.2.

122 The first settlement of Cambridge dates from 1630 referred to as Newe Towne. The name was changed to Cambridge in 1638 but as a city, Cambridge was officially incorporated in 1846.

§ 6.2 Conditions stimulating innovation in MIT and Cambridge-Boston area

This section focuses on six aspects creating the conditions to accelerate the processes of knowledge creation, diffusion and its application to develop new technologies illustrated before in Figure 1 Conceptual framework representing the measurement of innovation in the knowledge economy. It distinguishes input- and output indicators. and explained in chapter 4 of this dissertation. As said before, each of them is a necessary but not a sufficient condition to stimulate innovation. Therefore, they are interdependent, but they also have different functions -including attracting and retaining knowledge workers- to accelerate such processes. The following paragraphs, illustrate with empirical data the conditions that have been accelerating innovation in MIT and its hosting city-region from the case study perspective.

§ 6.2.1 Concentration of innovators: MIT leading a prestigious science and technology cluster



This indicator refers to the essential parts of the system in which technology-based knowledge is created and transferred. In other words, the organisations engaged on research activities in technology fields (basic research and R&D). On the one hand, there are the universities, HEIs and research institutes advancing knowledge, while on the other hand there are firms transferring that knowledge into industrial products.

On the first group of innovators, the MIT campus is home of MIT, which is a prestigious research university ranking among the TOP 10 best universities of the world based on several indicators[123]. The MIT community has accumulated selected honours that ratify its excellence in education and research including 81 Nobel Laureates. In addition to teaching and conducting research within their departments, the MIT community works in 56 interdisciplinary research centres, labs and programs.

Similarly, MIT collaborates with other well-known independent research institutes, which are also accommodated in the vicinity of the campus. Examples of those are the Broad Institute (independent from MIT and in collaboration with Harvard since 2003), the Charles Draper Laboratory (started as a teaching laboratory of MIT in 1930) and the Whitehead Institute for Biomedical research (started with faculty from MIT's biology department in 1982), among others.

123 MIT was ranked #1 in the QS World University Rankings® 2014/15, #3 in the Academic Ranking of World Universities - ARWU 2014 and #6 in The Times Higher Education World University Rankings 2014-2015. These ranks are based on scores given to different indicators including academic reputation, employer reputation, student-to-faculty ratio, citations per faculty, international faculty ratio, international student ratio, quality of education, quality of faculty, research output, per capita performance, teaching, and industry income.

Next to MIT, Cambridge hosts Harvard University, which is the oldest university in the US and one of the most competitive universities in the world[124] and it is located at only 15 minutes by public transport from MIT campus. In addition, two other colleges are part of the higher education system of Cambridge: the Cambridge College and the Lesley University. These four higher education institutions are part of an extraordinary concentration of 65 colleges and universities in the Greater Boston area. 51 of them are inside the Boston route-128 loop [See Figure 6.5] and at least eight of these are among the TOP150 global university rankings (THE 2013-14).

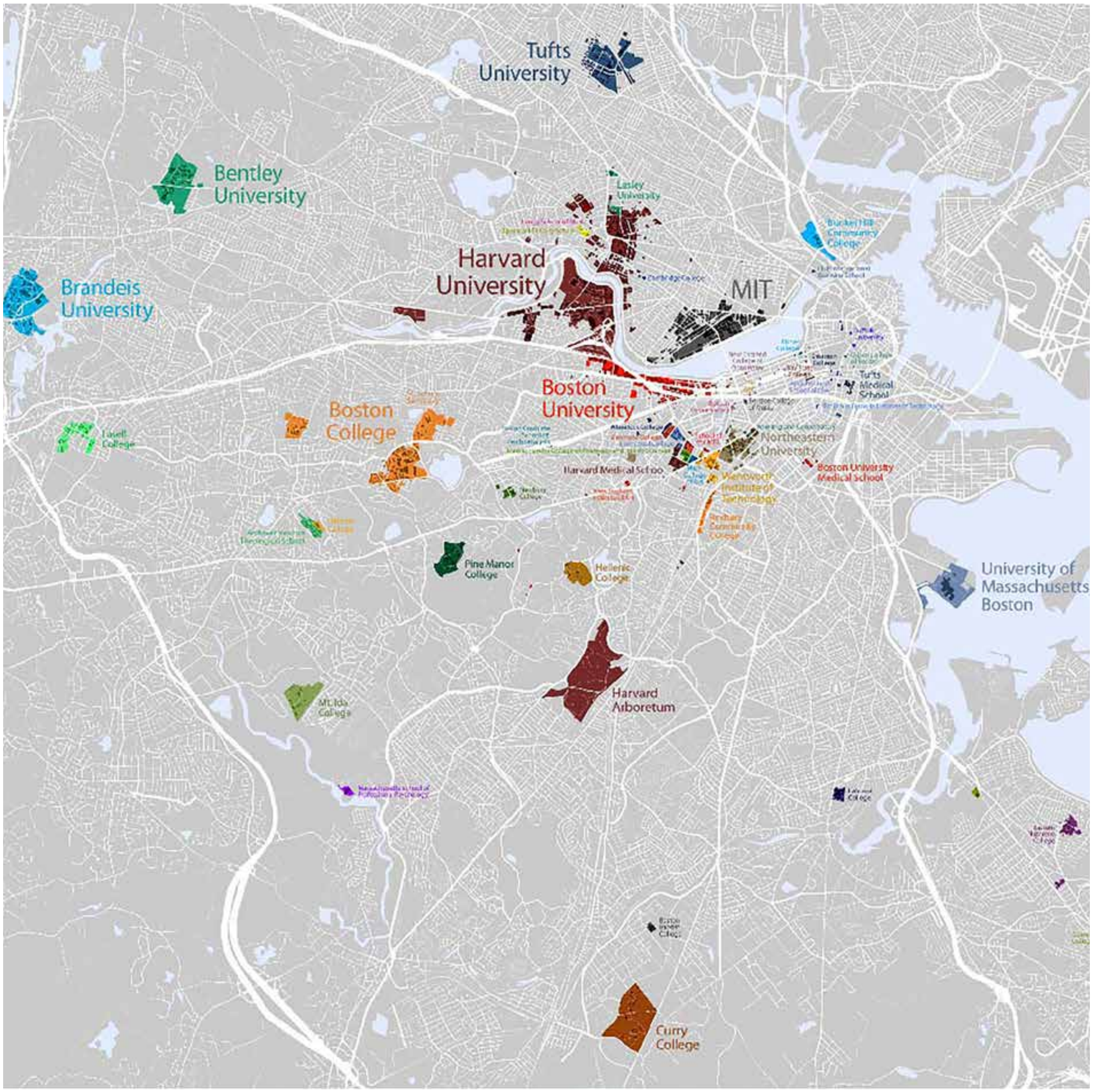


Figure 6.5 Land owned and leased by the 51 colleges and Universities inside the Boston route-128, by Bill Ranking, 2007, 2009 (CC BY-NC-SA 3.0)

124 Harvard University was ranked #4 in the QS World University Rankings® 2014/15, #1 in the Academic Ranking of World Universities - ARWU 2014 and #2 in The Times Higher Education World University Rankings 2014-2015.

On the second group of innovators, MIT campus accommodates -in its commercial property- several companies doing R&D in particular fields corresponding to the economic sectors of the city of Cambridge (Biotechnology and Tech-businesses). Along the 20th century, several multinationals with a long trajectory in research activities have been accommodated in Cambridge and in the vicinity of MIT academic plant (e.g. Raytheon in the 1920s, Polaroid in the 1970s, Akamai and Microsoft since the 1990s and Novartis or Pfizer since the 2000s). The focus of their businesses illustrates the changing dynamics of the economic cycles in the region from Electronic and hardware, to Software and Information, to Life sciences.

Today, in addition to multinational companies there is strong presence of start-up companies[125] and venture capital firms strengthening the IT and biotech sectors. These later seek to establish in Cambridge because of the research, start-ups and talent pool generated by MIT and Harvard University, helping the growth of the Biopharmaceutical and High technology businesses in Cambridge-Boston area[126] . Only in the Kendall Square area, adjacent to MIT, there were approximately 95 biotech companies registered in 2008. In 2005, that number was 55 (Roberts & Eesley, 2009). In this study, an MIT-related life science complex in Cambridge is described showing that at least 242 life science companies have strong ties with the MIT community by means of on-going connections, recruiting new employees, doing joint research and/or having MIT's faculty advisors or directors.

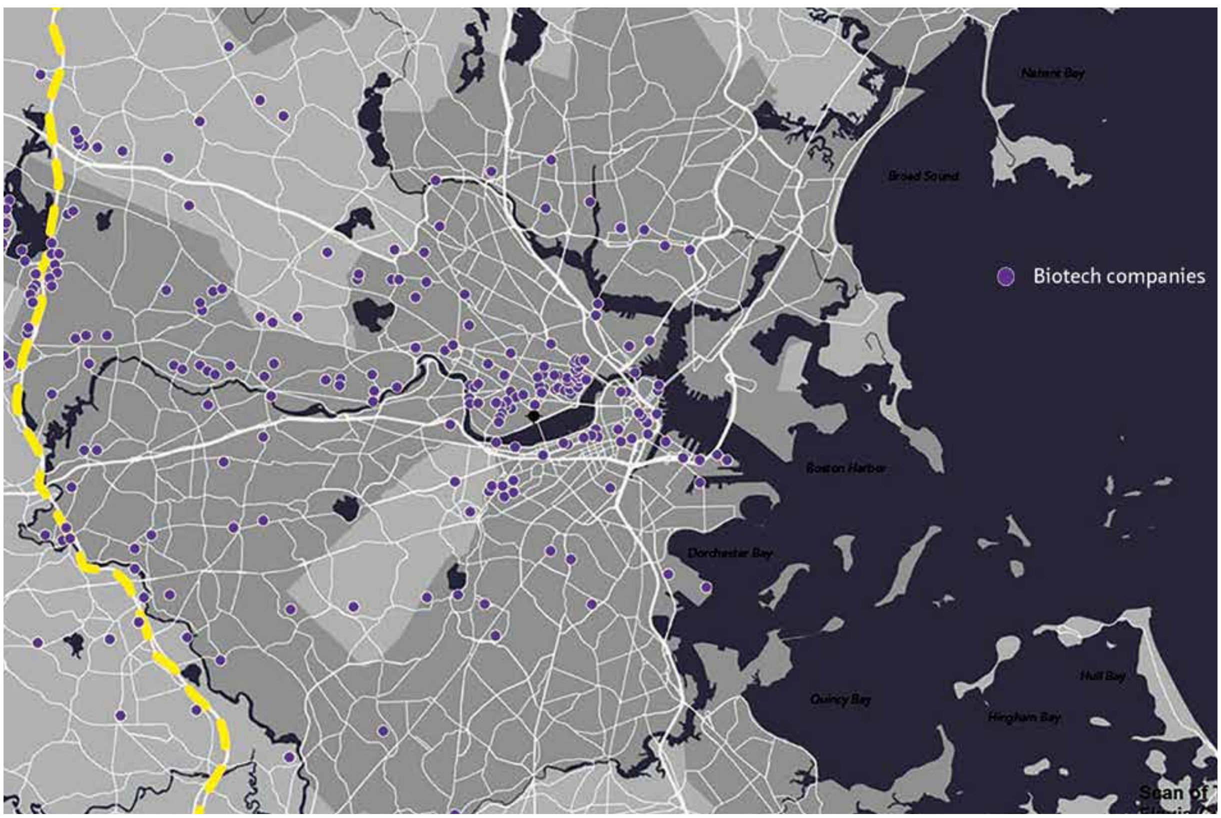


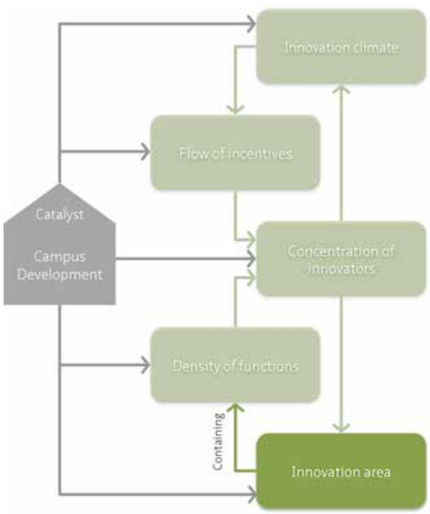
Figure 6.6 Location of Cambridge at the north of Boston and MIT campus in the south of Cambridge by the Charles River. Base map data: Esri, 2014.

125 Only the Cambridge Innovation Center (CIC) accommodates 600+ companies from which most of them are start-ups (CIC website, accessed in January, 2015)

126 60% of the VC funding in Massachusetts ($564 million) went to Cambridge-based biotech firms in 2013 (Massachusetts Biotechnology Council, report 2014)

These dynamics can also be observed at a larger scale in the region. Massachusetts has emerged as a leading centre for life sciences because of the high presence of research institutions venture capital and entrepreneurs. This cluster -sometimes referred to as a 'Biotech Hub' (The Boston Globe, 2012) or Life Science Corridor is composed by companies in seven subsectors[127] that are located all over Massachusetts, especially on the East part of the state around the cities of Somerville, Cambridge, Boston, Quincy and Braintree [See Figure 6.6 . These five cities are perceived by local authorities as important nodes in this cluster because of the presence or close proximity of skilled labour force available, leading research universities, research hospitals and venture capital resources.

§ 6.2.2 Innovation area: MIT campus at the heart of the Cambridge-Boston area



This indicator refers to the geographical area allowing contacts between the concentrated innovators. The innovation area is delineated by the positions of the innovators in a territory and by the physical characteristics of such territory allowing contacts and interactions between the innovators. Thus, scale and connectivity of these areas are important aspects of this indicator.

In the case of the MIT campus, the innovation area takes shape at the scale of the region considering the innovators -outlined in the previous section- are concentrated around specific knowledge nodes located in the state Massachusetts and circumscribed within the road loop of the Boston's Route-128[128]. The identity of the area has shifted from a college town to a biopharma and IT business location.

A location analysis of these innovators shows that a high concentration of universities, biotech-firms and hospitals are located in a radius of 5 km from a central point of the MIT campus. A subway line connecting north and south of the state of Massachusetts intersects this area and it constitutes an important transportation hub for innovators at regional level. In addition, there are other transportation systems such as bus lines, bike sharing and dedicated shuttle services for specific users of the area -such as the shuttle bus for the MIT community around campus- facilitating the connectivity of this area. In fact, innovators in this area can be reached within 15-20 minutes with public transport[129]. This innovation area is designated in this research as Cambridge-Boston area and illustrated in Figure 6.7.

127 According to the Massachusetts Biotechnology Council, the cluster of Biotech companies are classified in the following subsectors: Drug development, Medical device, Research products & instrumentation, Human diagnostic development, Agricultural/Industrial biotechnology, contract research & manufacturing and Others (hospital, academic, disease foundation, bioinformatics, non-profit research institution)

128 Route 128 is one of the first modern beltways around Boston, which is well-known because of a reindustrialisation period in Massachusetts where new companies in high tech industries located along the Highway or Route 128 during the years 1975-1980 (Castells & Hall, 1994). Route 128 was built in 1951 connecting about 20 towns, which were focus of manufacturing and service activities of the old industrial region.

129 This distance is calculated by using Magnificent, an online application using data generated automatically from the Massachusetts Department of Transportation and the Massachusetts Bay Transportation Authority, accessed on March 2015.

An important physical characteristic of this area is the presence of the Charles River dividing –also administratively- the cities of Cambridge and Boston. This physical separation strengthens the role of the transportation system in allowing contacts between the innovators of this area. Besides, this separation creates two different levels of physical connectivity within the same area: pedestrian-oriented in each side of the river and transport-oriented across the river. These levels are defined by the means used by innovators to reach face-to-face contact while travelling short distances. In this case, the efficiency of the transport system (subway and buses) is critical in connecting the separated zones, given the existing physical conditions. In addition, this innovation area is connected nation-wide through three railway stations located in the area and worldwide, through the Boston Logan International Airport accessed within 45 minutes with public transport. According to the Cambridge Redevelopment Authority, 'the development patterns in Cambridge have been shaped by its important position in the region, with rail and roadway connections and adjacency to the Charles River and the ponds near the headwaters of the Mystic River' (CRA, 2014).

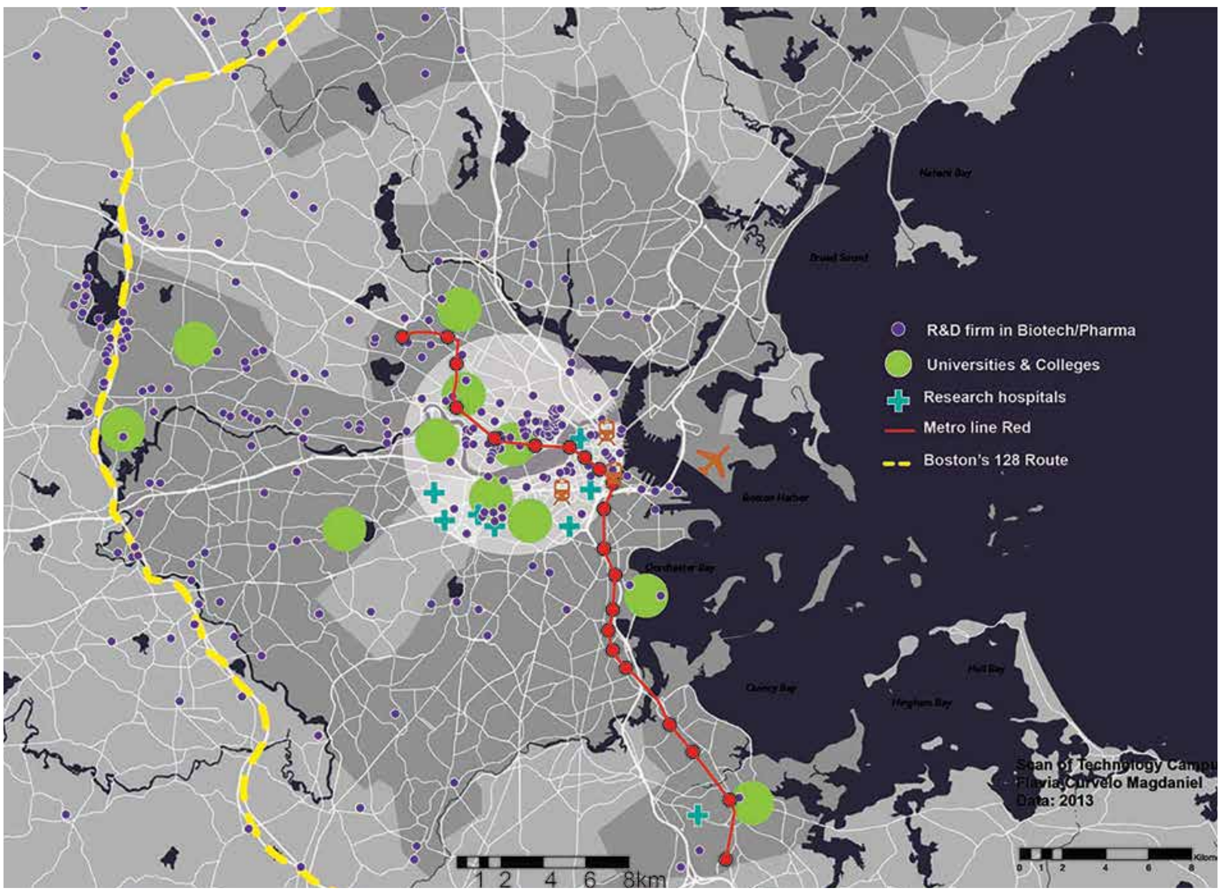


Figure 6.7 Innovation area around MIT campus. Base map data: Esri, 2014

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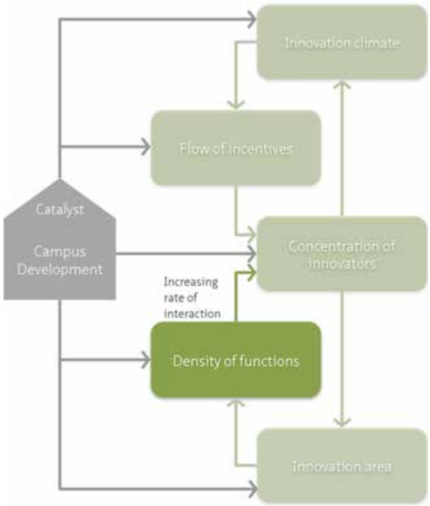
§ 6.2.3 Density of functions: the MIT community generating diversity



This indicator refers to the diversity/mix of activities in the innovation area ensuring frequency (or increasing the rate) of interaction between the innovators. This indicator has an important social component because knowledge sharing and idea generation are strongly tied to social interaction and trust developed among innovators through frequent interaction.

The city of Cambridge is one the most densely populated areas of the US (6.361 inh./km2) and the share of knowledge workers is representative in the city's population. Since 1950, the attainment of higher education in the population of Cambridge has increased significantly. For instance, the share of the population older than 25 that has a bachelor's degree or higher increased from 14,2% in 1950 up to 72,4% in 2009 (CDD, 2011). The city of Cambridge has 106.000+ residents (USCB, 2012) including 36.000+ college and university students (MIT Facts, 2015).

In 2015, MIT campus had population of 11.319 students, which is mainly composed by researchers. For instance, from the academic plant the amount of graduate students (Master's degrees and doctoral students) is larger than the undergraduates, representing 60% of the total. In fact, there are more doctoral students than master's degrees (3.782 and 2.904 respectively)[130] in MIT campus. These numbers represent a large pool of talent for the industries based in Cambridge. In 2015, approximately 3,750 researchers (including 574 visiting faculty and scientists) worked with MIT faculty and students on projects funded by government, foundations and industry. 'Approximately 2,550 graduate students are primarily supported as research assistants and 610 are appointed as teaching assistants, 1,675 are supported on fellowships.' (MIT facts 2015).

Similarly, Massachusetts is regarded as having a high quality of labour due to the concentration of education basis and the industrial tradition of skilled manufacturing. A recent survey among MIT alumni (Roberts & Eesley, 2009) found that most of the factors for them to locate their companies depend on network contacts, quality of life, proximity to major markets and access to skilled professional workers. High tech start-ups depend heavily on the availability of skilled professionals. They locate where these professionals like to live. Accordingly, 'quality of life issues include access to strong educational system, cultural facilities, open space and good transportation' (Roberts & Eesley, 2009).

In the case of the MIT campus, the mix of activities is outlined first at the level of research activities. MIT campus (academic and commercial property) accommodates three types of organisations that conduct research activities. These are the departments, centres and labs of MIT, external research institutes and R&D firms (including multinational companies, small and medium enterprises and start-up firms). The presence of these diverse research-focused organisations broadens the scope of the cluster, which covers not only scientific research but also R&D.

130 MIT Briefing Book 2013, September edition

This brings a diverse users population at the MIT campus since the campus accommodates not only the personnel and students from the 5 diverse schools[131], 26 departments and 56 interdisciplinary centres, labs and programs of MIT, but also the personnel of 200+ companies accommodated in the commercial property. These are mainly R&D companies and research institutes in the fields of Biotechnology, Pharmaceutics, IT Data, Energy, but also Venture Capital firms and service companies, which together constitute a large group of users having diverse interests, activity routines and preferences.

The overlapping condition of the campus and the city benefits the allocation of functions both in campus and the city. For instance, the city of Cambridge provides a safe and relatively attractive social environment for its residents. Its cultural, sport and leisure amenities include a main library with six branches, six museums, 80 parks, playgrounds and reservations and eight commercial districts –including retail, shops, hotels and restaurants. Within these districts, three of them are located in the vicinities of the student communities and at the main important transportation nodes connecting Cambridge with Boston. These are Harvard Square near to Harvard University, Kendall Square next to MIT and Central Square between the two of them [See Figure 6.8]. These areas are lively environments offering of activities that support the academic and business communities around them [See Figure 6.9].

Figure 6.8 Commercial district in Cambridge. Data: CDD 2009

131 School of Architecture and Planning, School of Engineering, School of Humanities, Arts and social sciences, MIT Sloan School of Management and School of sciences

1 Harvard Square in 2014

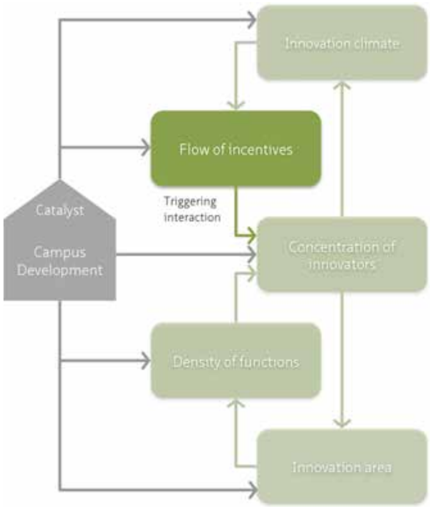
2 Kendall Square in 2014

Figure 6.9 Impression of main commercial districts of Cambridge surrounding the universities and R&D areas

In 2014, Kendall Square commercial district is a central point of attention for redevelopment in the city because it is surrounded by two important development districts, which are defined as major employment centres or mixed areas offering housing and office and R&D space to technology companies (CDD). These development districts are University Park - Lower Cambridgeport and Kendall Square – East Cambridge. These two development districts overlap with zones of MIT campus (North-west campus, University Park @MIT, North Campus and the North East campus).   The planning study for Kendall Square and Central Square covers an area including parts of MIT's East campus and the North Campus [See Figure 6.10]. Thus, the city of Cambridge and MIT -together with other stakeholders- are working in collaboration to convert this area into an attractive environment that will fit the ambition of all stakeholders involved in its development and the interest and preferences of its end-users. Close proximity to Boston advantage/disadvantage but reason to compete.

Figure 6.10 Study area of Kendall Square - Central Square planning study.

§ 6.2.4 Flow in incentives: the entrepreneurial tradition of the Triple Helix in Massachusetts



This indicator refers to the actions needed by the innovators to start and to carry on the processes of knowledge creation and transfer. The role of the stakeholders in the Triple Helix is an important aspect of this indicator. For instance, the University-Industry-Government relationships determine the actions that will trigger interaction between the innovators. The quality of these relationships is crucial because each of these spheres has their own interests on innovation.

Examples of these incentives are research expenditure, availability of working opportunities, institutional frameworks and policies, entrepreneurial activities, among others. These incentives or actions are can be strategically organised in close collaboration between these parties.

In the case of the MIT campus in Cambridge-Boston area there is a flow of incentives coming from the roles taken by each of these spheres (university-industry-government), bringing together resources that have triggered interactions between innovators to carry on their knowledge-creation and transfer processes.

First, it is the entrepreneurial role of the university in firm formation contributing to the social and economic development of its hosting city-region. At campus level, MIT promotes an entrepreneurial ecosystem for faculty and students, who want to turn their inventions into start-up companies. This ecosystem focuses on creating and capturing new technologies and businesses as they emerge from the Institute's research. For instance, the Institute has set up a number of programs, projects and incentives aimed to guide and help MIT community through the process of setting up technology-based companies formed to commercialize the inventions made at MIT. They are protected via intellectual property rights owned by the Institute. Over the last ten years, the Institute has started about 20 companies a year (MIT Technology Transfer Office, 2010). In that regard, the track record of MIT includes successful companies like Akamai (1998), Momenta Pharmaceutics (2001), E Ink (1997), Luminus Devices (2002), QDVision (2004), among others. There are 800.000+ MIT man-hours per year devoted to foster collaboration with industry (MITIMCo, 2013). The major components of these entrepreneurial ecosystems are:

- MIT Technology Transfer Office, which patents MIT inventions, copyrights software ad licenses that intellectual property to companies,
- The Desphande Center for technological innovation provides grants for research to be done in MIT laboratories and hosts events and programs to help building connections among innovators and the funding and business companies,
- MIT Venture Mentoring service supports activities that provides advice and coaching to faculty, alumni and staff and licenses of MIT technology, who lives in the Boston area,
- MIT Entrepreneurship Center offers courses to educate and inspire MIT students in all aspects of business and entrepreneurship and hosts networking events bringing together CEOs, alumni, students, faculty and venture capitalists,
- The $100K Entrepreneurship Competition is a series of events providing entrepreneurial experience that ends in the Business Plan Competition, judged by panels of experienced entrepreneurs, venture capitalists and legal professionals,
- MIT Enterprise Forum offers networking and educational programs about technology entrepreneurship,

- The Student Clubs provides educational and networking opportunities for all MIT community (Entrepreneurs Cub, Innovation Club, Science and Engineering Business Club and the Venture capital and Private Equity Club),
- The Lemelson-MIT Program offers a pool of awards (US$630.000 annually in three prizes) to recognise and support inventors and innovation as well as outreach activities to celebrate the innovative spirit,
- The Martin Trust Center for MIT Entrepreneurship provides expertise -through advice- and connections -through events- for MIT students to become entrepreneurs, MIT Office of Sponsored Programs and MIT alumni association.

Second, it is the promoting role of the government enhancing the working opportunities in the area through firm formation strategy rather than only attracting companies to relocate. The city of Cambridge does not have an explicit innovation policy. However, stimulating innovation is an important goal of the economic development department of the Community Development Department (CDD). The city of Cambridge wants to enhance innovation while maintaining a vibrant and liveable city. This goal is reinforced by a national strategy, which in general addresses the economic growth and international competitiveness of America depends upon the capacity to innovate. Specifically, this strategy focuses on the acceleration of Biotechnology, Nanotechnology and advanced manufacturing as one of the National priorities. In this context, the city of Cambridge not only aligns with such ambition but also is taking advantage of it since a there is a dense presence of IT and Biotech firms in the area. The employment in Cambridge accounts for 105.000+ jobs[132]. Educational services constitute the top employer's sector with 28.000+ jobs and Professional and Technical Services -including Scientific Research and Development services in the Biopharma sector- with 25.000+ jobs[133]. In fact, a large part of the jobs available in Cambridge comes from the two research universities[134] and several Biotechnology and Pharmaceutical companies[135]. In addition, many jobs in Massachusetts come from the Biotechnology sector[136]. Thus, the share of high-skilled jobs in universities, research institutes and IT and Biotech firm is representative for the city's employment, which makes Cambridge-Boston area an attractive environment to retain high skilled workers and young entrepreneurs. Overall, the government takes its role as a promoter by means of:

- Making innovation part of their strategic vision.
- Building networks via sharing information that connects innovators with municipal and state resources (e.g. finding sites or getting permits to establish businesses, promoting networking events),
- Political and social support via collaborative initiatives involving the university-industry spheres. Example of this are the Life Sciences Corridor, a regional economic development initiative focused on the life sciences sector, and the Innovation district in Boston,
- Launching programs that help young entrepreneurs starting their companies in the early stages.
- Promoting the establishment and consolidation of shared office and lab spaces for start-up and VC firms. For instance, over 10 co-working and incubator spaces are promoted in Cambridge while 20

132 Massachusetts Executive Office of Labor and Workforce Development, 2011

133 Massachusetts Executive Office of Labor and Workforce Development, 2010.

134 MIT employs around 11.840 individuals (MIT Facts, 2015), which together with Harvard University employ over 18.000 people in the city of Cambridge (CDD, accessed in March, 2015).

135 Novartis Institute for Biomedical Research, Vertex Pharmaceuticals, Genzyme Corporation and Biogen Idec, are the top employers after Harvard University, MIT and the City of Cambridge. (CDD, 2011)

136 In 2013, the Biopharma industry in Massachusetts employed 57.642 people (Source: U.S. Bureau of Labor Statistics, Quarterly Census of Employment and Wages (QCEW).

star-up hubs are found in Boston. Good examples providing office space are the Cambridge Innovation Center (CIC) accommodating 600+ companies in the commercial property of the MIT campus and Boston's District Hall [See Figure 6.11], which is the first 'civic' co-working space developed by a public-private partnership aimed to strengthen the city of Boston's vision for the Innovation district. This is an initiative from Boston's Mayor to transform the South Boston waterfront into an 'urban environment that fosters innovation, collaboration and entrepreneurship'.

- Building the image of a science and technology region via supporting communication and advertising strategies that focus on social engagement.

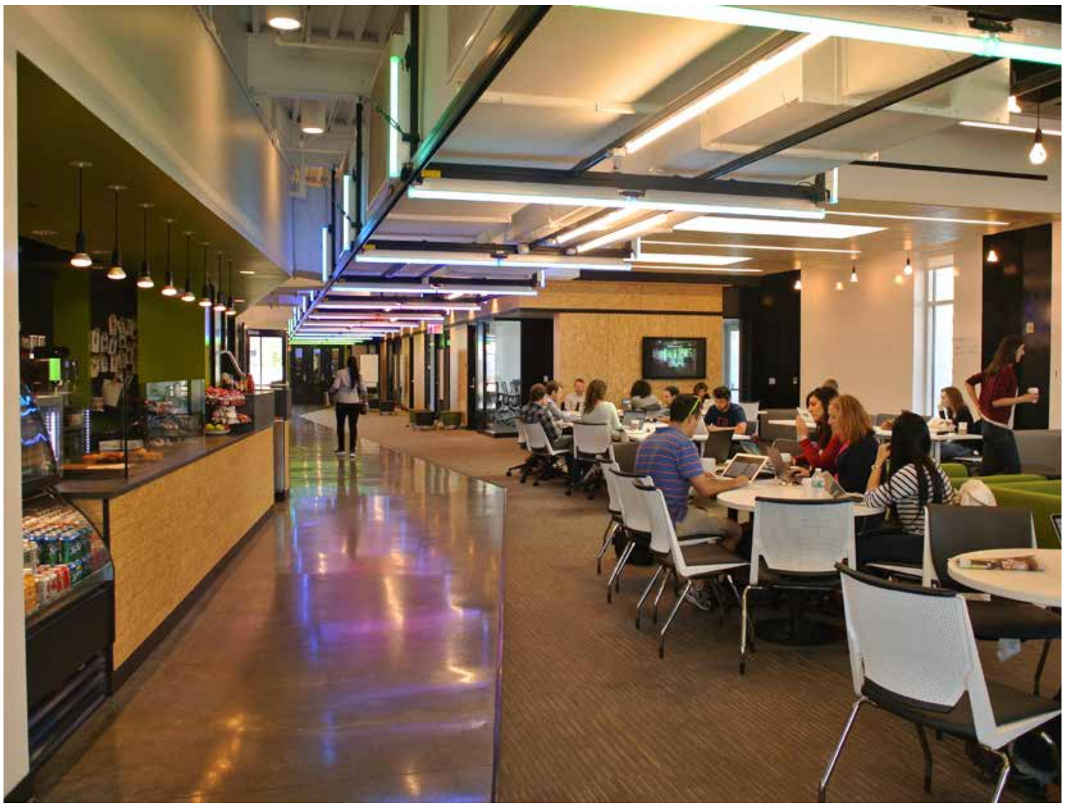
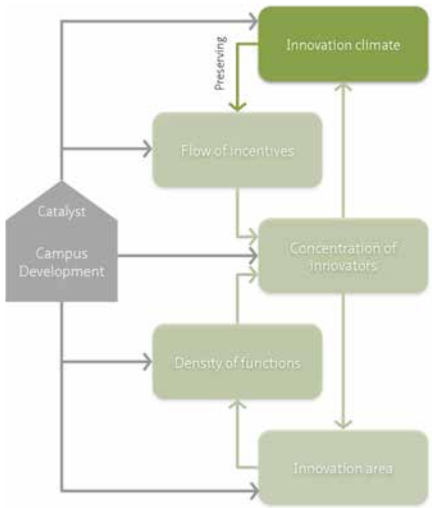


Figure 6.11 Co-working space open to citizens at Boston's District Hall in 2014

Last, it is the capitalist role of both industry and government investing in research activities in universities like MIT. Indeed, the founding principle of the Institute to provide knowledge and teaching with a methodology 'conductive to the progress of invention and the development of intelligent industry' (MIT libraries) suits very well the ambitions of the government and industry to attain economic development. As mentioned before, 99% of the research expenditure at MIT campus is externally sponsored research. Only in campus, federal research expenditure (69% - US$465 million~) includes all primary contracts and grants from sponsors such as the Department of Defense, Department of Energy, Health and Human Services, NASA and National Science Foundation. Non-federal research expenditure in campus (30% - US$190 million~) is sponsored by external parties such as industry, foundations and non-profits organisations, state, local and foreign governments. Over the last ten years, the share of non-federal research expenditures coming from external sponsors has increased from 19% to 30% of the total campus research expenditures. (MIT, Briefing book 2013). In addition, several of the activities already mentioned in the paragraphs above (events, programs, facilities, etc.) are sponsored by industry as well.

§ 6.2.5 Innovation climate: Massachusetts adapting the shift of technology over time



This indicator refers to the interrelated -social, economic and technological- developments in context preserving the flow of incentives or increasing the actions needed for innovators to carry on their processes.

Historically, Massachusetts has been a centre of industrial and technological innovation for a long time. For instance, New England became the first industrialized region in the U.S. producing leather goods, textiles and machine tools'. Indeed, the concentration of industries in Massachusetts is addressed as one of the factors that led to the foundation of the MIT in Boston in 1861 as school of Industrial Science. MIT became the first university of technology in the US which came to strengthen both the industrial tradition established in the region and the academic tradition already existing with the already established presence of Harvard University in Cambridge (also the first university of US). The interrelation of both, academic and industrial traditions have been essential enhancing the innovation climate in the region, which has been an evolutionary process linked to technological change.

Over the last century Massachusetts has gone through different economic cycles related to periods of technological developments leading three waves of change and revitalisation of industrial processes in the U.S. At the beginning of the 20th century Massachusetts was the home of traditional industries in the textile and apparel sectors, which declined during the 1930s and 1940s (Castells and Hall, 1994). Accordingly, the presence of MIT as basis of scientific and technological excellence in Cambridge is outlined as 'a decisive factor in the ability of Massachusetts to reindustrialize'. This view is supported by other studies outlining the shift in technology as the trigger for change in Massachusetts, which combined with the 'state's natural advantages' –e.g. concentration of universities, research labs, entrepreneurial tradition and a community of venture capitalists- have shaped the state's economic development making Massachusetts a role model in the U.S. (Dorfman, 1983; Lampe, 1988). The following paragraphs collect the most important of many factors shaping the innovation climate in Cambridge Boston area and the MIT campus over the last 70 years[137]. Figure 6.12 illustrates the main events shaping the innovation climate at MIT and Cambridge-Boston area in relation to three periods of technological developments.

137 The information presented in this section relies primarily on existing research (Castells, 1985; Castells & Hall, 1994; Etzkowitz, 2004; Lampe, 1988; Nelsen, 2005), interviews with technology transfer officials at MIT and many official reports and online public data of MIT and other institutions mentioned in the text.

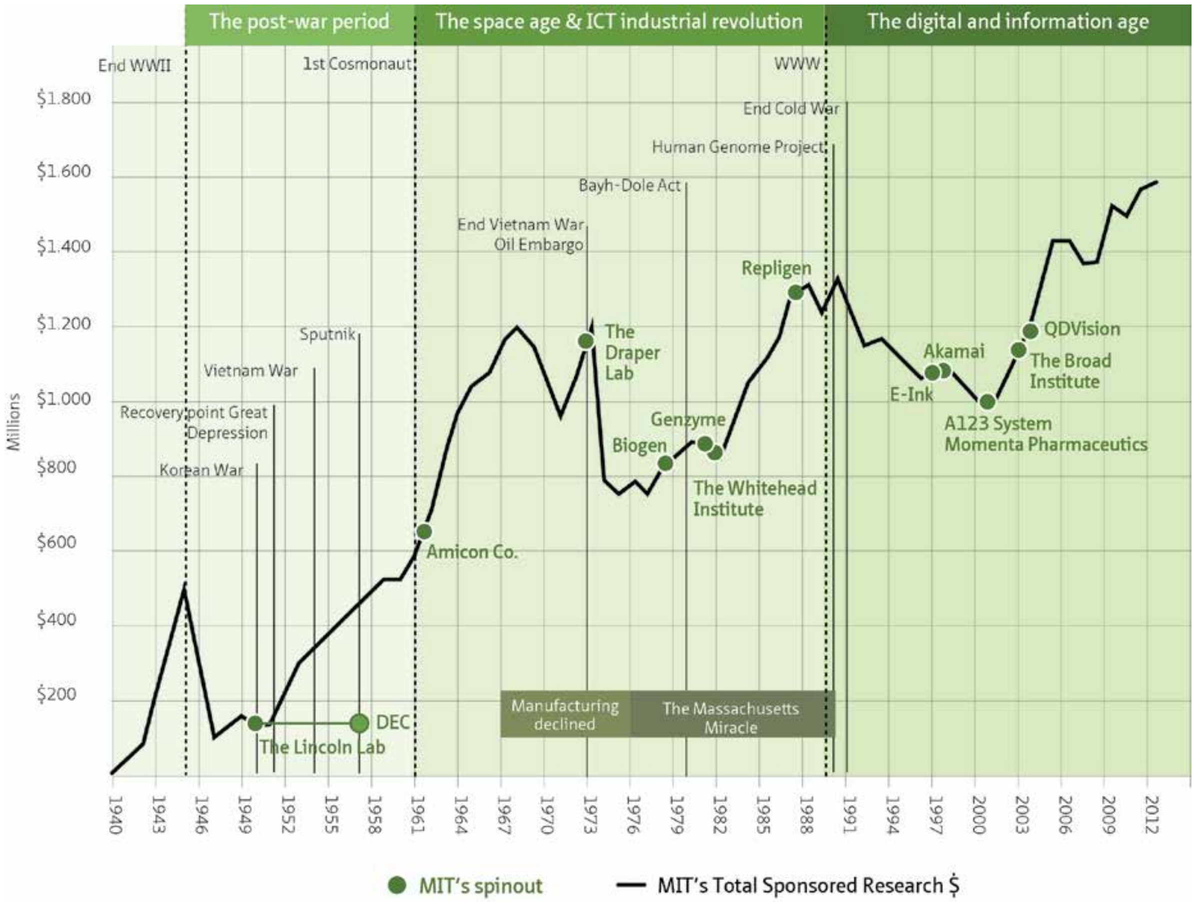


Figure 6.12 Interrelated developments shaping the innovation climate at MIT and the Cambridge-Boston area (Data on sponsored research: MIT Institutional Research, 2014)

The post-war period

The first revitalization wave took place during a period of technological advancements referred in this research as the post-war period or atomic age: 1945-1960 (Chapter 3). In the U.S., this period is associated with a phase of political and military tension that followed the end of the WWII in 1945, known as the Cold War[138]. Simultaneously, the US began recovering from the Great Depression, which turning point is marked in 1951 (Florida, 2010). During this period, technology advanced to support military and space programs. According to Castells and Hall (1994), Massachusetts concentrated research and manufacturing 'mainly in precision instruments, avionics, missiles and electrical machinery'. The origins of technology shift in warfare trace back to the 1930s and during the WWII. By that time, MIT had the oldest and most distinguished electrical engineering department in the US and was open to conduct contract research with the Government and industry.

During this period, three advanced laboratories at MIT set the seeds for the establishment of a defense oriented research complex in the state with strong ties to the academic community. First, there was the MIT's Radiation Laboratory -where the Radar and its applications were perfected- later converted to the Electronics Research Laboratory. Second, there was the MIT's Instrumentation Laboratory, which became

138 During this period, there were major regional wars in Korea (1950-1953), Vietnam (1954-1975) and Afghanistan (1979 – 1989) in which the US was involved.

in 1973 Draper Labs, an independent not-for-profit R&D corporation. And third, it was the MIT Lincoln Laboratory, a federally funded R&D centre established in 1951 with the mission to apply technology to problems of national security. This research spirit not only supported the Institute's mission but also led the formation of important companies working in military research and manufacturing in the region. According to different sources many of these companies spun off from Raytheon, a major American technology company specialized in defense and security, which started also at MIT in 1922 and still is established in Massachusetts (Castells & Hall, 1994) and the MIT Lincoln Lab, which by the end of 1980 had spun 39 new companies (Lampe, 1988). In addition, during this period several MIT's Faculty members that led research programs at MIT worked as science advisors for the US government. The same research programs that spun off research and manufacturing companies in the area. Altogether, create a strong network tied by the trust of actors moving across government, university and industry spheres. The close relationships of this network helped to enhance the technological potential of MIT, which advanced its electronic research with the support of the government.

Similarly, a good example adapting this technological shift is the role of the entrepreneurial tradition in the area. Indeed, the modern concept of venture capital firm emerged in Massachusetts around the same period. An initiative of representative stakeholders from the academic and business communities (e.g. Harvard, MIT and the Federal Reserve Bank of Boston) emerged to discuss the ways of boosting capital to start new companies emerging from the inventions and expertise of these knowledge institutions. They founded in 1946 American Research and Development Corporation (ARDC). According to many (Lampe, 1988, Cambridge Historical Society, 2012, WGBH History Unit 2004, The Boston Globe 2008), this company was not only the first modern venture capital firm having a great impact in the state's firm creation[139], but also inspire the founding of new VC firms in Massachusetts and in Silicon Valley. Another important initiative boosting the technological capacity of the area include the establishment of policies of Boston's financial communities adapting their practices to the special needs of the emerging firms in the late 1950s (Lampe, 1988). Accordingly, the Bank of Boston begins 'accepting federal research contracts as collateral for loans to high tech entrepreneurs'. This kind of incentives, besides credits and loan, helped young firms and entrepreneurs to obtain additional support from VC firms.

The space age and the ICT industrial revolution

The second revitalization wave took place during a period of technological change referred in this research as the space age and the ICT industrial revolution: 1961 - 1988 (Chapter 3). An important seed for this wave was the launching of the first satellite –Sputnik- in 1957, which led to an important influx of federal research funding to the region coming not only from the Department of Defense but also from NASA, the Department of Energy, the National Institute of Health, the Department of Transportation and the National Science Foundation. This period was characterized by advancements in microelectronics brought by competitive space programs between the US and the Soviet Union since 1961, when the Soviet Union put the 1st cosmonaut in orbit. These advancements created fast-changing industries that evolved from minicomputers to networks of computers, software, artificial intelligence and telecommunication technologies. This reindustrialization wave has its origins in the loss of manufacturing jobs between 1967 and 1975 resulted from the increasing competition of other national and foreign industrial bases. In addition, the technology-related businesses that emerged in the 1950s grew too dependent on the defense-related work and were affected because of the recession

139 ARDC invested in more than 150 companies including MIT-related ventures such as Ionics, High Voltage Research and Digital Equipment Corporation. This last is a well-known success story because DEC became an influencing company in the computer industry from 1960s to 1990s, which led to major technological advancement in the computer products and services including microcomputers.

of military spending on research. According to Lampe (1988), the unemployment rate of Massachusetts in the early 1970s went down to more than 11%, one of the highest in the US. In addition, expenditures by state and local governments and the increasing cost of living because of the oil crisis in the 1970s drove up the state in deficit. This in turn, forced the government to keep taxes high creating a hostile environment for the business community. Two interrelated aspects were decisive leading the state's recovery from this downturn spiral.

On the one hand, there was a shift of technological paradigm that traces back to the establishment of Digital Equipment Corporation (DEC) in 1957. DEC was a company specialized in computer manufacturing initiated also by two MIT's alumni of Electrical Engineering who had been working at the MIT Lincoln Laboratory. This company -located in a vacant textile mill in Maynard, Massachusetts- was the first of many companies that laid the grounds for an entire new industry that grew out of new knowledge and played a major role in the economic recovery of the state during the 1970s. The big electronic companies that spun off from military research during the 1950s did not shifted to microelectronics and many of them closed. Accordingly, many factors removed them from fast-changing networks such as the bureaucratic environment in their corporate culture and the reliance on government funding coming from the Defense establishment.

This fast changing industrial network was based on computers and was independent from the old electronic or defense base. In the region, the new companies in high technology industries began locating in vacant factories along the Highway 128 and 495 during the period of 1975 – 1980. This geographical agglomeration gave shape to the high tech complex known as Boston's Route 128, which characterized a period of economic growth known as the Massachusetts Miracle. The employment in the state grew up because of the jobs generated by the fast technological changes of the ICT industrial revolution. The spin offs from the area's research and academic institutions are addressed as key leading the economic boom. Many of these new companies traced their origins also to research projects linked to MIT and/or other R&D firms. According to a MIT study by 1986, MIT alone had spun off around 400 companies in the state and most of them since 1950 (Lampe, 1988).

They developed innovations such as the mini-computer and the workstation concept, which were more oriented to the citizens' consumers market. These high tech businesses began to make a lot of profit from the many commercial applications for their products and services. As engineering advances reduced the size and the cost of computers, new markets opened up for computers and computer-related products and services.

On the other hand, there was an alignment in the relationship between business and state government resulted from the need of economic revitalization (Lampe, 1988). Accordingly, the state of Massachusetts and business leaders began to take a series of actions and to have more clear roles in shaping the economic development of the region. These concrete actions allowed taking advantage of the high tech boom in place for sustaining a business environment. In the middle of the 1970s a package of incentives were incorporated by law and targeted to creating new jobs to attract manufacturing and R&D to establish and to encouraging existing companies to expand. In addition, several proposals were presented by the local government for controlling the state spending and decreasing the costs of doing business in the Massachusetts.

Simultaneously, between the late 1970s and the beginning of the 1980s there was another wave of federal spending in funding the new high-tech industry to defense and military programs. This significant share of funds in the region coming from federal government coincide with a severe economic downturn in the period 1984 – 1986 that affected the computer market. Thus, the computer companies became dependent on military markets until the end of the Cold War in 1991, which decreased the defense spending on research. Nonetheless, many of these companies were determined to escape their dependence on narrow and predictable market of the federal government. The already mentioned advances the computer industry helped them to diversify into commercial markets with many applications in other businesses, such as banking and retail stores besides manufacturing. The high technology sector played a leading role in the economic revitalization of Massachusetts by providing new-needed jobs, resulted from the receptive local and foreign markets to the emerging commercial focus of the computer industry. Most of the manufacturing jobs were in the areas of office machinery and electronic components. However, most of the jobs grew in the service sector led by business services such as 'computer services, data processing services, management consulting, advertising and public relations and software' drawing income in the area (Lampe, 1988)

The digital and information age

The third revitalization wave has taken place during a period of technological change referred in this research as the Digital and Information age: 1989 - present (Chapter 3). This period begins with the invention of the WWW allowing computers to connect anywhere on earth. Global discoveries with an impact on society include the use of the GPS systems for commercial applications such as mobile devices, the first successful case of a cloned mammal and the first draft of the human genome, perfected in Cambridge. In the region, the knowledge coming from the many universities and research institutes advanced technology in diverse fields such as artificial intelligence, biotechnology, novel materials and medical equipment. Hence, this wave is not associated with a need to reinvigorate the state's economy as the two previous waves described above. Rather, it can be seen as an evolutionary process of steady economy growth with an expansion of the industrial focus towards the creation of a biotechnology cluster. Biotechnology, which is an entirely new industry that evolved from basic research in the life sciences, is a good example of how advances in academy has continued to provide ideas for new products and improved processes, tested in the diversity of companies that started up in the area. In turn, this process can be associated with a so-called knowledge-driven reindustrialisation, resulting from the global orientation of nations to use academic knowledge in strengthening their economies (see Chapter knowledge economy). Indeed, in the case of the Massachusetts, it traces back to an important economic development initiative introduced by the U.S. Congress in 1980 that has been the trigger for change. This initiative together with the technological advancements of the academic establishment in Massachusetts have led to a major biotechnology cluster in the U.S. According to a recent report (FASEB, 2014), Massachusetts is home to 2,090 bioscience business establishments, providing almost 78.000 jobs in 2012.

On 12 December 1980, the U.S government enacted the Bayh-Dole Act which created a 'uniform patent policy among the many federal agencies that fund research, enabling small businesses and non-profit organisations, including universities, to retain title to inventions made under federally-funded research programs' (AUTM). The technology transfer mechanism created a 'public Venture Capital system' as an extension of basic research to commercially license the inventions coming from federal government-funded research. Not always the public expenditure put on research has been translated into outcomes or products (Etzkowitz, 2004). This mechanism, which had an economic development purpose, spread through the research university system in the US and it has been a way for the government to fuel the industry through the university establishment. Accordingly, the reformed patent system gave intellectual property rights to universities from federally funded research under the condition that they had to take steps to put them to use (Etzkowitz, 2004). This act provided legal basis and economic incentives for universities, giving them the right to own patents, grant licenses and collect royalties arising from their federally sponsored research (Nelsen, 2005). As a result, the face of university technology transfer in the US changed dramatically since the federal government funds almost 90% of the basic research in American universities. For instance, the number of patents issued to American universities, hospitals and research institutions increased from less than 400 US patents in 1980 to more than 3.500 in 2002. In 2002, these institutions granted more than 4.300 technology transfer licenses and founded over 400 new companies based on their intellectual property (Nelsen, 2005).

For research universities like a MIT this led to an emphasis on licensing. In 1986, MIT reorganised its 'Patent, Copyright and Licensing Office' established in the 1930s into a 'Technology Licensing Office - TLO' (Nelsen, 2005). The new office hired people with strong technical and business backgrounds and put emphasis on marketing and licensing of inventions, while outsourcing the patent prosecution to law firms. As a result, the participation of faculty in patenting and licensing increased dramatically as well as the number of licenses between 1986 and 2000 to almost 100 licenses per year. In 1987, the MIT TLO run a policy experiment –followed up by a setup of strict rules to avoid conflicts of interest- that allowed MIT to grant exclusive licenses to companies in which faculty members owned equity and to accept equity from licensed start-up companies as a form of royalty (Nelsen, 2005). Since then, MIT has started more than 350 companies, which were formed to exploit MIT intellectual property in the fields of pharmaceutics, superconductors, batteries, internet distribution, weather forecasting and more recently in clean energy, among others. The formal role of this office is not incubating companies by investing money or providing laboratory facilities at MIT. This office's philosophy is preserving the Institute mission while keeping the university and the companies separated. Instead, 'its formal role in starting companies is limited to filing patents and negotiating license agreements with the companies' (Nelsen, 2005). Informally, its role is larger by encouraging the formation and growth of the start-up companies such as introducing them to investors and companies in raising capital. Besides, the TLO organises a set of incentive activities that were mentioned as components of the MIT entrepreneurial ecosystem in the previous input indicator of innovation in this chapter (Section 6.2.4).

Simultaneously, at the beginning of the 1990s there was a decrease of federal-funded research in universities, which stimulated partnering between industry and academia. A foreseeing strategy from the government came into place. The Advance Technology Program (ATP) enacted in 1988 was created to encourage public-private cooperation in the development of technologies with broad applications in industries (Schacht, 2005). The purpose of the program was to reduce government spending while encouraging the growth of partnerships among firms', universities' and governments' laboratories. ATP provided funding to single companies or to industry-led consortia of universities, businesses and/or government laboratories for development of broad-based technology that have many applications across industries. Even though few assessment reports of the program in the early 2000s show positive but limited impact of the program on the development of new technologies, ATP has been highly criticized because it has been seen as a means for the government to select commercial firms and/or technologies for support.

Largely, the growth of formal technology transfer at universities such as MIT has had a significant contribution to the Massachusetts' biotechnology cluster, since most of the companies in the biotechnology sector have started as small, entrepreneurial companies within the past 15 years and a great deal of them were formed around MIT licenses[140]. Similarly, there are over 220 medical device companies and 90 biotech VC firms located in the region, which together provide over 55.000 jobs strengthening the regional economy. In this context, the role of the basic research at MIT and the other prestigious academic institutions in the area has been essential for the economic development of the region (MassBio, 2013). They have provided not only a high quality research infrastructure, but also a business and service infrastructure made up of a community of talented and connected researchers,

140 Since 1998, only MIT has started over 40 biotech companies in a wide variety of fields (Nelsen, 2005).

scientists, managers, technology transfer professionals, experienced investors and specialized venture capitalist, entrepreneurs and supporting professionals in services working together in the formation of new companies. This solid base of suppliers has grown in the area over the last 40 years since the Massachusetts' high tech boom in the 1980s. Some of these suppliers did not emerge in region. For instance, most venture capital firms moved in from New York, California and other regions after seeing their opportunities in the Boston area increased. In addition, the established regulatory framework of the city of Cambridge regulating DNA research since 1977 helped in attracting the attention of biotech venture capitalists. These suppliers are well connected through networking organisations strengthening the ties among members of the biotech community. An important one is the Massachusetts Biotechnology Council, which is an association of more than 650 biotechnology companies, universities, academic institutions and others dedicated to advancing research through professional development and networking activities.

Another important aspect sustaining the growth of the biotech research infrastructure in Massachusetts has been the National Institute of Health (NIH), which is a medical research agency part of the U.S. Department of Health and Human Services. Over the last decade, NIH has funded over US$2,4B of research grants to more than 170 universities, research institutes and research hospitals, which advance fundamental research in biology and medicine fields (FASEB, 2014). An important advancement in medical research is the human genome, which is the complete set of DNA in the human body. In 1990, the NHI and the Department of Energy together with international partners formed the Human Genome Project, which will help to build knowledge on the genetic factors that contribute to human disease (NIH Report, 2010). Twenty universities and research centres in the United States, the United Kingdom, Japan, France, Germany and China participated in this consortium. In the same year, the Whitehead Institute/ MIT Center for Genome Research (WICGR) was founded[141] and it soon became an international leader in the field of genomics and a flagship of the Human Genome Project' (Broad Institute). The human genome project was completed in 2003, which knowledge has led the way for new strategies on human diseases' diagnosis, treatment and prevention, having a major impact on drug discovery and other applications. The same year and with the support of private gifts, the Broad Institute is founded. This institute grew out of the large-scale scientific collaborations in genomics and chemical biology between Harvard University and MIT, which started early in 1995 in the Whitehead Institute. In 2008, the Broad Institute became a fully independent institution and it is today a pioneering community in biomedical research based at Kendall Square in Cambridge, on the next door to the Whitehead Institute and the Koch Institute for Integrative Cancer Research at MIT (founded in 2007). The strong presence of these scientific institutions and its research community has increasingly attracted R&D firms to establish in the area, surrounding MIT (Schroeder, 2014). In 2008, Kendall Square accommodated 95 biotech companies compared to 55 in 2005. Data from 2009 shows the density of biotech and IT firms in Kendal Square is higher than in any other biotechnology area in US, including San Francisco Bay area (Capital IQ Database, US Census Bureau, March 2009). This outlines the importance of the geographic location of knowledge and research institutions as anchors in the cluster formation instead of a large pharmaceutical company as expected in a traditional supply chain model of a biotechnology cluster.

In this context, physical proximity gains importance since the ties of this scientific community -addressed as one of the success factors sustaining the growth and evolution of the biotech cluster in Cambridge-Boston area- are strengthened by the trust generated by frequent opportunities to meeting. Examples of those are the strong relations between MIT and the entrepreneurial and industrial community in Cambridge. Studies have found that nearly 500 life scientists are involved in the founding, the managing

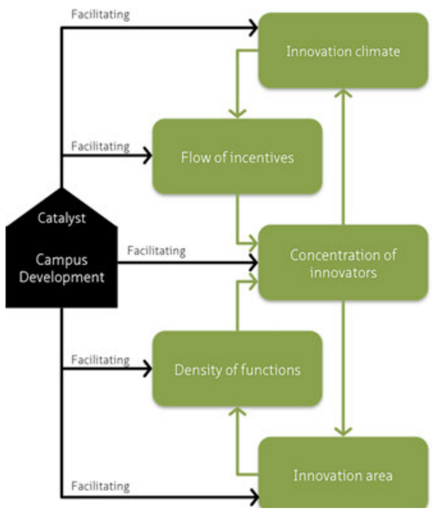
141 The Whitehead Institute for Biomedical research was founded in 1982 as part of the MIT's biology department. Later, it became and independent research institution affiliated to MIT through its members who hold faculty positions at MIT.

and/or the advisory boards of venture-funded companies in the Cambridge's Kendal Square area (Roberts & Eesley, 2009). In addition, MIT stresses that entrepreneurial culture among its students by exposing the students to cutting-edge- research projects in their early undergraduate education, to the achievements and success of MIT faculty as role models that can change students' aspirations for their future careers and also develop a risk-taking attitude and by maintaining contacts with the MIT's surrounding business communities. In that regard, the MIT Sloan School of Management began to help the Institute in fostering this culture by providing innovation and entrepreneurial formation to the MIT community.

Last but not least, the presence of the human capital has been an important component of the evolution of the innovation climate and economic development in the region. During this period, the number of graduate students at universities as well as the amount of residents with higher education attainment increased in the Cambridge-Boston area. At MIT, 1980s marked a period of change in the student population. Since the end of the WWII, the number of students at MIT has grown steadily. In 1980, the population of graduate students surpassed the one of undergraduate students, which before then had been always higher. Since then, the difference between the amount of grad and undergrad students is increasing. Similarly, the share of women in the student's population grew exponentially from the 1970s, especially for undergraduate studies as well (MIT Institutional Research, 2014). This influx of students and researchers has also contributed to the economic development of the area. Not only because of their fundamental contribution advancing knowledge and becoming young entrepreneurs for the city, but also because they pay rent, food, clothing and support a lot of businesses in the area.

Overall, the MIT campus has been home of institutions and activities that have been key in a complex process, which can be best described as an evolving knowledge-base and industrial renewal across different technological paradigms. Undoubtedly, without the presence of MIT and the other leading universities and research institutions, the innovation climate in Massachusetts would have not been as successful as described in this section. Extraordinary examples of the MIT's leading role in this process are the broad knowledge base of MIT with its five schools and many research centres advancing science and technology in several areas and its entrepreneurial attitude towards the transference of their technology into industrial application over the years. In the last 70 years, Massachusetts has successfully adapted the shifts in innovation processes from electronics to software and to biotechnology. Today, a trend towards energy research is perceived as major theme among MIT's faculty and researches and can be the next technological paradigm spun out off campus. The evidence provided in these and the previous paragraphs had the purpose of providing understanding of the interrelated conditions that are part of a complex process bringing about innovation. The next section focuses on the last of necessary but not sufficient condition stimulating innovation.

§ 6.2.6 The presence of a catalyst: the development of MIT campus accelerating innovation



This indicator refers to a type of resource facilitating all the previous necessary conditions to stimulate innovation. In the review of the literature on innovation in the knowledge economy, the built environment is addressed as a resource-type of infrastructure facilitating this process. They are either referred to as part of science systems (e.g. laboratories and facilities for research), or places attracting talent. This position matches the traditional view of real estate management in which the built environment or real estate is the fifth resource in achieving organisational performance, next to people, technology, capital and information.

This research assumes this view of the built environment as a resource for stimulating innovation. However, it proposes a differentiation of this resource from the others. The built environment is a catalyst for innovation, which makes it a slightly different type of resource. That is, because the built environment –in contrast to capital for instance- is not exclusively targeted to stimulate innovation.

The built environment can simultaneously support a different goal (e.g. sheltering people's activities and/or maximizing investments among others). In addition, the built environment can be re-used or adapted to changing goals over time (e.g. transforming manufacturing buildings into offices or housing).

Similarly, this proposition considers the existence of inhibitors reducing the actions of the built environment as catalyst. These are the conflicts created by a lack of balance in the different perspectives of the stakeholders involved in the development of the built environment.

The analysis of the previous input indicators has allowed identifying five interventions in which the MIT campus has acted as a catalyst for innovation in MIT and Cambridge-Boston area. As shown in Figure 6.13, each of them facilitates specific conditions for innovation. These campus interventions are:

- A. Land acquisition,
- B. Urban area development,
- C. Shared facilities,
- D. Flexible facilities and
- E. Physical connectors,

This chapter dedicates the following section to illustrate, with much empirical information as possible, the findings validating this proposition.

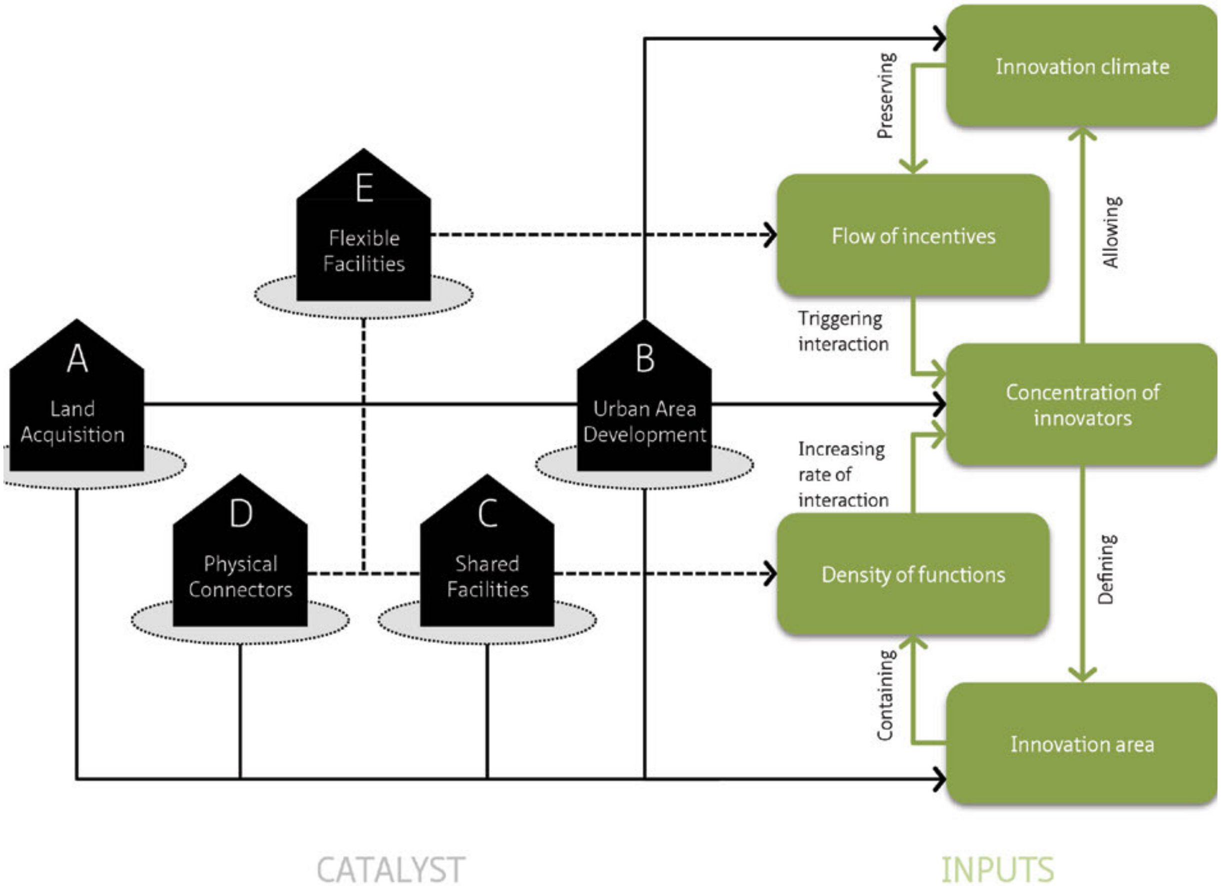


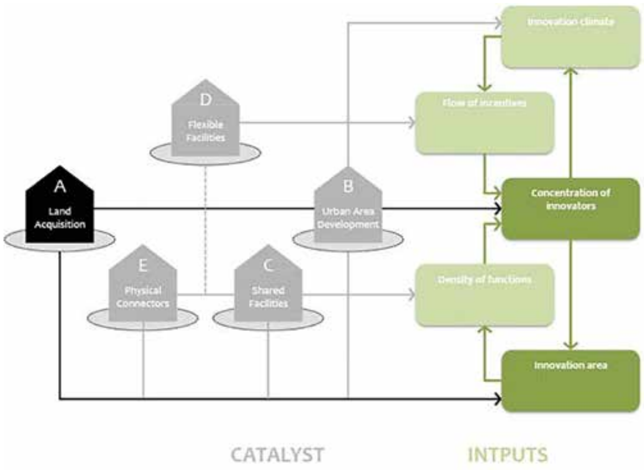
Figure 6.13 Five campus interventions of the built environment facilitating innovation in the case of MIT campus

§ 6.3 The development of MIT campus as a catalyst for innovation

The following paragraphs collect the most important of many observations from empirical information and events related to the development of the MIT campus over time, documenting the proposition of the built environment as a catalyst for innovation[142]. Thus, the catalytic role of the built environment is documented in five types of interventions that were identified through the case analysis. The following paragraphs provides empirical information that help to understand how each of these campus interventions at MIT facilitated some condition for innovation at MIT and Cambridge-Boston area.

142 The information presented in this section relies primarily on the works of Simha (2001) and Mitchell (2007), interviews with campus decisions makers at MIT in 2014, maps and photos of the campus collection at MIT Museum archives and many official reports and online public data of MIT and other primary sources [See Appendix F].

§ 6.3.1 Campus intervention A: Land acquisition



As described in the previous paragraphs of this section, the location and concentration of universities has played an important role in stimulating innovation in Massachusetts. In using their resources efficiently, most universities locate where they own property. Thus, it matters where these properties are. For instance, Cambridge and Boston have many universities that are located in urban land in contrast with many American universities that are separated from the cities. This condition is perceived as a natural advantage in the region, because with the increasing number of companies wanting to locate close to universities there is a potential option to develop special economic development zones or enterprise campuses[143] in the city.

In this case, the MIT's acquisition of land at specific locations in Cambridge has acted as a catalyst for the concentration of innovators on the one hand and for the identity of the innovation area on the other hand.

For MIT locating in Cambridge was not an intended plan but an emergent accommodation decision that turned out to be a positive strategy for the Institute and for Cambridge. The MIT was founded in Boston and for more than 70 years, it was accommodated in this city[144]. However, the growing number of students in the beginning of the 20th century created the need for expansion of the Institute's physical plant. In 1909, MIT began a consultation process for a new campus –including conducting surveys to the community, commissioning sites' studies, raising capital and making negotiations- that led to the purchasing of an initial 18-hectares plot (46 acres) located in Cambridge.

In 1911, the president of Harvard University manifested its opposition to MIT's acceptance of Cambridge's invitation to move in the city, because he believed the presence of two major universities in the same city would create conflicts with residents and businesses about tax exemption[145]. Nevertheless, the same year MIT acquired the landfill without any landscape features but the clean surface along the Charles River ready for development, where the first buildings began construction in 1914. Besides, this area was surrounded by industrial districts that did not offer an attractive environment for the MIT community but soon, some of these areas became available for the institute land acquisition plans [See Figure 6.14]. In 1912, the Institute arranged the purchasing of additional land to the west of Massachusetts Avenue anticipating the MIT's future growth. Later, this zone developed as the supporting

143 The enterprise campus is an American model of a technology campus, accommodating R&D activities in land and buildings that are not necessarily owned by the universities but the intellectual capital doing research or driving those businesses are associated with universities.

144 The first classes of the Institute were held in 1863 in the Mercantile Building in Boston's downtown. From 1866 until 1939, a group of buildings in Boston's Back Bay accommodated the academic activities of MIT, including the Rogers Building, which was the first MIT's building.

145 In the US, the property owned by universities and colleges that are used for academic purposes is tax-exempt. The cities in Massachusetts are highly dependent on real estate taxes. In 2012, taxpayers in Cambridge generate approximately 65% of the revenues that fund the city's budget. Since 2013, the city of Cambridge levies the highest property tax rates in the U.S. (AAA ratings from the nation's three major credit rating agencies)

environment for the academic life, providing housing, sports and cultural-related functions for the MIT community. In the years that followed, MIT purchased additional land for 'either immediate academic use or for investment use on an interim basis, awaiting the need for academic purposes' (Simha, 2011). With this early intervention, MIT began a long-term acquisition plan for its land resources that secured its future growth many years in advance and determined its relationship with the city.

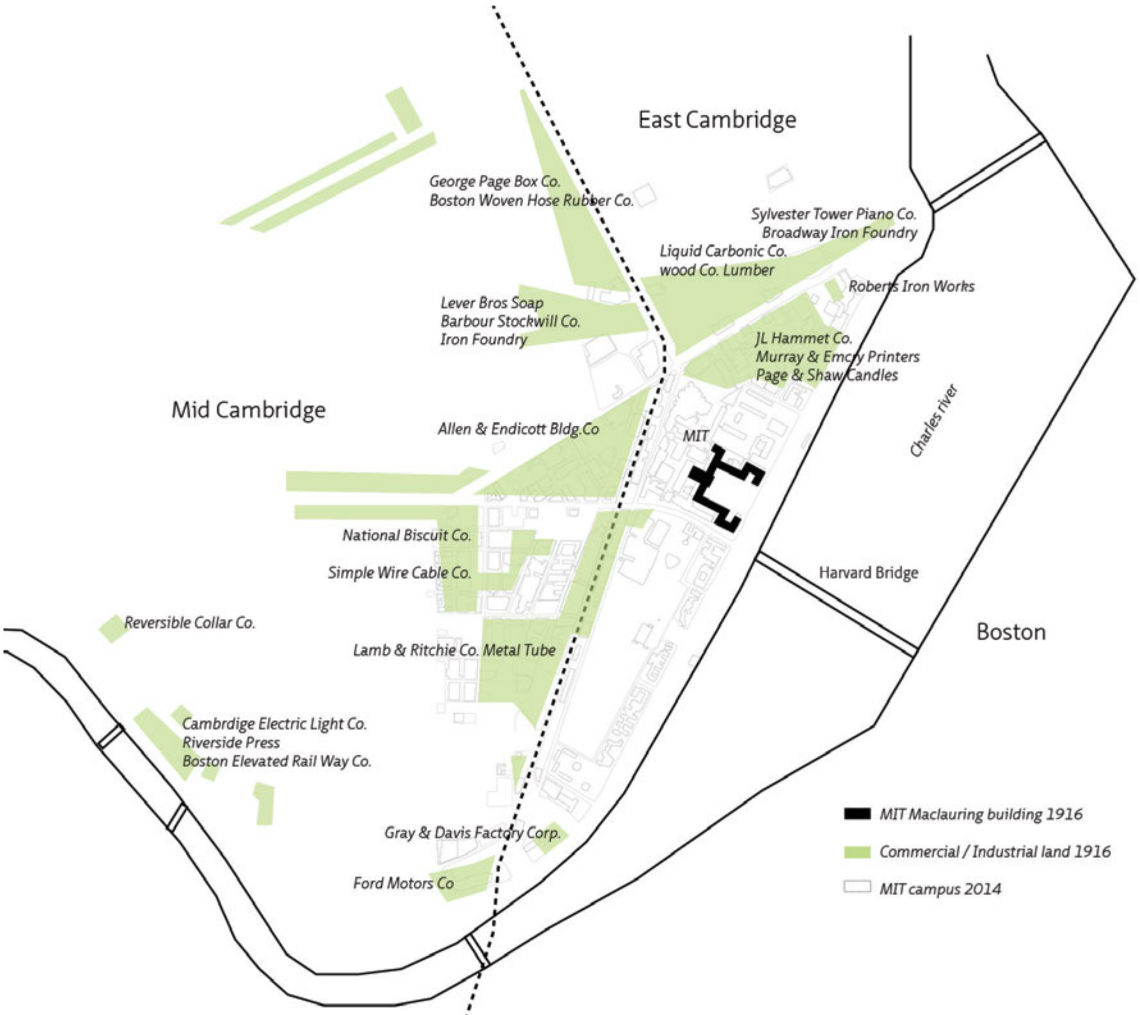


Figure 6.14 Cambridgeport Land Use in 1916. Data retreived from MIT Museum archives

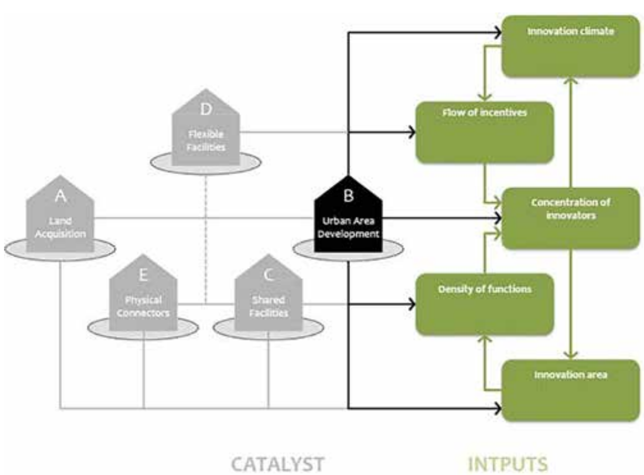
Today, MIT owns 104 hectares in Cambridge from which 68 hectares are tax-exempt. For long, the use of the land resources by tax-exempt institutions such as the MIT has been a concern in Cambridge. In that respect, since 1928 MIT signed different agreements with the city of Cambridge to payments in lieu of taxes for a period of twenty years, payment contribution's for all MIT' tax-exempt land and credits used to the city to write off their shared in urban renewal projects based on MIT land purchases.

Over the years, these friendly agreements, which are not legal requirement, have sustained a good relationship between the Institute and the city since they both have benefited from it. On the one hand, the university has secured its future growth many years in advance, while enjoying a unique tax-exempt position. In addition, the land acquired by MIT has been an important resource for investments in supporting the Institute's mission. On the other hand, the city has not only received payments for land removed from the tax rolls but has also benefited of the presence of the MIT's land users for the city's economy. These are the students and employees of the academic plant and the business tenants of the MIT's commercial property, who are mainly large companies and research institutions attracting more companies to establish in the surrounding area of the MIT campus. These two groups of users of the MIT campus and its surroundings are the actual innovators who not only advance knowledge but also pay rent, food and clothing contribute to the local businesses in Cambridge. In addition, the second users are important taxpayers generating revenues for the city. Those that are located in MIT's commercial property are making MIT the top real estate taxpayer in Cambridge[146].

The 104-hectares of land acquired by MIT over the years may be a small portion of the city's land surface (1.665 hectares). Even including the land owned by all universities and colleges located in Cambridge (200+ hectares), the actual amount occupied by these institutions is less significant than the representative role of their locations in the city. Specially, Harvard University and MIT have consolidated the evolving image of Cambridge's from a college town towards a business location for R&D activities. For instance, the branding of the city as 'the heart of innovation', would have not make sense if these institutions were not on the Cambridge's map.

Overall, in land acquisition interventions it has been important for both the Institute and the city sustaining a good relationship for mutual benefits. In this sense, continuing a balanced and long-term planning based on mutual respect and understanding of each party's ambition is crucial to avoid political disagreements. This and other issues related to land acquisition as a catalyst for stimulating innovation are discussed in §6.4.

§ 6.3.2 Campus intervention B: Urban area development



Over two different periods of technological advancements, MIT in collaboration with public and private sectors have been involved in the development of three major urban areas surrounding the academic property that have enhanced all the previous conditions necessary to stimulate innovation. These are Technology Square, Kendall Square and University Park @MIT. The developments of these areas began during the Space age and the ICT industrial revolution and some of them spanned along the Digital and Information age today. These areas have accommodated the changing activities resulted from the evolving knowledge base and industrial renewal across different technological paradigms that characterized Massachusetts' innovation climate.

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146 In the fiscal year 2013, MIT paid over US$36 million in taxes for its commercial property which accounts for 11% of the total tax levy in Cambridge. The top ten taxpayers in Cambridge generate 32,4% of the total tax levy of Cambridge. Eight of these top 10 are commercial businesses (MIT Investment Management Company, 2013)

The following paragraphs outline with many examples as possible, how these three developments changed the identity of Cambridge as an innovation area, attracted innovators to locate near to the MIT campus, increased the density of functions in the city, helped channelling the flow of incentives and ultimately, contributed to accelerate the innovation climate. An overview of the location of these areas in relation to the MIT campus is illustrated in Figure 6.15.

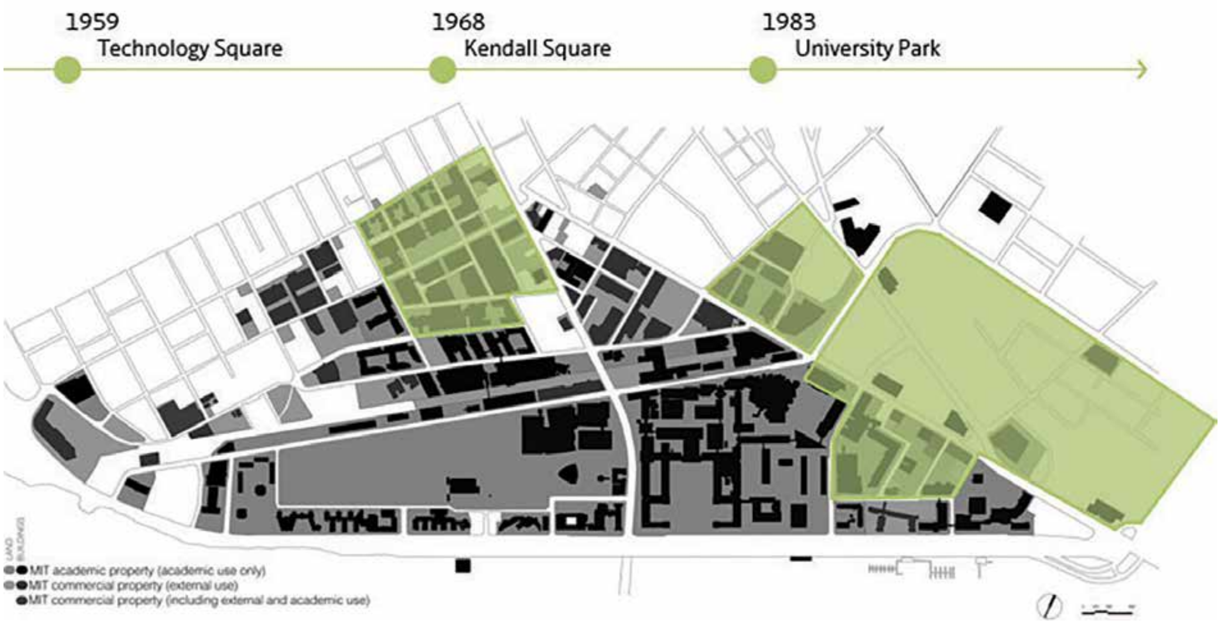


Figure 6.15 Location of urban areas developed by MIT in collaboration with public and private partners since 1959. Green: urban area developments. Grey: MIT's owned land. Black: MIT's owned and leased buildings.

Technology Square

In the late 1950s, the city of Cambridge pursued an urban renewal project in one of its industrial districts east of Cambridge. The area intended for development comprised residential land, known as the Roger's Block and an industrial land, accommodating a major plant of the Lever Brothers Soap Factory established in Cambridge since 1898. Two important events accelerated the urban renewal project in the area. In 1957, the municipality demolished the Roger's Block and in 1959, the headquarters of the Lever Brothers moved to New York and soon afterwards the plant closed. This situation left a complex of 30 buildings of the manufacturing plant vacant and hundreds of people unemployed[147]. Thus, the demolition of the whole area was imminent since the city lost revenues coming from the employment and property taxes generated by this company. In 1959, the Major of the city contacted MIT to develop the vacant site and MIT saw an opportunity for investment. In 1960, MIT and Cambridge began the plans to convert the 6-hectares plot into an offices and R&D complex. In 1962, MIT partnered with the real estate firm Cabot, Cabot & Forbes (CC&F), to begin the construction of the project. This marked a precedent, since it was the first time an educational intuition worked together with a private firm to create a business environment.

147 During the manufacturing boom of Cambridge, the Lever Brothers Soap Factory was the third largest soap manufacturer in the country, employing about 1.000 workers in Cambridge and 1.400 workers across the US (Erin Dornbusch, 2012)

By 1967, the first four buildings of the complex were ready and Polaroid set up its headquarters in Technology Square as well as others such as IBM, government agencies and MIT's research groups. At the beginning of the 1970s, MIT sold its interest in Technology Square to CC&F but continued renting space for special research projects. During the 1980s Draper Laboratories –which became and independent research institute from MIT in 1973- begin the construction of a new building in Technology Square. In 2001, MIT purchased the entire complex with the intention to maintain it as a tax-paying commercial property. This MIT's decision has benefited the city, which still receiving real estate tax revenues from this area and at the same time has reached its economic development goal of converting a former depressed industrial area into a R&D complex. Today, Technology Square is a mixed use built environment that accommodates several offices, biotechnology labs and street-level retail in 11.000m2 [See Figure 6.16].

1 Retail and open area in Main Street

2 Public space inside the block

Figure 6.16 Technology Square in 2014

Kendall Square

During the space age in the 1960s, NASA funded research programs in Cambridge involving Harvard University and MIT. The expected accommodation of NASA's research activities triggered the redevelopment plan for Kendall Square area in East Cambridge. According to Simha (2001) 'Technology Square's success inspired the NASA Electronics Research Centre to set up its headquarters in the adjacent Kendall Square in 1967.' At the beginning of the 20th century, the land use of East Cambridge was dominated by industrial manufacturing plants. In the period 1964 – 1966, the Boston Redevelopment Authority (BRA) oversaw the economic benefits for the region from NASA's presence and presented an urban renewal proposal for Kendall Square to clear the old industrial use. The proposal was presented to MIT because financing this urban renewal project would require MIT's cooperation and commitment to the city of Cambridge[148]. After MIT agreed to provide credits for the city, Cambridge invited NASA to locate its centre here.

148 According to Simha (2001), the city of Cambridge received from the Federal Government over US$5 million in credits, used by the city to write off its share of the Kendall Square Urban Renewal Project. These credits were based on MIT's land purchases for educational use.

In 1968 the BRA, the Cambridge Redevelopment Authority (CRA) and NASA began the renovation works of the 12-hectares plot. The clearing of the old industrial uses took place between 1967 and 1975 and the sale of the redevelopment land took longer than expected because of the economic recession. Within that period and after changes in the federal administration in 1969, NASA announced the termination of its Cambridge's activities. The new building erected for NASA's research centre became vacant, but soon the CRA found a new occupant. This was the federal Department of Transportation (DOT) Research Center. In 1971 the DOT released 4.5 hectares of land that they considered a surplus. The CRA considered the option to sell the site to MIT for academic purposes but the Institute was interested in maintaining its academic activities compact. Instead, they proposed to convert the site into a housing neighbourhood.

During the period 1974-1977 there was an active planning process for Kendall Square involving proposals and negotiations of different parties including MIT. It began in 1974, when MIT and East Cambridge Planning Team proposed a plan for a lively 24/7 neighbourhood of mixed use including housing. This plan was based on 1964's study commissioned to Kevin Lynch, professor at the School of Planning and Architecture at that time, who had been leading the project the Image of the City. In his report, Lynch outlined that Kendall Square was an undefined space bordering the campus with opportunities for a lively mixture of commercial, office, cultural, hotel and housing developments. The plan was rejected because the city had in mind a more commercial and industrial development for this area. In 1975, the CRA proceeded with the plan with changes allowing housing but not as a required function. Finally, in 1977 the Zoning plan is approved in line with the comprehensive Zoning Ordinance Review of Cambridge. For first time, mixed development zones for a variety of different land uses on a common site were proposed.

In 1979, Boston's Properties was selected as developer for the project, whose design proposal was highly criticized by MIT. The main oppositions were against the group of massive buildings proposed along Main Street and the lack of public space, which increased the built density around the campus. During the early 1980s, the proposal began development as well as the increasing traffic congestion issues. The planning of the new Kendall MBTA[149] Red Line began in 1983 while a new hotel is being developed in the site where the new subway station will be located. In 1986, MIT participated in the design of the Kendall / MIT subway station, which construction in the 1990s would improve the connectivity of Cambridge in the region. As Boston's Properties continued the mixed industrial and commercial development up today, the results have been criticized for being monolithic and lacking sufficient services.

In 1999, the Cambridge Innovation Centre (CIC) is established in Kendall Square, which became one of the earliest co-working spaces for start-up companies. The CIC began offering affordable and flexible real estate for young entrepreneurs in the area. CIC's founder began renting space-floor from MIT's owned building located in One Broadway. Soon, CIC's business model became successful accommodating a growing number of start-ups, other medium and large firms that established at CIC. In 2014, the CIC rents from MIT half of the space available in the same building (28.000~ sqm) providing office space for over 500 companies, from which nearly 450 are start-ups. In addition, CIC offers venue for social meetings and organise networking events for their tenants and the Kendall square community. The success of this model has inspired the launch of LabCentral in 2013, a 2.600~ sqm facility which is the first shared laboratory space for start-up companies in life-sciences biotech industries in Cambridge.

149 Massachusetts Bay Transportation Authority (MBTA) is the public operator of most bus, subway, commuter rail and ferry routes in the Greater Boston, Massachusetts's area.

During the 2000s, several R&D companies, research institutions and VC have located in Kendall Square. Most of them, conduct businesses or research in the biotech and pharma sectors, but also in IT and Data and more recently in energy fields. Examples of those are the Broad Institute in 2001, Genzyme in 2003, VMWare in 2004 (the first company from silicon valley to establish in Kendall Square), followed by Google in 2005 and Microsoft New England R&D centre (NERD) in 2007. These and other companies a well as the local businesses located in the area are part of the Kendall Square Association (KSA), founded in 2009 to help drive the direction of the area. They are actively strengthening the network of companies and institutions in the area, by organising events, informing Kendall square residents about developments in the area and building the identity of the innovation area[150].

In 2011, the city of Cambridge released a planning study for Kendall square which study area include 10-hectares parcel of MIT academic property. The same year the Institute formally filed a rezoning petition for this area. The MIT community raises its awareness about the need for a long term planning that considers the preservation of academic land resources and social inclusion that can be hindered with the commercial development emerging in Kendall Square area. Recently, a design committee for MIT's Kendall Square Initiative was established to supervise and guide the design principles of the area. This committee, formed by faculty from the MIT School of Architecture and Planning and the MIT community, is a form of participatory planning and design to ensure high quality of the built environment and alignment with the current planning and design principles of the MIT campus. The first outcome of this initiative is the MIT Gateway to Kendall Square Zoning petition, which was approved by the Cambridge City Council in 2013. According to MIT News office, 'the new zoning preserves existing academic development potential and enables the creation of new housing, retail, lab and commercial space, as well as more engaging open space and way-finding'. The MIT's vision of mixed use neighbourhood for Kendall Square persists from the 1970s up to date.

1 *Google offices in Main Street*

2 *Microsoft offices in Main Street with Broadway*

Figure 6.17 Kendall Square in 2014

150 One example of these is the first Entrepreneurs Walk of Fame which was launched in Kendall Square in 2011, which is a sidewalk with stars part of the public space located near the Kendall / MIT subway station.

In 2014, the Kendall Square continues under development and it is facing a spatial and functional transformation. It has become denser resembling the image of a financial and business district rather than a university environment. The strong presence of large corporations such as Google, Microsoft and Novartis are dominant in the landscape [See Figure 6.17]. The public space is still poor in some areas and the existing shops and restaurants as well as the new residential development are getting expensive for the students' and Cambridge's communities. These and other concerns are raised regarding the development of Kendall Square, which are issues related to urban area development as a catalyst for stimulating innovation. These are discussed further in §6.4 of this chapter.

University Park @MIT

University Park @MIT is a mixed use development of commercial, private laboratory, incubator and residential functions, located North East of Massachusetts Avenue in the parcels once-occupied by the Simplex Wire & Cable Co. This company was a manufacturer of wire and cable for telephones established in Cambridge since 1888. In 1969, this company is sold to a company in New York that decided it was not viable to continue operating and Cambridge and moved the operations to Maine – another state in New England. The property was placed in the market and after the success experienced with Technology Square, MIT saw the potential of transforming the industrial district into a housing and commercial development. This time the Institute did not consider allocating any academic use or MIT's related research projects in the area. Between 1970 -1971 MIT acquired the property of 74.500m2.

In the years that followed MIT conducted a study aimed to identify the site's needs, considering the interests of the Cambridge's community on housing development. This led to a complex process of negotiations with the city and the community before the plan was completed. In 1983, MIT selected Forest City Enterprises (FCE) as developers for the site. In 1985, the City Council appoints a Planning Committee involving representatives of MIT, FCE and the Cambridge's community. In 1987, these parties completed a Masterplan, which was approved by the City Council in 1989. This masterplan is changed because of rezoning in Cambridgeport Industrial District in 1992, including more areas for parks and students housing in the development. The same year the development of the area began.

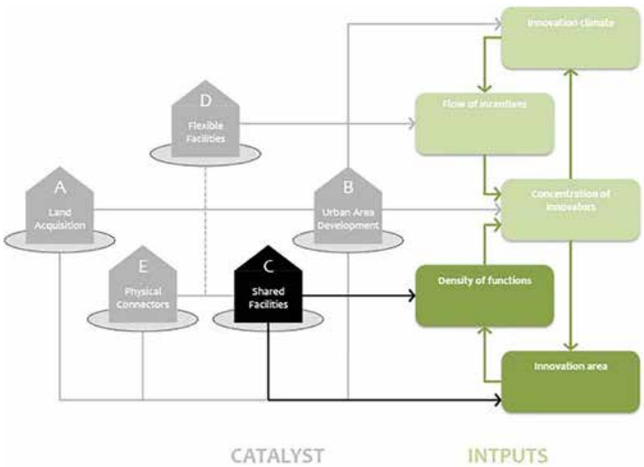
University Park @MIT is an example of real estate development in which the MIT established a long-term relationship with the community, because of the social component of housing development. The construction works took longer than a decade in completing the plan. Today, University Park is mixed use neighbourhood, including 37.000m2 of residential use, 150.000m2 of commerce, a large Biotech innovation Center and high quality of public space and green areas [See Figure 6.18].

1 University Park Commons

2 Intersection of Massachusetts Avenue with Sydney Street

Figure 6.18 University Park in 2014

§ 6.3.3 Campus intervention C: Shared facilities



Cross-disciplinary education and research is one of the foundation philosophies of MIT, which is attributed as one of its strengths in discovery and advancing knowledge. Correspondingly, a number of buildings at MIT campus have enhanced this philosophy, where sharing one facility for a variety of users is an organising pattern since the MIT moved to Cambridge. Three important examples of those are acknowledged. The first building in the campus (1916) initially accommodated the administration, the library and most of departments of the Institute.

The Building 20 (1943) set up as a temporary facility to accommodate the Radiation Laboratory and used by many until 1998 when it was demolished against the will of the MIT community. And the MIT Media Lab (1984) recently extended to a complex accommodating a broad range of research centres and programs in design, communications systems and collaborative research among different departments of the MIT.

Sharing working facilities is becoming a popular solution in accommodating start-up companies in Cambridge. These are seen as vehicles to increase collaboration among firms and to strengthen the research and business networks in the area. An important example of this is the Cambridge Innovation District (1990), which is one of the pioneering co-working facilities in the US that deserves attention in this case. The following paragraphs outline with several examples, how some of these facilities have helped to increase the density of functions and to strengthen the identity of the innovation area in MIT and Cambridge.

MIT's Maclaurin Building

This building is the first and most representative of MIT Campus, designed by MIT's alumnus Welles Bosworth and built in the period 1914 - 1916. His design was inspired in a 1912's study conducted by another MIT's alumnus John Ripley Freeman when the president confirmed the decision to move from Boston to a new campus in Cambridge. The studio known as 'Studio No.7: A design for the New Technology' proposed four functional design principles for the new buildings of MIT:

'First of all, we must obtain a flood of window light,

Second, a flood of fresh air under perfect control,

Third, an efficiency and avoidance of lost motion by student and teacher, equal to that which obtains in our best industrial works.

And fourth, the consideration of the psychology of student life, the cultivation of the social instincts, the development of personal contact, must strongly control the layout of the very masonry. (Some fruits of this consideration will be found in the serious attention given to cloisters, cloister garden and to unusually ample corridors and entrance halls.)'

Accordingly, the third and the fourth principles are important in this context because they clearly outline the need for interaction as part of the MIT's educational model and the key role of functional buildings providing places for meeting and informal encounter. Thus, the design of the main building emphasized the use of cloisters, large halls and ample corridors to accommodate a variety of departments, laboratories and activities of the Institute. These include academic, research, cultural, sport and administrative activities. The main building accommodated the entire campus in its early years. The building set the pattern for growth and development of the main campus, in which new buildings attached to its functional structure of corridors and courts.

In 1945, Prof. Frederick K. Morris, a member from MIT's Department of Biology, drew a 'Whimsical Map' of the MIT in the years 1944-5, depicting the variety of activities accommodated in this growing-building by the time (Figure 20). Today, some of the location and activities mapped in Morris' comic still exists and many of them are no longer present. These users sheltered under one single roof, not only shared the use the corridors and halls- outlined as significant in the next campus intervention- but also shared common facilities in the building such as the library, cafés, student clubs and centres and laboratories used by people in different disciplines such as optics, mechanics, electronics, chemistry, physics and mathematics. It was not difficult to get lost in the building because of the many users accommodated in this building and the complicated room numbers. This building was referred in a newspaper article as the MIT's Labyrinth (The Boston Herald, February 1947).

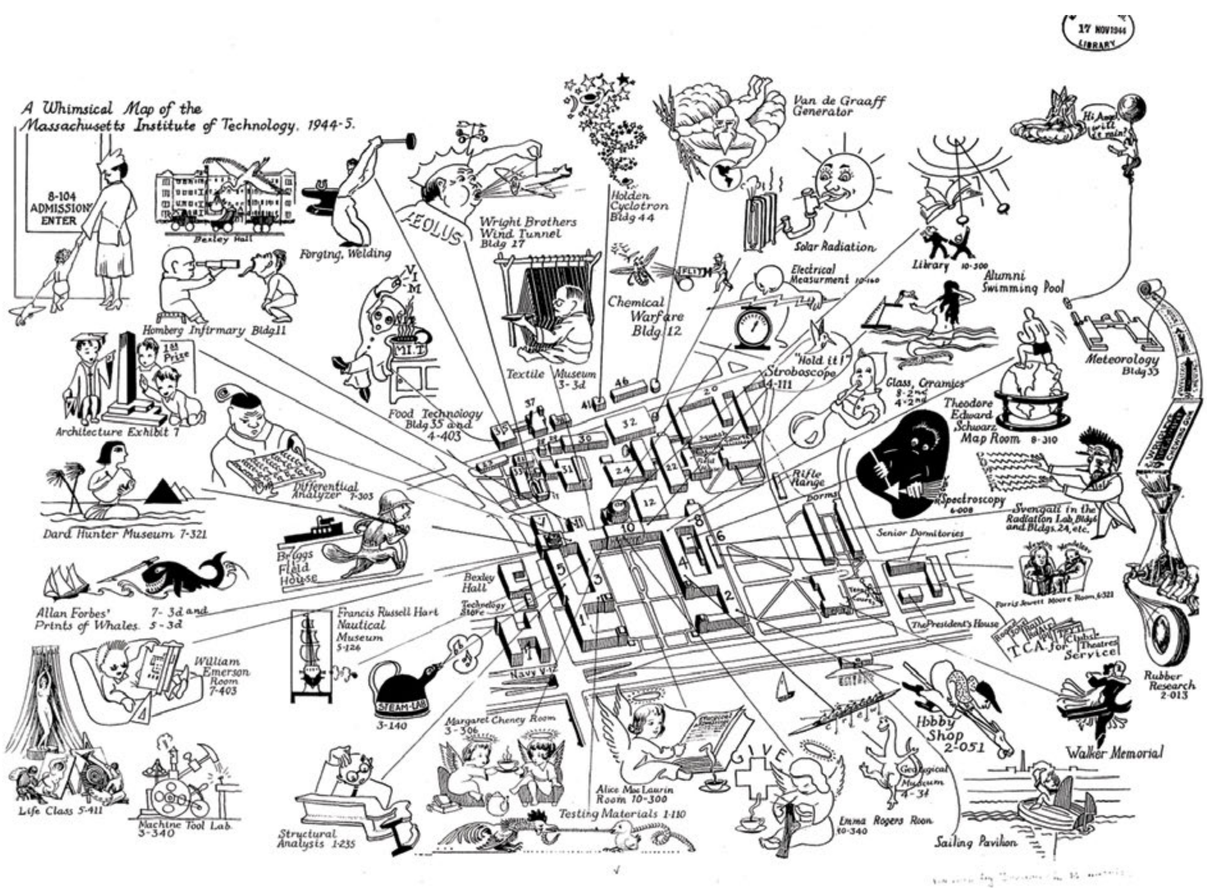


Figure 6.19 Whimsical Map of the MIT in the years 1944-5. Courtesy MIT Museum

The central location of this building in MIT campus is an important characteristic for being a shared facility. The building is at the eastern edge of main campus, acting as a connecting hub between East and West campus zones. In addition, this building is representative of the MIT community: the 'Great Dome' and 'Killian Court' -facing the Charles River- have become emblematic of MIT.

Building 20 - MIT's Magical Incubator

This building was built in 1943 as a temporary facility to accommodate the Radiation Laboratory (Rad Lab), where the radar technology was perfected during wartime. This building was supposed to be demolished right after the end of WWII, but for 55 years was home to a variety of research labs, academic departments, student clubs, machine shops and administrative offices.

During 1945, the spaces used by the Rad Lab were dismantled but Building 20 remained useful to MIT accommodating machine shops, research labs and offices. When the Rad Lab was officially terminated, the Basic Research Division was established because of an initiative of MIT and the government to continue advancing the scientific and technological work in the fields if electronics and microwave physics. On July of 1946, this division became officially part of MIT and incorporated as the Research Laboratory of Electronics (RLE).

The RLE was also an interdisciplinary lab that was initially formed with five groups in different fields[151], which were accommodated in Building 20. Soon the building became home of the Laboratory of Nuclear science (LNS), another interdisciplinary research organisation with various research divisions. In addition, various research offices of the armed forces that continue to be located after the termination of the Rad Lab were housed in the same building. During the 1950s research programs from the army, the Air force and the Navy moved into the building too. This demonstrates the variety of people and activities that took place in this shared facility.

Building 20 was a typical functional building which appearance was regarded as ugly. However, it has been described by several users (MIT Libraries) as being inspiring, independent, pro-creative place, a breeding ground and a magical incubator, outlining the importance of non-territorial characteristic of shared facilities. Such character strengthened the sense of belonging of the users towards a building that became iconic for the MIT's research community. In 1996, MIT announced this building will be demolished in early 1998 and the occupants began moving in 1997. In March 1998, the users commemorated Building 20 in an event where speeches, demonstrations and displays took place [See Figure 6.20]. During the 55 years of existence, this building accommodated temporarily more than 100 occupants performing different activities, where notable technologies were developed and research activities were incubated that have grown to be MIT departments or independent laboratories, such as the Lincoln Lab. The flexibility of its design is outlined as an important aspect enabling such diversity of functions. This aspect is further discussed in the campus intervention D.

151 RLE's initial five groups were 'microwave electronics, microwave physics, modern electronic techniques, microwave communication and electronic aids to computation'. (MIT Libraries)

Figure 6.20 Location of Building 20 in the main Campus in 1996 (Source: Google Earth, Image U.S. Geological Survey, July 5, 1996).

Cambridge Innovation Center - CIC

This office facility was established in 1999, when MIT's alumnus Timothy Rowe saw a potential market for offering flexible accommodation solutions to young companies in Cambridge next to MIT campus. In the early days the initial idea of an incubator developed further into real estate services to help start-ups in setting up and managing an attractive entrepreneurial environment for their businesses[152]. The CIC has established a long-term commercial relationship with MIT Investment Company (MITIMCo), which has provided leasing space for CIC since its establishment. CIC started leasing floor-space from MIT's commercial property located in Kendall Square. The 17-story building has accommodated CIC's growth from 1.800~m2 to over 14.000 m^2 Nowadays, CIC houses over 600 companies from which 450+ are start-ups[153].

The real estate strategy of the CIC is simple: it provides diversity and flexibility of both, financial agreements[154] and spatial arrangements[155] necessary to accommodate the uncertain-growing mode of start-ups. This concept is enhanced with high spatial quality and a dynamic social infrastructure, strengthening the entrepreneurial environment in CIC and Cambridge. This social infrastructure is essential in activating the potential of shared amenities within this facility. For instance the stocked kitchens, conference rooms, copy and printing corners and the leisure zones, are important elements of this infrastructure allowing informal and unplanned interactions[156]. Next to it, are the social events organised to formally arrange interaction among CIC's tenants and stakeholders in the Cambridge-

152 Setting up furniture, stationary, infrastructure, etc.

153 Start-ups vary from one-man company or founding team of 2-3 people to a growing company of 4 to 30+ employees. The companies at CIC are also varied in their businesses (e.g. technology and life sciences companies, professional service firms and venture capitalists)

154 The leasing terms are very flexible especially for start-ups, which benefits from arrangements that can be terminated every month because of their unstable lifespan.

155 Spatial arrangements vary from co-working set-ups (e.g. sharing desks and rooms of different sizes) to private space (e.g. one-man company, private rooms for small and medium size groups, etc.)

156 Planned 'Happy hours' in these shared spaces facilitate interaction and help overcoming the vertical arrangement of building, which is perceived as a burden because each floor works as a exclusive community. To avoid lock-in, the CCI is encouraging people to move across floors by providing particular snacks in the kitchen and dining areas of each floor and at specific times of the day. The Venture

Boston area such as VC firms, students and other interested parties in establishing relationships[157]. These social events and the venues that support it, have helped to strengthen the identity of Kendall Square area as an entrepreneurial environment attracting companies to move in and have released the need for incubators.

In contrast to the previous example (Building 20), the quality of the place seems to be very important for the type of users at CIC. Unlikely to researchers in an academic environment, entrepreneurs value the role of design in building image for their companies. CIC helps providing a high quality environment for start-ups with high standards of interior design[158]. Figure 6.21 illustrates the quality of CIC's office space and venues for social interaction.

1 *Shared office space*

2 *Shared kitchen*

3 *The Venture Café*

4 *Meeting room*

Figure 6.21 Workspace at CIC in 2014

Café is another example where every Thursday people gather for networking since the organisers invite Venture Capital and other firms in the vicinities of the CIC.

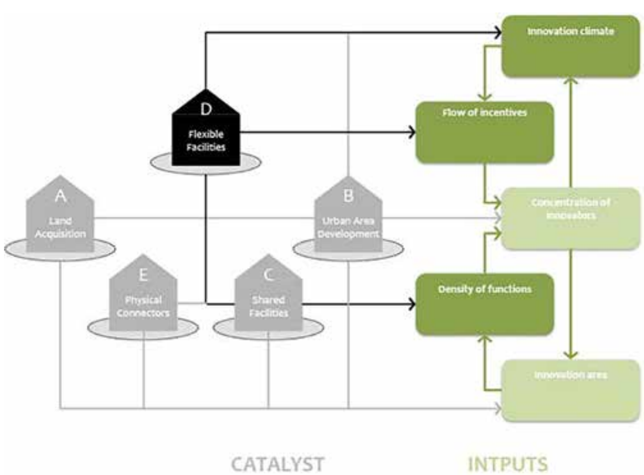
157 A sister organisation of the CIC, the Venture Café Foundation, organise dedicated activities for the CIC communit on regular basis.

158 According to CIC's founder, spatial quality is part of their philosophy of creating inspiring environments for entrepreneurs.

In 2014, CIC expanded its operations in St. Louis and Boston. Similarly, CIC is collaborating with other partners in two important pilot projects of shared facilities in the area. The first is Boston's District Hall, which opened in 2014 in the new Boston's Innovation District. The District Hall is referred to as the first 'civic' co-working space in the world because is open to any citizen willing to use it. This facility provides workspace, classrooms, assembly space and flexible use of workstations to gather and exchange ideas. Similarly to CIC, District Hall offers a social infrastructure fuelled by a café and a restaurant operated by experts associated with CIC. District Hall is the result of a public-private partnership between the City of Boston, private developers and the CIC, involved in the operation and programming of the facility.

The second is LabCentral, which the first shared laboratory space for life science start-ups. This facility offers ready-to-use lab space including permits, waste handling and lab equipment for bioresearch, communal conference rooms, event space and kitchens. In addition, LabCentral hosts programs targeted to the specific interests of life-sciences start-ups. This initiative is the result of a private partnership including CIC with the support of public institutions involved in the development of the Bioscience clusters in Massachusetts. The MITIMCo is a real estate partner since LabCentral is accommodated in MIT's commercial property. Over the years, CIC's model has inspired others in offering similar services in Cambridge-Boston area[159]. This type of commercial shared facilities stresses the relevance of density of people and social interaction, in creating new business ideas and in building an entrepreneurial environment. However, the promotion of this innovative environment around the MIT campus obscures some critical issues of this reality, which is driven by the profitability goals of industry in contrast to those of the academia. These issues affecting the MIT community will be discussed in §6.4.

§ 6.3.4 Campus intervention D: Flexible facilities



Building flexible facilities has been an important catalyst for innovation in the long term. Most of the success of the Massachusetts area is being attributed to its capacity to adapt to the shifts of the technological paradigms over time. Research programs at universities led many of the technological advancements enabling those shifts. Ultimately research activities were accommodated in the facilities of universities. In the MIT campus, several buildings have facilitated the accommodation of the changing requirements of research activities and processes. The influence of rational and functional design principles inspired a generation of architects that helped building the MIT campus in the early years as a horizontal megastructure.

The following paragraphs illustrate with examples how building flexible facilities has been a catalyst for the density of function by allowing diversity of activities under one single roof, for the flow of incentives by channelling capital in a more efficient way and for the innovation climate by accommodating the changing social and technological requirements of research activities over time.

159 Today, there are several co-working spaces in Cambridge-Boston area

TOC

The Main Complex

The Main Complex refers to the set of buildings that are interconnected with the original Maclaurin Building following its functional pattern of arrangement. As described before, the Maclaurin building is inspired by the design principles proposed by John Ripley Freeman in his 1912's study 'A design for the New Technology'. Accordingly, the new buildings should reflect the 'learning by doing' attitude of the pedagogical model of MIT, where the students have practical knowledge and expose other kind of disciplines. Freeman developed a building scheme that resembled the arrangement of modern factories and industrial architecture. His scheme illustrates a concept of a massive building accommodating a group of different academic activities under one single roof, connected by double-loaded corridors for efficient circulation and avoidance of unnecessary traffic. The structural system used modular reinforced concrete frames and light partitions that could be easily removed, increasing the efficiency and flexibility in the construction process.

The interior rationality of Freeman's scheme was synthesized in Bosworth's proposal in 1913 using a double-loaded corridor as a connector of the megastructure[160]. The final proposal adopted the modular reinforced concrete-framed system that was covered in a classical skin preferred by the commissioners of the project at that time. Such structure defined a plan of modular rectangular compartments separated by non-structural partitions that could be easily removed. In fact, this system has allowed accommodating many changes in space use and interior layout in this building over the years.

The expansion of the main building following the same principles led to the main complex that grew in different stages [See Figure 6.22]. During the 1920s and 1930s, adjacent buildings were built in the same style of the Maclaurin building emphasizing the idea of a massive building as urban megastructure[161]. In the 1940s and 1950s, more buildings were added at the North of to the main campus and connected though the system of corridors and bridges[162]. The new buildings began showing their functional and rational character not only in the interior but also in their facades, such as the Compton laboratory designed by the architectural firm Skidmore Owings & Merrill (SOM). This firm was in 1961 selected to design a plan and the new buildings for the northern area of the main campus. In the 1960s, four buildings designed by SOM as part of their plan were realized in this area, including the Bush Building.

These buildings also used a modular reinforced concrete-framed system allowing a degree of flexibility in the interior layout. By the same years, buildings and plans for the eastern zone of the main campus were commissioned to I.M. Pei & Associates. The design of this part redefined the Bosworth spirit because, in contrast to the developments in the northern part, Mr. Pei's design re-created the concept of the courtyards. These two commissioned plans to these well-known architectural firms (SOM and I.M. Pei & Associates) were part of the 1960 Campus master Plan prepared by the Planning Office, in which new rules for the future development of the MIT campus were grounded. During the 1970s, both firms continue reinforcing the functional structure of the campus while showcasing the modern architecture character in the new buildings. In the late 1990s, the commission of the Stata Center to Frank O. Gehry & Associates replaced Building 20 and interrupted the functional system of interconnected buildings in main campus.

160 The expansion of the well know 'MIT's infinite corridor' system became an organising pattern in the main campus. The Infinite corridor is described as a different campus intervention in section 6.3.5.

161 For instance, William Welles Bosworth, with the exception of Building 6, designed most of the added buildings. Also, a group of laboratory facilities (Buildings 31, 33 and 17) were built in the same area but separate from the main building.

162 Some buildings remains but some are already demolished. A notable example of this period is Building 20 already mentioned in section 6.3.3. Similarly, its flexible design deserves to be addressed separately in this section.

Figure 6.22 Development of the main complex from the expansion of the main building in different stages.

Building 20's Design

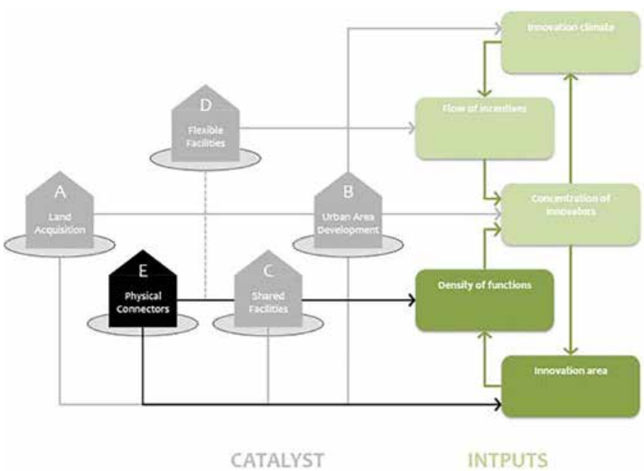
As described in §6.3.3, Building 20 was built in 1943 as a temporary facility to accommodate military research programs during the wartime. However, the building to be demolished right after the end of WWII accommodated a variety of research labs, academic departments, student clubs, machine shops and administrative offices until its demolition in 1998.

Building 20 was a pragmatic functional building which appearance was regarded as unpretentious and sometimes as ugly. However, it has been described by several users as being 'inspiring, independent, procreative place, a breeding ground and a magical incubator' (MIT Libraries). An important feature outlined in the users' stories retrieved in the MIT Libraries is the ample space available in the building.

The design and construction of this building are quite particular because it was meant to be a temporary facility. It has been said the building was designed in one day. The building had a horizontal design consisting of six three-story wings. Its wood frame structure did not have a basement because it was built on concrete slabs. These features provided and adaptable system that for many years allowed the changing occupants of Building 20 to reconfigure the workspace according to their research projects' needs. In addition, the temporary status of the building and the modesty of its appearance permitted the occupants of this building to made tailored modifications without having constrains regarding physical appearance and costs.

It is believed that the horizontality of this building encouraged collaborations between its users in the long hallways, which were once connected to the entire system of corridors of the main campus. Indeed, the design of this building retained all the functional principles of the main complex 'modularity, the double-loaded corridor layout with standardized dimension, connectivity and arrangements of linear buildings to form bounded open spaces' (Mitchell, 2007). Despite its positive effect expanding the connecting system of the Main Complex, Building 20 creates also grimy spaces because of its simplistic approach to the Freeman's rational scheme. In the 1990s, this scheme was revised producing contrasting responses, which followed a different accommodation pattern increasing the built density while reducing the footprint. However, some of these responses have been criticized as pretentious ignoring the strengths of the organising scheme of the campus and the need for flexibility in research and academic facilities. Some of these aspects are discussed as inhibitors in §6.4.

§ 6.3.5 Campus intervention E: Physical connectors



There are different types of physical connectors in the MIT campus enhancing physical proximity among innovators and therefore, facilitating the chances for encounter and interactions. Those types depend on the different scales in which the interactions between members of the MIT community and other communities happen in the innovation area.

At the campus' scale, the corridors, bridges and cloisters between buildings became the physical connectors of a campus system, in which shortening the physical distance between disciplines and increasing interaction between members of the MIT community have been essential fostering research and education.

At the neighbourhood's scale, pedestrian oriented infrastructure plays an important role connecting the MIT community with its surrounding community of entrepreneurs, biotech firms, VCs, services and residents based in Cambridge. At the region's scale, transit-oriented transportation provides the physical infrastructure connecting the MIT community with other institutions and activities in the Cambridge-Boston area. For instance, the Massachusetts Bay Transit Authority (MBTA) subway- and bus systems are the physical connectors shortening the physical distance between the MIT campus and the rest of the innovation area.

The following paragraphs illustrate with three examples at different scales, the important role of physical connectors facilitating the chances for encounter and interactions and therefore, acting as a catalyst for the density of functions and for the innovation area.

MIT's infinite corridor system at campus' scale

In the previous sections, it has been mentioned how the interdisciplinary research and education philosophy of MIT were translated into design features that stressed the informal interaction between teachers and students, as well as the cultivation of social life (Freeman, 1912- MIT libraries). The buildings for the new campus incorporated these principles in the design of large corridors, ample halls and cloisters that became the spaces for encounter for the 'new technology'. These spaces became the organising pattern for the future campus' growth of the main campus since 1916.

The so-called 'infinite corridor' is the most remarkable example of a physical connector in campus. It is a hallway of 251 meters long spanning through the main buildings of the MIT campus. This double-loaded corridor is considered the spinal cord of the campus because it is the most direct indoor route between the East and West zones of the campus [See Figure 6.23]. This corridor was designed as the central spine of the Maclaurin building, which has been home of several interdisciplinary labs, departments and activities of MIT since 1916. The corridor has five levels including the basement of the building and it is accessed through three different entrance halls, elevators and numerous staircases. All these elements in the Infinite corridor's system are spatially ample (e.g. high ceilings, ample halls and wide staircases).

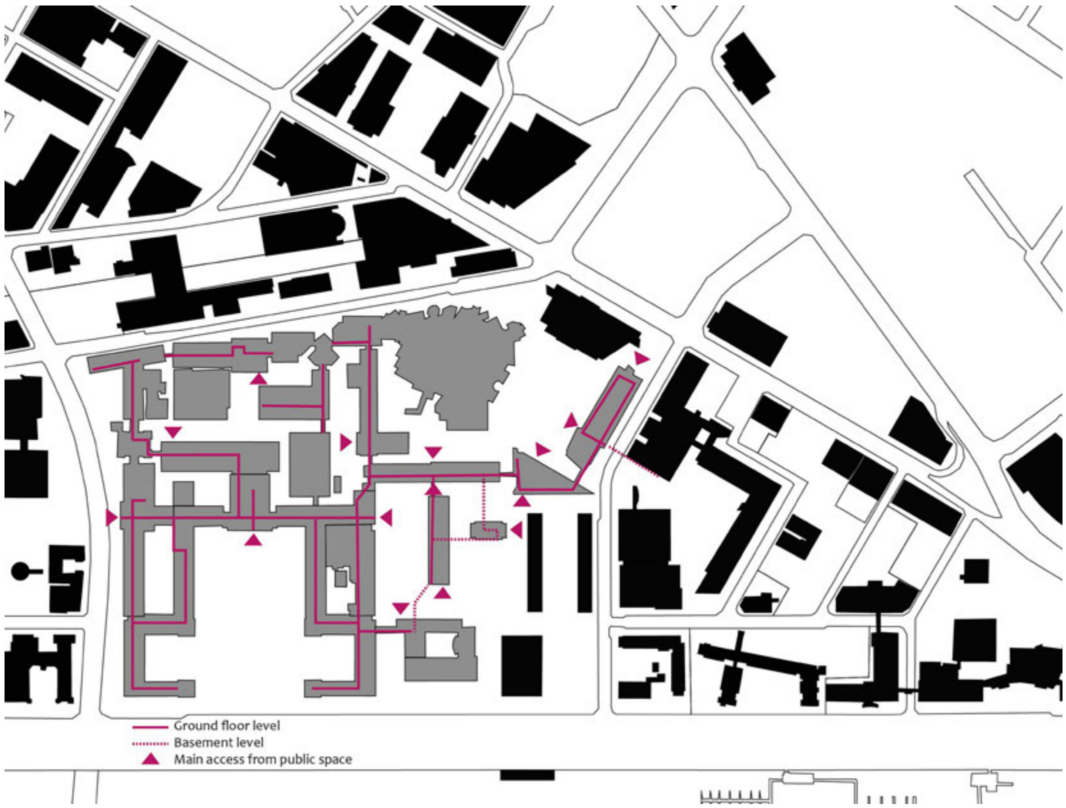
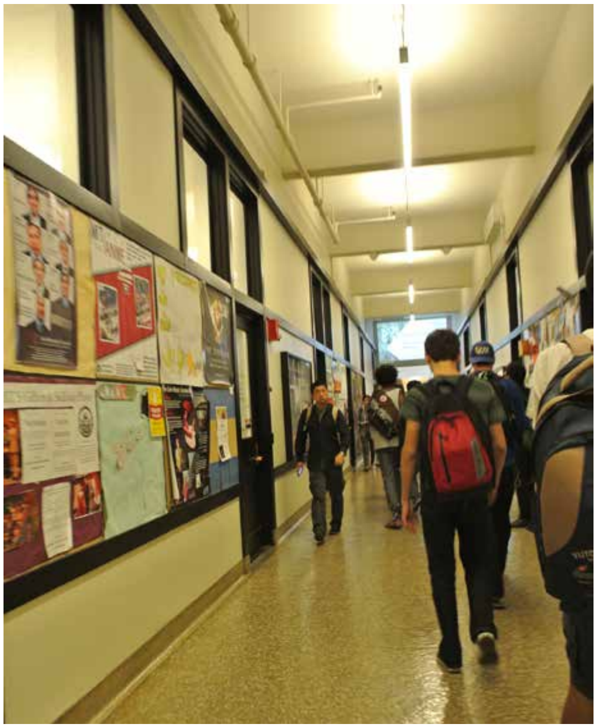


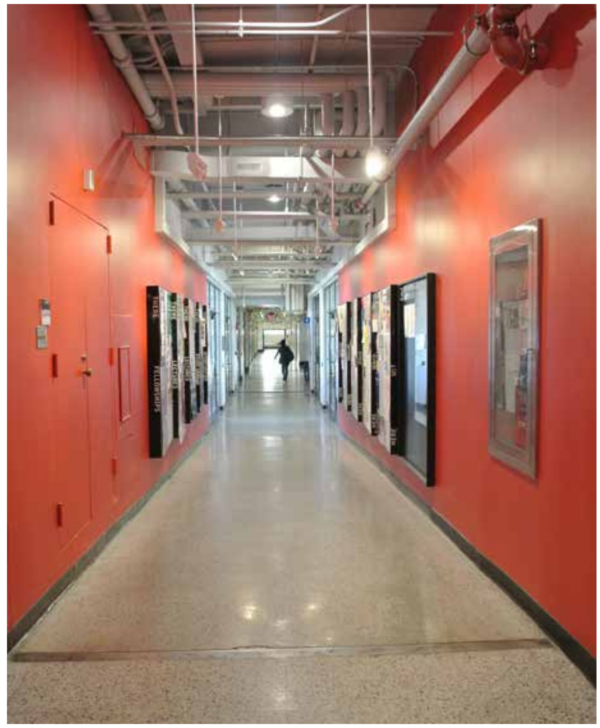
Figure 6.23 MIT's Infinite corridor system in main campus

The extension of the infinite corridor -trough the basement and different bridges in the upper floors- became the main hub in a network of interconnected buildings that characterized the growth of MIT's main campus. The connecting pattern is being replicated later in East Campus and Northwest campus. Despite its strong character, the continuation of the infinite corridor's system was interrupted in the main campus with the construction of the Stata Center (Building 32). This 1998's building ignored not only the design principle of interconnectedness but also a long tradition of functional buildings established at MIT since the 1910s.

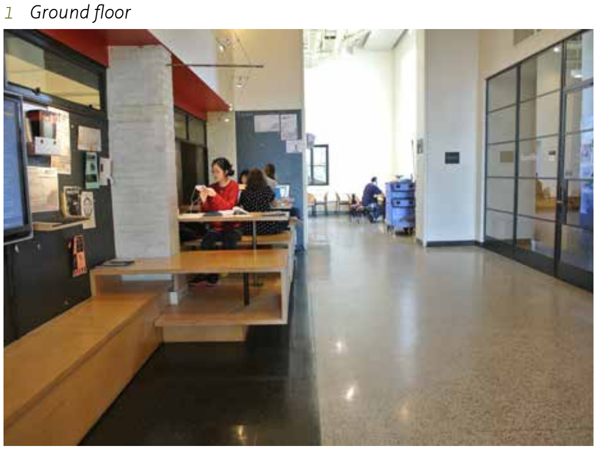
Besides its functional role in shorting distances in campus, the infinite corridor is a major communication channel arranging serendipity. Imagine a walkable highway carrying a continuous and dense flow of people from different departments during the entire day. In the infinite corridor, people meet accidentally and stop by just to shake hands or share bits of information. Similarly, people get informed about what is going on campus because the infinite corridor displays information –by physical and electronic means- hanging on the corridor's walls. Ultimately, people hang around the infinite's corridor because the changing width of the corridor allows the placing of furniture that works as flexible workstations for the MIT community [See Figure 6.24].



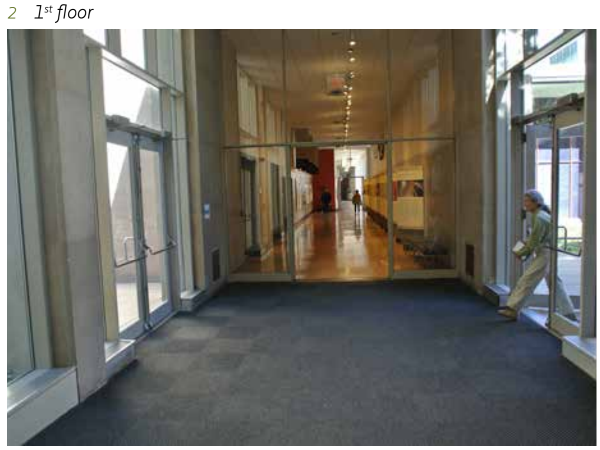
1 *Ground floor*



2 *1st floor*



3 *1st floor*



4 *Ground floor*

Figure 6.24 MIT's infinite corridor in 2014

Lastly, this physical connector has a strong symbolic value for the MIT community enhancing the identity of the innovation area. The infinite corridor has been over the years the place for research demonstrations, artworks, students' hacks and happenings. The most remarkable of these happenings is known as the MIThenge, referring to Stonehenge's alignment with the sun. In fact, in mid-November and in late-January every year, the path of the sun crosses the axis of the MIT's infinite corridor along its 251 meters. When this phenomenon takes place, the MIT community gathers in the infinite corridor to observe such event, which is predicted by MIT's researchers every year.

Pedestrian oriented infrastructure at neighbourhood's scale

The walk-ability of the MIT campus and its surrounding area is an important aspect facilitating the reachability of- and the communication between the different communities using in the area.

For example, building relationships between officers of the MIT's Industry Liaison Program (ILP)[163] and the MIT's research community is an important step in establishing linkages with industry. Informal meetings in events, restaurants, or just on the street facilitate that step because people get specific information out of informal communication and also people build trust with frequent encounters. Similarly, other area's users build their relationships when attending entrepreneurial events, lunch meetings, coffee breaks, exhibitions and other activities accommodated in the MIT campus and its surrounding areas.

In this context, the public space, the bike infrastructure and other supporting systems to walking (e.g. dedicated shuttle services for targeted communities) have become the physical connectors in the MIT campus and its surrounding area in Cambridge. Indeed, the location of MIT campus in the southern edge of the city emphasizes its walkable connections towards North-, East- and West Cambridge rather than to south where the river the river acts as a natural barrier between Cambridge and Boston.

First, the public space plays an important role creating comfortable pedestrian access to buildings and services in the area, which are mostly located on the ground floor such as stores, restaurants, cafés, etc. In the case of MIT campus the public space is an evident physical connector because the overlapping characteristic between MIT campus and Cambridge[164]. Overall, a continuous urban structure makes the area a friendly walkable unit. However, the strength of the public space as a connector is facilitated by the activities along- and the quality of the public space. For instance, the walkable connections of the MIT campus are different according to the functional campus zones. A good example of this is how the quality of the public space in the Northeaster zones of the campus towards Technology Square and Kendall Square has improved with the mixed use developments. The public space in these areas -especially along the Main Street and Vassar Street [See Figure 6.25]- emphasize the design of wide pedestrian paths with good quality of pavements and urban furniture, trees, sufficient traffic signs, bike lanes and commerce in the ground floors of the buildings. These elements provide safe opportunities for walking and biking inviting pedestrians to use this space. Unfortunately, this is not the case in many other zones of the MIT campus and its surroundings, which deserves attention for improvement.

1 Main Street, 2014

2 Vassar Street, 2014

Figure 6.25 Public space where campus intersects the city

163 The MIT Industrial Liaison Program (ILP) -established in 1948- is dedicated to creating and strengthening mutually beneficial relationships between MIT and corporations worldwide.

164 According to empirical data compared in the exploratory research, Overlaps is one of the five characteristics of technology campuses in relations to its hosting cities. In this characteristic, the city and the campus share common points that happen to be at the level of the public space.

Second, the bicycling infrastructure is becoming important as a fast-connector between the MIT campus and the immediate neighbourhoods in Cambridge and Boston through the Harvard Bridge along Massachusetts Avenue. In both cities, bicycling is encouraged by the municipalities and increasingly popular among the young population. There is an extensive network of bike-ways in Cambridge and Boston, connecting different zones of the MIT campus with the neighbourhoods and with the region.

In the campus, these are located along the main roads[165]. This infrastructure is being complemented with Bike sharing systems[166], sufficient bicycle parking and bike-accessible transit on MBTA's boats, subway lines and buses equipped with bike racks. Nowadays, there are four bike-sharing stations in the MIT campus area. In addition, the campus provides with more than 100 bike racks on campus and several bike repair station, proving the importance of this infrastructure as a physical connector for the MIT community [See Figure 6.26].

Figure 6.26 Bike infrastructure in MIT campus. Data: MIT Facilities, October 2014

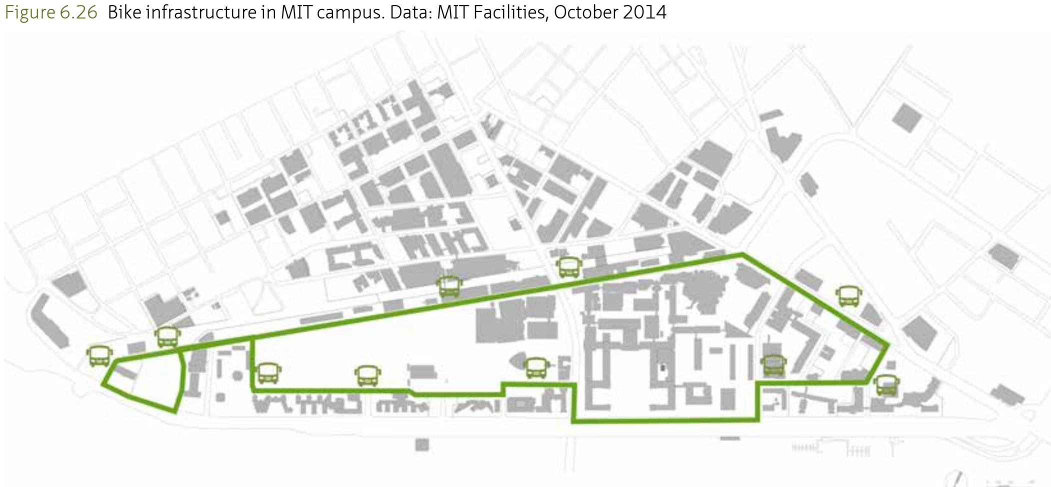


Figure 6.27 Route of the Tech Shuttle. Data: MIT facilities

165 Main bikeways in MIT campus are located along Massachusetts Avenue connecting Cambridge with Boston, Vassar Street, Main Street and on the side of Memorial Drive in Charles River Paths.

166 Bike sharing systems are public bicycle systems in which bikes are made available for shared use on a short term basis. In the Cambridge-Boston area, this system is called Hubway and it was established in 2011 as a milestone of the 2007's Boston Bikes program initiated by the Major's office.

Last, a dedicated shuttle service for the MIT community is a transit means supporting the pedestrian oriented system at the neighbourhood's scale. For instance, the so-called Tech Shuttle provides transportation around campus within working days and from 6.15AM to 7.10 PM. This dedicated service runs every 10 to 20 minutes and has 11 stops around the campus [See Figure 6.27]. This system aims to complement the pedestrian infrastructure because it improves the connection between the different zones of the campus, which are less time-efficient by walking, especially in wintertime. Simultaneously, it increases the use of the pedestrian paths within specific campus zones from the bus stop to the users' destinations.

Kendall Subway Station at regional scale

In a larger scale, the public transportation is the element connecting the MIT campus with the Cambridge-Boston area and the entire region. The Massachusetts Bay Transit Authority (MBTA) operates 29 bus routes through Cambridge connecting to the metropolitan area. In addition, there are two subway lines (Red and Green) with six stations and one commuter rail station in Cambridge connecting to (inter) national accessibility nodes[167]. For the MIT campus, the Red line with its Kendall station is the most efficient physical connector in this transit system shortening the distance between MIT campus and the Cambridge-Boston area and beyond [See Figure 6.28].

The Red line runs through the metropolitan area in direction North-South connecting five different municipalities: Somerville, Cambridge, Boston, Quincy and Braintree. This subway line is the flagship of a regional economic development initiative so-called the Life Sciences Corridor, that focuses on Transit Oriented Development (TOD[168]). The Life Sciences Corridor is connecting and providing access to a number of universities, research institutes, R&D firms and university hospitals located along this line [See Figure 6.29]. In addition, it strengthens the identity of the innovation area with a life science brand.

Kendall Station is an important node in this corridor because of the presence of MIT and the high concentration Biotech and Pharma companies around it. For the entrepreneurial environment at Kendall Square, the presence of the station is an important location factor because it provides access to the airport and other transport systems[169]. In addition, the strong identity of the station associated to MIT helps strengthening the brand of the Life Science Corridor. For instance, its interior design displays a timeline with MIT's technological achievements next to the urban development of the area. Overall, this station is a main physical connector integrating the whole connecting system of the MIT campus at the three different scales described in this section. For instance, the station is located in an area where the pedestrian oriented system (of public spaces and bike lanes) is being consolidated and where there is clear path connecting East campus to West Campus through the infinite corridor system of main campus. However, there is a need for improvements between Kendall Square, East Campus and Main Campus concerning pedestrian oriented design. In addition, the integration of the different elements in the system deserves more attention. Some of these issues will be discussed in in §6.4.

167 The Red and Green subway lines connect with the main rail stations in Boston (North Station, Boston Back Bay and Boston South) that are part of the national rail system. Besides, the Red line quickly connects to the Silver Line that provides access to Boston Logan International Airport.

168 TOD focuses on mixed use residential and commercial development designed to maximise access to public transport.

169 For instance, an important connector for the area is the EZ Ride Shuttle. This is a dedicated bus route running 5 days a week and connecting Cambridgeport, Kendall Square, East Cambridge to Boston's North Station. It works as a complementary system of the regional network, allowing access to this area from other locations in and outside the state. (Cambridge Just the facts, 2014).

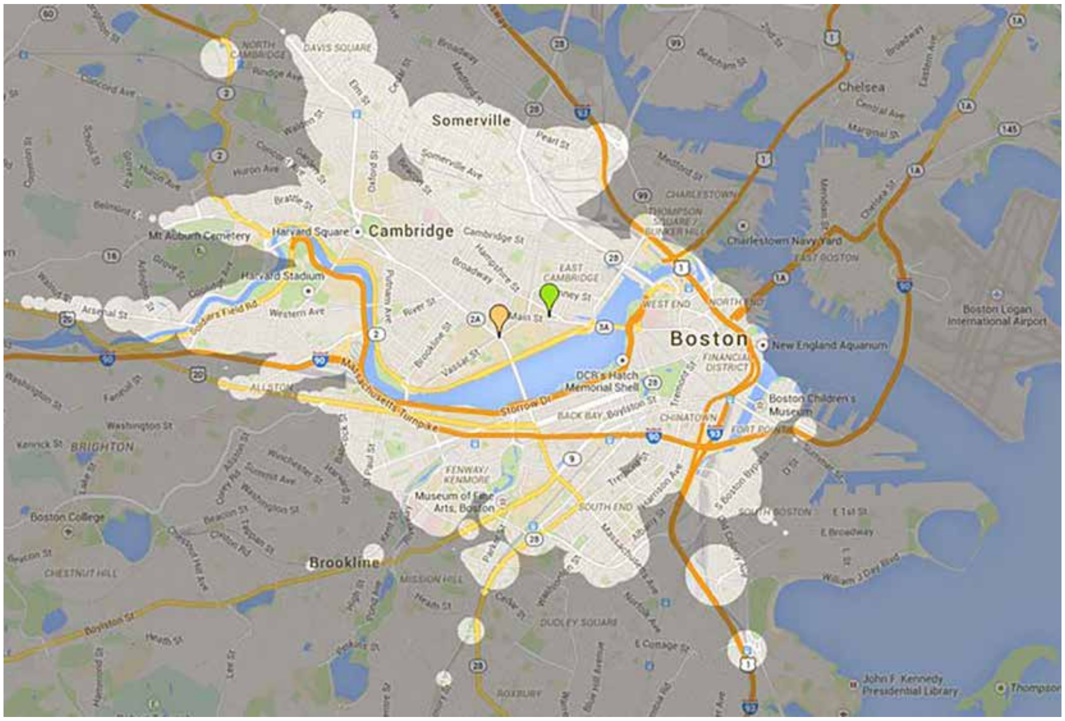


Figure 6.28 Accessibility within 15-20 minutes from MIT campus using public transport. Map: Magnificent, using data generated automatically from the Massachusetts Department of Transportation and the Massachusetts Bay Transportation Authority, accessed on March 2015.

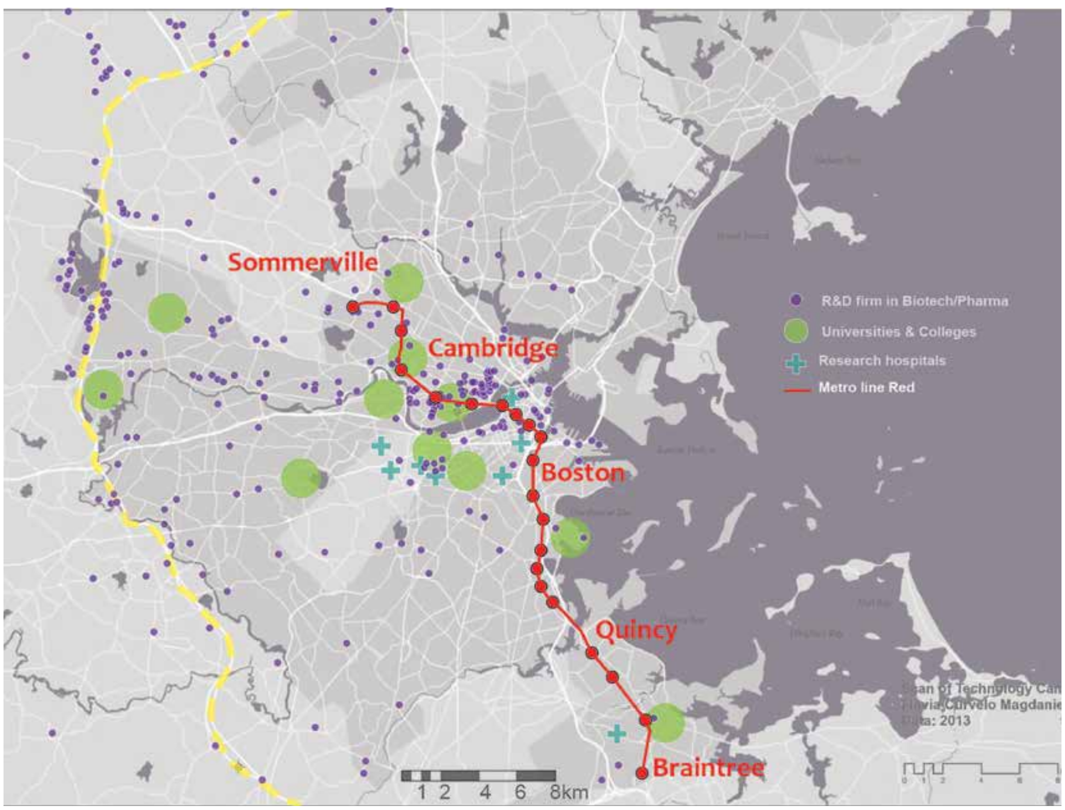


Figure 6.29 The Life Sciences Corridor in Greater Boston. Base map data: Esri, 2014

§ 6.4 Discussion

In the previous sections, the development of MIT campus has been studied as a historical phenomenon linked to a specific context in which innovation has been successfully stimulated. This study has used an analytical framework to validate the proposition that built environment can be a catalyst for the inputs of innovation. This chapter has illustrated with examples how five types of interventions on MIT campus have facilitated specific conditions for innovation in MIT and the Cambridge-Boston area. Few issues related to these interventions have been found through the analysis. They deserve special attention because these issues can hinder the role of the built environment as a catalyst for innovation. Thus, this section will discuss these findings based on the available empirical information and the research proposition above.

§ 6.4.1 Relationships between the campus interventions as a catalysts for innovation

In validating its proposition, this study has found that the built environment as a catalyst for innovation has taken place by means of specific interventions, which appear to be related in the case of MIT campus. Two relationships are distinguished because of the focus of each intervention facilitating the conditions for innovation.

The first relationship is defined by interventions focused on supporting the goals of organisations, which outline the role of management and planning in campus development. These are land acquisition and urban area development. Both interventions were directed to support the strategic mission of the MIT in the long-term, which turned out to have unexpected impacts. For instance, these interventions have helped to establish and maintain a collaborative relationship between MIT and the city of Cambridge in fostering the economic development of the city. Over the years, MIT has acquired land in Cambridge to secure its accommodation growth in the long term, while its presence in the city and the tax-exempt status of its academic land has been employed by its hosting city in fostering development[170]. In addition, both interventions have facilitated the concentration of firms in Cambridge accelerating the process of technology transfer and the fulfilment MIT's mission of applying knowledge into practice.

The second relationship is defined by interventions focused on supporting the activities of organisations, which outline the role of planning and design in campus development. These are shared facilities, flexible facilities and physical connectors. These interventions were alternative responses in solving the accommodation needs of MIT's core activities: education and research. These interventions have shaped the social, academic and working environments in MIT campus. For instance, translating MIT's founding philosophy into an accommodation solution that has been replicated for several years, allowed MIT to build flexible facilities housing different types of activities and people, who shared spaces under one single roof while creating the opportunities to meet and communicate thorough physical connectors[171]. These interventions have facilitated mainly the density of functions, activities and people, believed to accelerate the process of knowledge creation as part of MIT's educational and research model.

170 Empirical information explaining these observations is found per each intervention in sections 6.3.1 and 6.3.2.

171 Empirical information explaining these observations is found per each intervention in sections 6.3.3, 6.3.4 and 6.3.5.

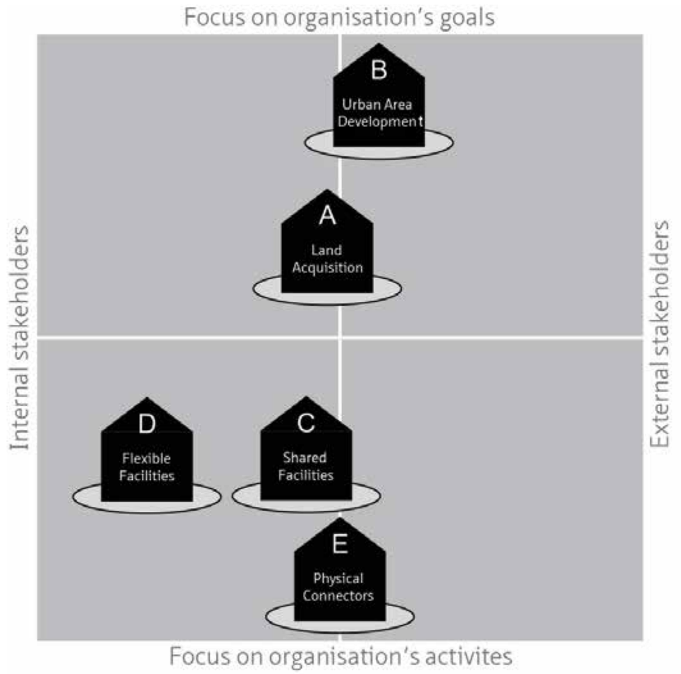


Figure 6.30 Relationships between the campus interventions according to their focus supporting organisational goals or activities.

These campus interventions not only define the relationships among them, but also the involvement of various stakeholders in campus development [See Figure 6.30]. These stakeholders have different perspectives on campus interventions as a catalyst for innovation. Such differences have raised a number of issues that can inhibit the catalytic action of these interventions. These issues will be discussed in the following section.

§ 6.4.2 Stakeholder's perspectives on campus interventions as catalysts for innovation

Section 6.3 slightly mentioned some issues related to each campus intervention that can inhibit their function as a catalyst for innovation. These issues are not exclusive to a single intervention and that is the reason they are addressed in this section. These issues are associated to the stakeholders' perspectives on campus interventions as a catalyst for innovation. This means stakeholders perceive innovation in different ways according to their ambitions and perspectives on the built environment. Therefore, some issues arise when the incompatibility of their ambitions generate a lack of balance in campus interventions. These situations can reduce the function of the built environment as a catalyst for innovation and they could hinder the processes leading to innovation in the area in the long term. The following paragraphs address conflicts between specific stakeholders in different campus interventions and how they become issues that can inhibit the function of the built environment as a catalyst for innovation.

Commercial development vs. Academic accommodation

Since the late 1990s, there has been a change in focus in land acquisition policies at MIT. The allocation of campus' land resources and area development efforts to commercial uses has been raising a conflict between specific stakeholders, whose perspectives on the built environment as a catalyst for innovation are incompatible.

Decision makers and controllers of the MIT campus' properties perceive the commercial development of urban areas around Kendall Square as an opportunity to generate income that will sustain the Institute's mission while keeping an entrepreneurial environment around campus. For instance, during the development of MIT's Kendall Square initiative, the Institute abandoned its commitment to reserve the land south of Main Street for academic purposes. As a result, the 10-hectares parcel of MIT academic property will be converted into a mixed-use development including new housing, retail, lab and commercial space. Similarly, academic land reserves have been leased to private firms for long terms, closing off MIT's academic expansion in North Campus[172].

This internal initiative led by leaders of the Institute and controllers of MIT's properties have been supported by the City of Cambridge, because there is an alignment in their ambitions. With this type of developments, the city will benefit because of the revenues coming from property taxes, while succeeding in their ambition to create an attractive 'place to live, work and do business' as part of their economic development strategy. This alignment in ambitions has strengthened the relationship between MIT and the City of Cambridge for decades. The coordination of their strategies was based on a collaborative model of mutual respect and understanding. Nevertheless, the strategic nature of such relationship is increasingly built on financial ties, in which the lack of long term planning can result in uncontrolled development that can be followed by political action. Recently, members of the MIT community organised a committee to be formally involved in the planning of Kendall Square. The involvement of the community in this project is an initial MIT's political stand to ensure the long-term (social and financial) sustainability of this area in line with the future growth and expansion of the Institute as well as the preferences of its main users (i.e. academic staff and students).

Academic leaders and influential members of the MIT community have perceived these interventions as a threat for the Institute's future in accommodating academic growth and fulfilling its academic mission. Accordingly, this group of stakeholders argues that ensuring the institute's growth of academic space is as important as generating income to sustain its mission. Indeed, they perceived the emphasis on commercial development as a paradoxical strategy, which is focusing on short-term financial returns at the expense of long-term welfare of MIT. The implications of this strategy for the MIT's financial operations can be roughly drawn in possible scenarios.

If the MIT schools would need space that has been allocated for commercial use, they would have to pay for it at the high market price. In the end, if schools have financial trouble in accommodating growing education or research programs, they will have to get the financial support of the Institute. This can result in formal buying decisions in getting back those properties to academic use, which will de-capitalise the Institute's endowment. In addition, such decisions will raise political disagreements with the city that will suffer in the moment MIT decides to take such land off the city's tax roll. If that is not the case, the schools will have to lease more properties from other commercial parties at high costs. The Institute must subsidise the cost of the rent, or the schools will have to raise capital outside MIT to buy buildings or rent space at the cost of their research programs. In the last scenario MIT schools and departments will be threatened by their academic competitors because the sponsors of research programs are unlikely to spend their budgets on space rather than on actual research.

172 Novartis has extended a long-term lease with MIT for land to develop a 51.000 square meter campus of lab, office and retail space. The so-called Novartis Cambridge Campus will accommodate Novartis Global Research Headquarters. Similarly, Pfizer has entered a long-term lease agreement with MIT for more than 16.000 square meter building, located next to Novartis Campus. The site is home of the Pfizer's R&D labs in Pharmaceutical, Bio-therapeutic and Biological research.

Overall, there is a need for a healthy debate between these stakeholders to bring balance and to avoid uncontrolled development, which in the end can inhibit the role of MIT campus facilitating the innovation climate. It does so, because the MIT's mission of educating an advancing research – which is essential in creating knowledge and transferring technology in the Cambridge Boston area-, is threatened without ensuring academic space or generating income to support the Institute's core business. The poor communication between these stakeholders and the cultural differences in their practices are not facilitating the required space for debate. Decision makers and controllers are aware of the risks on the long term, but keep their position on investing MIT's capital according to the real estate opportunities while 'learning by doing' on the process. The other stakeholders have manifested their opinions and reactions to this strategy through formal communication channels (e.g. the MIT Faculty Newsletter) in order to raise these concerns among members of the entire community, which comprises students, faculty, staff, alumni, parents and more. Nevertheless, the periodic changes in administrations –both, in MIT and the City of Cambridge- are major obstacles to have a continuous and healthy debate in overcoming this issue.

Attracting firms vs. Retaining talent

The stakeholders' conflicts addressed in the following paragraphs can be seen as results of the situation described above. Indeed, the allocation of area development efforts to commercial uses is having an impact on campus life, in which the fostering of a mixed working, academic and social environment is raising major concerns among specific stakeholders. Similarly, their perspectives on the built environment as a catalyst for innovation are different, especially those concerned with area development in relation to physical connectors and shared facilities. These conflicting perspectives are described as follows.

The City of Cambridge, as well as real estate developers and investors, see the mixed-use development around MIT Campus as an opportunity to boost the entrepreneurial environment in Cambridge. The undeniable success stories of Technology Square and University Park @MIT facilitating the establishment of companies, is been replicated in Kendall Square since 1968. Though, its development over such a long period has taken a different scale and character shaped by the socio-economic events in context. Indeed, the municipalities are contesting the booming of the biotech and pharma cluster out of the advancements in biomedical research with urban development strategies aimed to sustain the presence of firms and research institutions in close proximity to the talent in academic institutions. For instance, the development of mixed-used districts and transit-oriented development are example of these urban strategies present in Kendall Square.

Nevertheless, the fostering of that mixed environment for 'working, living and doing business' is overlooking 'studying' as part of that existing environment and more important, as an essential activity in the city. As it has been described before, students and young people represent a considerable share of Cambridge's population. This trend is also visible in Kendall Square, where the MIT students' population is representative of the area's population. Nowadays the high concentration of firms and the intensification of commercial developments in Kendall Square are creating other problems. The area is becoming crowded and expensive. First, the dense concentration of users in the area generates traffic congestion with an environmental impact, which is not yet solved by the transit-oriented strategies on development. And second, the high rental prices of housing, office and retail space are increasing the costs of living in the area, which can become unaffordable for the young community of entrepreneurs and students.

These two issues are related and strengthened by the different perspectives on the built environment between developers and users. For instance, the lifestyles and commuter preferences of young knowledge workers are urban oriented. They see physical proximity and connectivity as strengths to boost their productivity. Some of them are willing to pay higher prices for urban real estate instead of moving to suburban areas[173]. This situation is optimal for commercial real estate developers, who see physical proximity as an opportunity to boost their profitability. However, commercial real estate development needs to be controlled, especially around universities because many young people (e.g. students) cannot afford it. In this regard, there is a need for more involvement from the municipality and representative of the communities, to create a balanced mixed-use development, which considers the income difference among individuals who are an essential part of their promoted 'entrepreneurial ecosystem'. For instance, investments in affordable housing, public transportation and public space are crucial to enable a healthy environment for all the involved communities in Kendall Square area. Otherwise, the promoted role of physical proximity in innovation will be hindered.

Another issue derived from the efforts to strengthen the proximity between firms in the area and the talent in the MIT campus is the promotion of an ideal collaborating environment that obscures the reality about the processes leading to innovation. The historical incompatibility of ambitions between industry and academy regarding innovation is not easy to solve through mixed-area developments or shared facilities initiatives. For instance, the examples described in section 6.3.3 about shared facilities, involved people either in academy, or in industry but not the mix of the two. That is because the end goals and research processes of these two spheres are opposing.

MIT focuses on advancing knowledge from fundamental research and transferring technology through licensing mechanisms, while firms in the private sector focus on generating revenues from research and development. Thus, the separation between university and industry is a policy established at MIT, after learning from experiences sharing research laboratories. Indeed, the mentality differences between academy and industry protecting their intellectual property failed in their efforts to build a proper and healthy relationship[174]. As described better through the innovation climate in section 6.2.2, MIT's Technology Transfer Office (TLO) focuses on establishing a relationship with industry as founding partner while keeping the MIT's research focus on fundamental sciences.

Similarly, fostering entrepreneurship is not a kind of magic resulting from placing industry next to academic talent. There is a long path between having an idea and developing it into a new product, which takes time, incentives and support. Many MIT graduate students in the fields of science and engineering struggle to develop research topics that they can simultaneously base their dissertation and take their inventions to market (Voosen, 2014). Thus, some of them have to push their academic work aside knowing that their ideas are more likely to succeed if they are fostered by themselves rather than licensed to a company. As described before through the flow of incentives in section 6.2.2, the Institute helped them by attracting investors, finding venture capitalist and keeping people interested on MIT's ideas. In this context, the new real estate developments aimed to accommodate young emerging entrepreneurs next to venture capital firms comes opportunistically to support and strengthen this flow of incentives. Nevertheless, these are also commercial activities driven by incentives for income.

173 Based on Informal talks with a student and a researcher, testimony of an office and rental prices and high demand – no vacancy. Walkability and spatial quality.

174 The industry's mentality of protecting intellectual property involves the necessity of non-disclosure agreements with employees and controlled laboratory space. This is largely the reason why science parks and university campus buildings have been separated.

Therefore, it is important to understand that the process of producing scientifically based commercial ideas emerges and it is nurtured in a different context.

Overall, these remarks are important to understand that the proximity between university and industry in this case, has evolved naturally and it is not to be forced. Therefore, the strategies encouraging their proximity -such as mixed-use development- have to be planned and implemented carefully, considering they are different spheres that collaborate while keeping their own status and ambitions.

Competitiveness vs. Collaboration

The dependency of municipalities' income from payments on real estate taxes creates political tension between neighbouring cities when companies choose locations for their businesses. This situation has increased the competitiveness between Cambridge and Boston, in which each municipality has chosen a different strategy in attracting and retaining firms. As described above, the city of Cambridge is encouraging the development of mixed-use districts around universities, such as Kendall Square.

On the contrary, the city of Boston is applying an experimental policy focused on providing housing and social infrastructure for young entrepreneurs, independent from the universities' owned territories. Conversely, the community feeling of a university campus is being replicated at area development. The Boston's Innovation District is one example of these neutral territories. For instance, the before-mentioned District Hall is the campus' version of the student centre but for start-ups. Similarly, the so-called innovation housing is a pilot project that allows building smaller but affordable housing units in urban areas for young people. The city is aware that Boston is an expensive location and reinforcing housing and social infrastructure is their strategy to social economic development.

On a regional scale, this neighbouring competition increases the flow of incentives for companies to establish in Massachusetts. Nevertheless, on a larger scale, overlooking the lack of collaboration between these two municipalities can be a threat in attracting and retaining companies, since there are other competitors at national level that can attract firms, such as New York that is only 350 km away. This city has also a strong concentration of renowned academic institutions, research establishments and tech-firms. Similarly, they are developing urban areas to attract firms in close proximity to universities leading to stimulating innovation. This type of strategy is replicated in several cities in the U.S. and it is being researched as an urban phenomenon in practice and in academia[175].

Form vs. Function

Section 6.3.4 has described how functional buildings have played an important role accommodating the changing activities and users of the MIT over the years. Similarly, it is been addressed how this campus intervention is perceived as a key facilitating the innovation climate (i.e. adapting to the changing spatial requirements resulted from technological shifts). Also, it has facilitated the flow of incentives (i.e. channelling capital into more productive uses over time), the density of functions (i.e. providing the spatial flexibility to accommodating diverse activities) and ultimately the innovation area (i.e. building identity of the MIT's environment). However, there are two inhibitors for flexible facilities as a catalyst for innovation, in which the allocation of building efforts towards form over function has raised concerns among stakeholders interested on campus' physical and functional perspectives.

175 The MIT Media Lab' Seminar 'Developing Cities' explore the role of innovation in urban development. Student's case studies showcased initiatives in New York, Las Vegas, Austin, San Francisco, etc. Katz and Wagner (2014) have developed a model for the so-called Innovation Districts, explained through case studies in U.S. cities including Kendall Square.

The first is the changing administrations at MIT and their lack of commitment of in giving continuity to the functional building traditions. Since the late 1990s, there has been a change in direction from the MIT's administration regarding campus development. The new administrations have disregarded the existing planning principles and the physical infrastructure's system that organised the growth and expansion of the campus since its establishment in Cambridge. This attitude resulted in a legacy of landmark buildings that overlooked the need for flexibility in the long term and for being part of a connecting system[176]. Thus, the role of flexible facilities catalysing innovation is inhibited by the role of attractive –and expensive- facilities capturing public attention.

Conversely, planners, designers and faculty, who know the MIT campus' building traditions, have criticized those interventions as being detrimental for the campus' organising structure. The Design Committee for MIT's Kendall Square' Initiative have labelled these past interventions as 'Building+Building+Building≠Campus' in order to avoid this approach in the future. An important issue outlined from these experiences, is the importance of working with preferred partners - such as local based consultants- who know the place, understand the local needs and share the culture.

The second inhibitor for flexible facilities as catalysts for innovation is delivering buildings, in which the form is a function of profitability rather than of productivity. Recently, real estate developers and the city of Cambridge have the intention to increase the building density in Kendall Square's development. This zoning modification will allow more commercial tenants in the area, which is substantially important for those stakeholders' ambitions. However, this will also result in smaller floor-plates and taller buildings. The building outcomes of this development are the opposite of the academic megastructure, which is horizontally connected by internal streets and characteristic of the flexible facilities at MIT campus. Thus, if Kendall Square happen to be a dense development with more and taller buildings, arranging serendipity with programs will become very important because there will be less chances for unplanned interactions among people in vertical accommodations. Thus, the functional mix in the ground floor and the public space in Kendall Square will become more important in shortening physical distance between innovators in this area.

§ 6.4.3 Final remarks and case recommendations

The observations discussed in the previous paragraphs illustrate the relationships between campus interventions as catalysts for innovation involving different stakeholders. In addition, it has been illustrated how these stakeholders have different perspectives on campus interventions, which can inhibit the actions of these as catalysts for innovation. It can be said that this difference relies on how innovation is perceived by these stakeholders.

This discussion helped to identify a dual perception of innovation among stakeholders involved in campus interventions, which reinforce the ways in which the interventions relate to each other (e.g. focus on organisation's goals or needs). On the one hand, stakeholders who focus on campus as

176 The Stata Centre designed by Frank Gehry and MIT's campus planners and faculty members of the School of Spatial Planning and Architecture address the Dormitories by Steven Hall as examples of it. The buildings that are isolated (the tower) are failures as academic buildings because the people in those buildings are isolated from the community and they complaint about it. The Stata Centre has a weak connection with the original buildings and it doesn't connect further to the new buildings. All the possibilities to dynamic relationships were lost. It is not part of the campus system. These building were designed as if they were in isolated places not as part of an organic system.

an accommodation solution tend to perceive innovation as a process driven by the exchange of ideas. They seek to facilitate people's activities and processes through the built environment. Therefore, the concentration of R&D firms around MIT campus is seen as an opportunity to encourage a creative environment leading to the discovery and the application of knowledge in attaining their goals.

On the other hand, stakeholders who focus on campus as an asset resource tend to perceive innovation as a market driven by the exchange of capital, while promoting the first perception. They seek to maximize investments through the built environment and to increase real estate value. Therefore, the concentration of R&D firms around MIT campus is seen as an opportunity to encourage commercial area development in attaining their goals.

The four conflicts from the stakeholders' perspectives described in section 6.4.2 are results of these two perceptions. For instance, 1) focusing on commercial developments over academic accommodation, 2) attracting firms over retaining talent, 3) competing over collaborating in urban strategies and 4) allowing form over functional needs, are four examples in which the perception of innovation as a market driven by exchange of capital is increasingly dominant in campus development. However, a trade-off for this perception of innovation can also inhibit the role of the built environment as a catalyst for innovation in MIT campus. Therefore, the following are important points of attention to tackle the inhibitors of the built environment as a catalyst for innovation in MIT campus:

Having a shared vision of innovation is not enough for the MIT and the Cambridge-Boston area. It takes stakeholder's consensus in delineating goals and most important, stakeholder's commitment in using their resources –e.g. the built environment- to attain the desired vision for the future. For campus & city managers, the main challenge is ensuring the continuity of goals and their implementation because of the short-term condition of their appointments. Thus, acting upon the changing demand should be seen in a long-term perspective.

Taking advantage of the overlapping characteristic of MIT campus in the city to strengthen collaboration with public and private partners and to negotiate when improving the weak points in campus (e.g. potential shortcoming of academic space, poor public space, traffic issues and affordability of students' housing). For campus & city planners, the main challenge is reaching the balance among the different ambitions of stakeholders involved in the development of MIT campus. Thus, opening spaces for debate leading to participatory planning is recommended.

Reinvigorating the design principles inspired by MIT's educational model in campus to strengthen the student's social instincts and the interaction among faculty and students across disciplines. For campus & urban designers, the most important points of attention for the brief are the functional roles of shared facilities, physical connectors and flexible facilities.

§ 6.5 Conclusions

This chapter studied the development of the MIT campus in order to gain and provide understanding about the roles of the built environment in stimulating innovation in the Cambridge-Boston area. The guiding questions of this chapter, providing such understanding, will be answered as follow.

How has the MIT campus developed?

This chapter illustrated that the MIT campus has developed influenced by specific decisions and interventions over a long period. This started in 1916 with the moving of the MIT to a new campus in Cambridge and intensified during the 1960s with the implementation of a Master Plan that guided the growth and expansion of the campus until the late 1990s. Within this period, important interventions defined the way MIT campus developed. First, it was a long-term acquisition plan for land resources in Cambridge anticipating the MIT's growth and building a collaborating relationship with the city. Second, the involvement of MIT in the development of urban areas around the academic plant changed the face of Cambridge East from an industrial site to a major R&D business location in Massachusetts. And third, it was the commitment of campus decision makers to develop a concerted vision for the campus as a social environment, which support the founding model of the MIT based on the discovery and application of knowledge across disciplines.

In the last two decades, a change of direction in planning and campus development has focused in the development of commercial properties around the MIT academic plant because of the high concentration of R&D firms wanting to establish in the area and the financial opportunities they bring for economic development. Today, the continuing of Kendall Square's development –started in the 1968- is important for MIT campus development because it incorporate experimental rezoning of the academic land into a mixed-use district including commercial development. In addition, the development of this area and its strategic location in the Cambridge-Boston area involve the interests and perspective of many stakeholders, whose perceptions on innovation are different and should be carefully addressed.

Why is the 'Overlaps' characteristic of the MIT campus in relation with the city evident?

In an international comparison of 39 technology campuses (Chapter 3), it has been observed that MIT campus has an evident characteristic in relation to its hosting city regarded as 'Overlaps'. Accordingly, the campus and the city share common points. For instance, MITC campus is not perceived as a separated area as many campuses do.

The 'Overlaps' characteristic of the MIT campus in relation to the city is the result of a dynamic process in which the city and the campus evolved in parallel, without the intention to be isolated from each other. The very first idea of the MIT campus in Cambridge was an urban mega-structure, which orientation in a given plot is defined by existing urban features (e.g. the roads, the rail track, the neighbouring industrial districts, the Harvard Bridge and the Charles River) rather than a group of buildings in the green in the middle of nowhere.

The stakeholder's choices play an important role shaping these processes. For instance, it was a design choice to build such a structure facing the Charles River and next to the main physical connector between Cambridge and Boston, as it was management choice to support such design. Similarly, it was a planning choice to acquire the lands around the initial plot to anticipate the institutes' growth and expansion and a strategic choice of the city in allowing it. It can be said that this overlapping characteristic between the MIT campus and the city has enhanced the role of the built environment as a catalyst for innovation. For instance, the physical proximity and connectivity facilitated the concentration of innovators and the density of functions in the area. However, the same relationship is generating issues because of the different stakeholder's perspectives on the built environment as a catalyst for innovation.

To what extent has the MIT campus developed been influenced by theoretical discourses of stimulating innovation? Is this influence explicit or accidental? Is it possible that the dynamics accommodated on MIT campus have indirectly helped supporting such discourse?

As explained in Chapter 4, the proposition of the built environment as a catalyst for innovation is based in a collection of theoretical concepts of innovation from economic geography. The empirical information analysed in this case points out that there is a link between theory and practice in the development of MIT campus. The discourse of stimulating innovation through the concepts of physical proximity and diversity people, are at the core of MIT campus development. For instance, designers, planners, managers, controllers, developers and policy makers involved in the development of MIT campus stand on the idea that physical proximity and diversity of people are essential for two processes. First, these notions are believe to facilitate idea sharing that creates new knowledge by means of the social interactions among interdisciplinary knowledge networks. And second, these notions are considered essential in boosting the entrepreneurial environment by means of the trust developed by face-to-face contact.

However, it is difficult to generalize the explicit of accidental influence of these theoretical concepts in practice. Indeed, this study observed that the ways in which these concepts are promoted differs among stakeholders and the ways they perceive innovation, as discussed in the previous section. For instance, it is observed that interventions supporting organisational activities (e.g. flexible buildings, shared facilities and physical connectors) explicitly address the concept of physical proximity and density of diverse people. This event traces back to 1912 when Freeman's study for the New Technology proposed the design principles for the new buildings as a way to support the MIT's teaching model:

'...Third, an efficiency and avoidance of lost motion by student and teacher, equal to that which obtains in our best industrial works.

And fourth, the consideration of the psychology of student life, the cultivation of the social instincts, the development of personal contact, must strongly control the layout of the very masonry.'

As described in section 6.3.3, this resulted in the design and construction of a single massive building accommodating the interdisciplinary activities of the Institute. Back then, the concepts of physical proximity or diversity of people for innovation where not explicitly discussed in agglomeration economies or economic geography. As described in Chapter 2, only Marshal explaining the externalities of specialized industrial locations has outlined the first conception of the role of proximity favouring the transmission of knowledge in 1890. However, the role of diversity was popularized only until 1969 when Jacobs explained that 'the variety of industries within a geographic region promotes knowledge externalities and ultimately innovative activity and economic growth'. In the 1990s, these two types of externalities were recognized to play a major role in the process of knowledge creation and diffusion as specialization externality and diversity externality.

On the contrary, it can be said that today's strategic interventions of creating mixed-use developments near academic environments can be seen as influenced by the diversity externality arguments. Overall, stakeholders use these theoretical concepts opportunistically in reaching their different goals (e.g. financial, strategic, functional and physical goals). In a sense, the theoretical concepts are signs of alignment in stakeholder's ambitions, but in reality, their opposing interests generate conflicts and can inhibit the role of the built environment as a catalyst for innovation.

What campus' interventions have facilitated the conditions leading to innovation in MIT and in Cambridge-Boston area and how?

Based on its research proposition, this study has identified five types of intervention of MIT campus' development, in which the built environment has been a catalyst for innovation. Section 6.3 of this chapter has illustrated with many examples as possible, how each of these interventions facilitates specific conditions, which altogether are necessary to stimulate innovation. An overview of the five types of interventions at MIT campus as a catalyst for innovation is illustrated in Table 6.1.

The chosen approach of this study to investigate MIT campus development as a historical phenomenon does not provide causal evidence of these interventions on the processes leading to innovation. Rather, it has chosen to provide understanding on the multiple events shaping these processes, in which the built environment -as many others- is a necessary but not a sufficient condition stimulating innovation.

Based on the empirical findings, this chapter builds upon a model of the built environment as a catalyst for innovation. It is targeted to campus decision makers, which can help to stimulate design, planning and management decisions aiming for a more efficient use of resources and thus, better built environments [See Figure 6.31]. The model outlines the following interventions as catalysts for innovation:

- Land acquisition in urban areas
- Collaborative urban area development
- Flexible facilities adapting the changing users and their activities over time
- Shared facilities accommodating diverse functions and users with common agendas
- Physical connectors making efficient the contacts and interactions between users as well as sharing knowledge in a passive way through the flow of information exhibited in these areas.

Similarly, this model illustrates the relationships between each intervention, which can be used to detect potential zones of alignments and conflicts among stakeholders when making decisions. In addition, the model outlined the main challenges encountered in this case, which can inhibit the actions of the previous built environment interventions as catalysts for innovation.

CONDITIONS / INTERVENTIONS	Concentration of Innovators	Innovation area	Density of Functions	Flow of incentives	Innovation climate
Incremental land acquisition	MIT's land acquisition plan and the agreements with the municipality enabled keeping MIT's community as an important resident for Cambridge, since later MIT became a magnet to attracting and spinning out other research organisations in the campus' vicinities.	The presence of the MIT as landowner in Cambridge East helped to transform this area from an industrial district to an R&D and high-tech business location regarded today as 'the heart of innovation'.			
Urban area development	Developing Technology square, University Park, and Kendall square have attracted and accommodate several R&D firms, research institutes, and IT-businesses to establish in the areas near to MIT.	The three areas developed by MIT in collaboration with public and private parties changed the identity of the area	These three developments favoured mixed-use in the area. The development of University Park, for example, included housing, green spaces, besides commercial and office space.	Developing these areas helped channelling the flow of incentives needed to revitalise the economy in specific periods (e.g. Technology Square during the space age). Today they are recognised as development districts or major employment centres, offering a mix of office, and R&D.	Since the 1960s, these three developments have accommodated the changing industries over significant periods of technological developments. From electronics & hardware (1960s-1970s), to software & networks (1980s -1990s), to life sciences and IT businesses (2000s).
Shared facilities	MIT's shared facilities have accommodated a concentration of innovators from different disciplines under one roof. They also attract external innovators. The shared office space and service package offered by CIC is attracting a high density of start-ups, SMEs to locate in this facility. Besides, this high concentration of start-ups attracts large companies to locate at MIT campus and its vicinities.	The MIT's Maclaurin building has been a central place of interaction and the most representative building on campus, well know because it represents the MIT's identity based variety and complementarity of many disciplines. The density of innovators in one place allowed by shared facilities is already promoted as strength of the Cambridge-Boston area as an innovation area.	MIT's shared facilities have accommodated diverse activities and people under a single roof, which increases the density of functions in one building. For example, in the Maclaurin building, people shared not only corridors and halls but also common services such as library, cafés, student clubs, laboratories, etc.		
Flexible facilities			The modular and standardised building structure of functional buildings at MIT allowed having flexible layouts that have accommodated different functions over time.	The functional buildings of the MIT's main complex allowed re-using space for research programs channelling R&D capital to other targets rather than building new infrastructure.	The functional buildings of the MIT have allowed matching the changing accommodation demands resulted from shifts in the socio-economic and technological developments.
Physical connectors		The Red subway line across the Cambridge-Boston area is the flagship of a regional economic development initiative that focuses on transit oriented development, connecting and providing access to a number of universities, research institutes, R&D firms and hospital in the area.	The MIT's infinite corridor shortened the distance between functions at campus scale and increased the chances for knowledge sharing. The pedestrian oriented infrastructure facilitates the connectivity and provides access to functions within the Cambridge-Boston area at neighbourhood scale.		

TABLE 6.1 Summary of MIT campus' interventions as catalyst for innovation conditions.

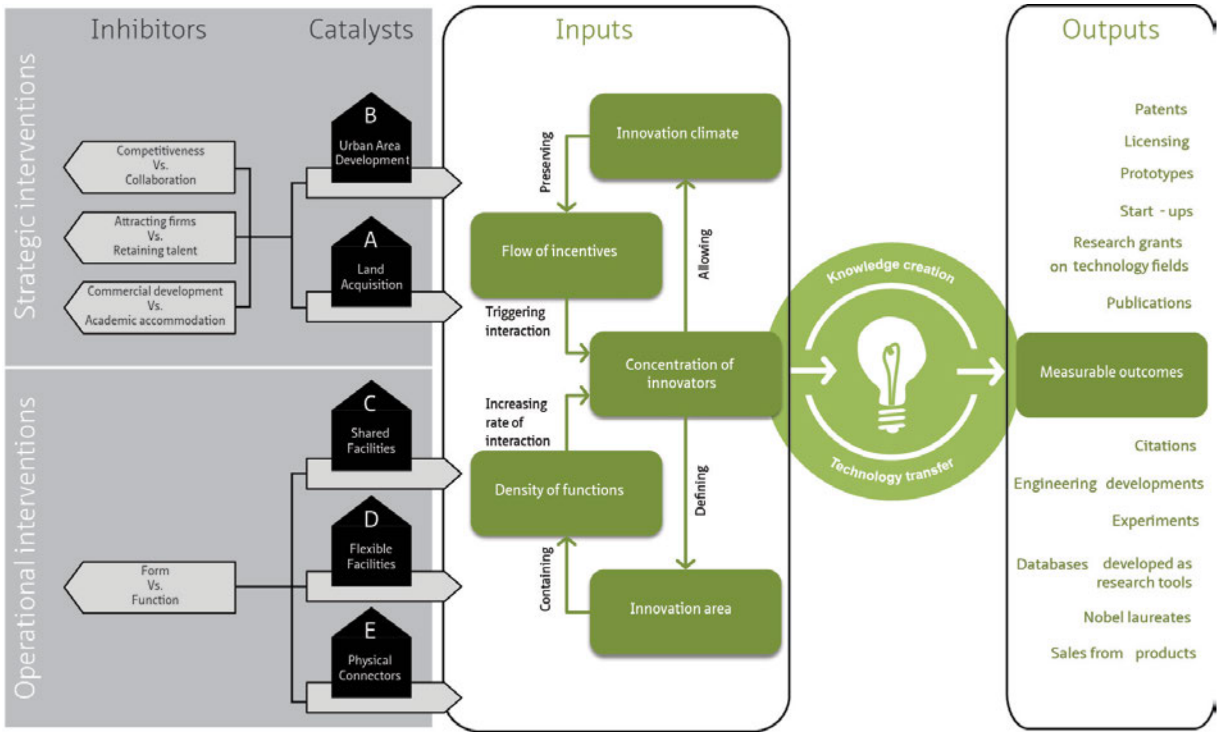
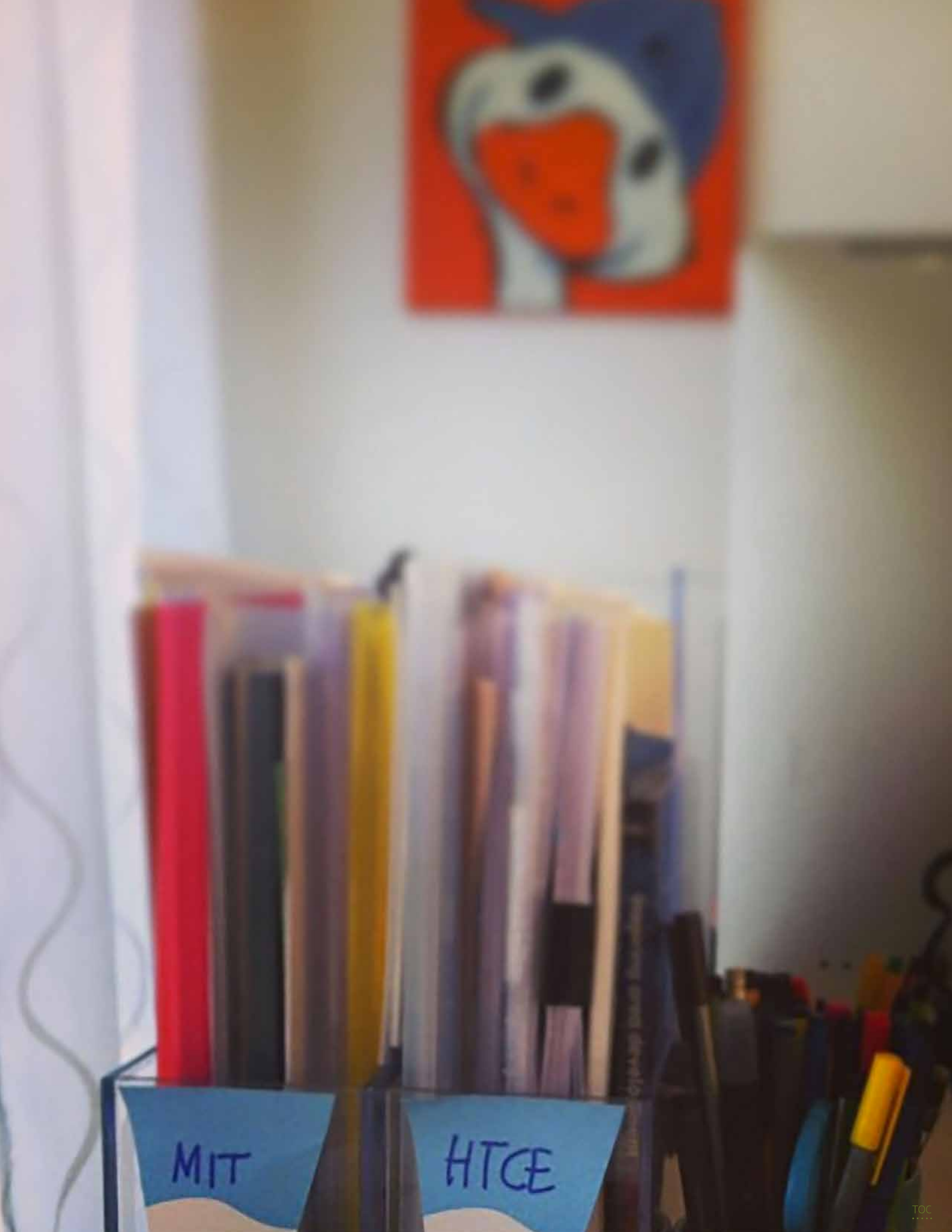


Figure 6.31 Preliminary model of the built environment as a catalyst for innovation aimed to improve campus decisions. Version 2 of the model based on the case of MIT campus.



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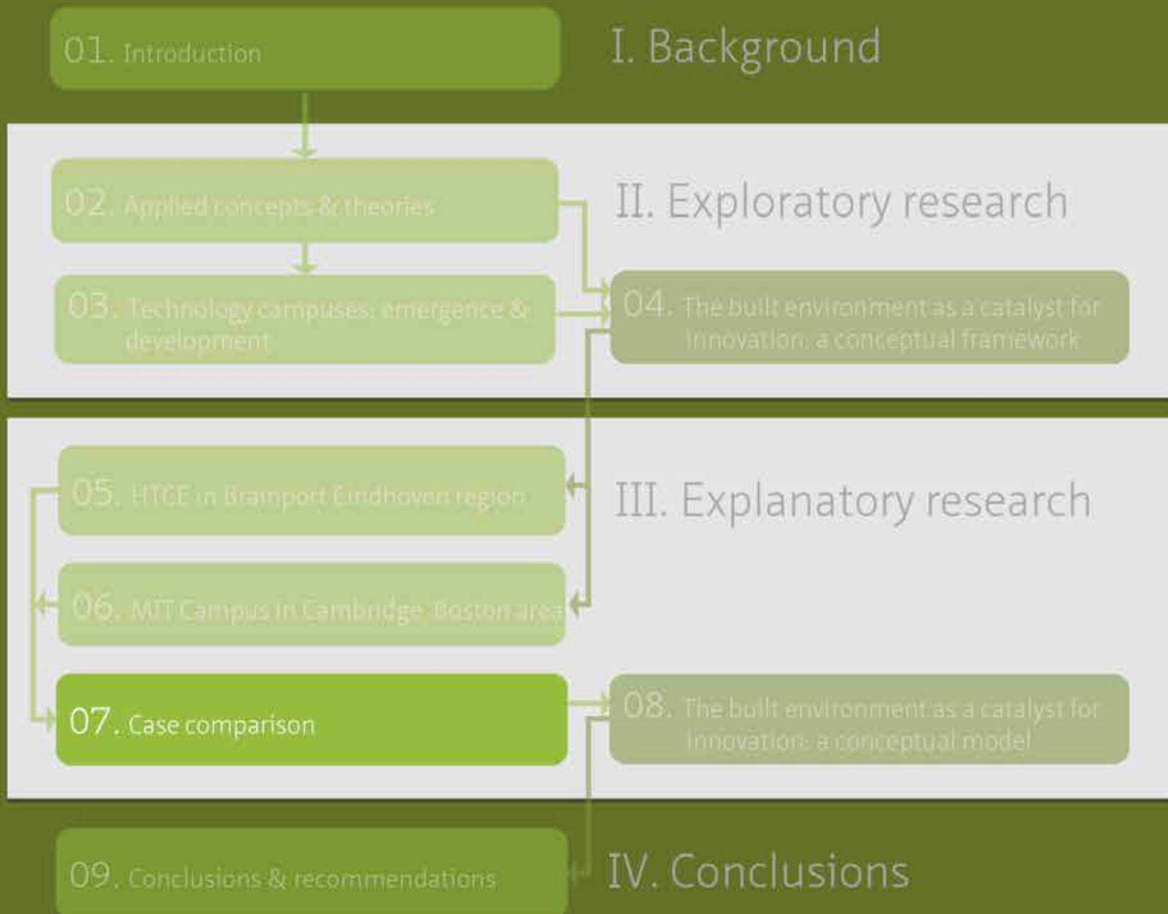
Chapter 7. Case comparison



Chapters 5 and 6 presented each an in-depth case study of campus development uncovering patterns of the built environment as a catalyst for innovation in different contexts. These chapters used a conceptual framework as a tool to collect, analyse and illustrate empirical evidence of each case via replication logic. The comparison of this evidence using this framework will serve the purpose to explain the research proposition that the built environment is a catalyst for the inputs of innovation depending on specific context-related conditions. Accordingly, this chapter presents the comparison of these two case studies, which contributes to answering the question: ***What are the common and distinctive development patterns between HTCE and MIT campus? And what is the nature of similarities and differences in their built environments as a catalyst for innovation?***

This chapter has the aim to uncover common and distinct patterns of the built environment as the catalyst for innovation. Thus, Section 7.1 begins introducing the logic of the case comparison. Section 7.2 presents a differentiating comparative analysis of the two cases explaining the research proposition through its conceptual framework. Section 7.3 discusses the findings of the case comparison and draws individual observations both on the proposition and the framework towards the construction of a conceptual model. Lastly, Section 7.4 draws the conclusions of this chapter and how its findings can be used to answer further the central question of this research.

7 Case comparison

§ 7.1 Introduction

§ 7.1.1 Chapter aim and questions

This case comparison aims to uncover common and distinct patterns of the built environment as a catalyst for innovation in two particular contexts in which 'stimulating innovation' is a goal that has been successfully attained. These are HTCE in the Brainport Eindhoven region and the MIT campus in Cambridge-Boston area.

The comparison will serve the purpose to validate the framework based on the explanations offered by interrelationships between context-related aspects. Explaining the proposition of the built environment as a catalyst for innovation is limited to the background provided by the case's circumstances.

In addition, the comparison of cases with different campus' profiles (strategic and operational) has also an illustrative purpose to show the importance of demand- and supply-driven aspects in explaining the research proposition. For instance, the nature of the campus' differences between HTCE and MIT campus (business and academic types of campus' end-users in the demand side; and 'Touches' and 'Overlaps' types of campus' locations in the supply side) might help to explain the different mechanisms of the built environment as a catalyst for innovation in each case.

The key question of this chapter is '***What are the common and distinctive development patterns between HTCE and MIT campus?*** And ***what is the nature of similarities and differences in their built environments as a catalyst for innovation?'*** The following sub-questions guide the comparison presented in this chapter:

- What are the similarities and differences in the contexts of the cases?
- How have HTCE and MIT campus been developed in comparison to each other?
- Why are their location characteristics in relation with the city different?
- To what extent have HTCE's and MIT campus' developments been influenced by theoretical discourses of stimulating innovation? Is this influence explicit or accidental compared to each other? Which theoretical concepts influencing campus development arise from the case comparison?
- What campus' interventions have facilitated the conditions leading to innovation in HTCE and MIT campus compared to each other? How do the mechanisms of these interventions differ in each case?

§ 7.1.2 Approach and methods

The two cases studied are examples drawing from specific contexts used to verify the research proposition that 'The development of technology campuses is a catalyst for innovation depending on the goals and activities of organisations involved in their developments, their location characteristics and the historical events shaping their emergence and development'.

As described before in Chapter 4 the two cases selected are exemplary because they are similar in addressing 'stimulating innovation' as a goal in campus development. Likewise, they are ideal because they are different in the strategic ways this goal is perceived by the stakeholders involved in their developments and the physical/functional ways these campuses have developed in their contexts. The comparison will serve to understand the differences in the underlying process by which the built environment can be a catalyst for innovation. In other words, this research assumes that the different organisational and spatial contexts influencing campus development explain the role of the built environment stimulating innovation.

The structure of the conditions present in each context becomes an important goal of explanation. The conceptual framework described in the previous chapters states the conditions under which the particular phenomenon is likely to be found. This research uses a literal replication procedure (Yin, 2009) allowing a systematically examination of similarities and differences in two international contexts. The framework facilitates this procedure during the analysis and reporting of the findings. An overview of the explanatory research design illustrating these processes is summarised in Figure 7.1.

The information in this chapter is based on data collected and described in Chapters 5 and 6 of this dissertation. An overview of the data collected in both cases is summarised in Table 7.1. Details of the data collection procedures for each case studied can be found in Appendix D and Appendix F.

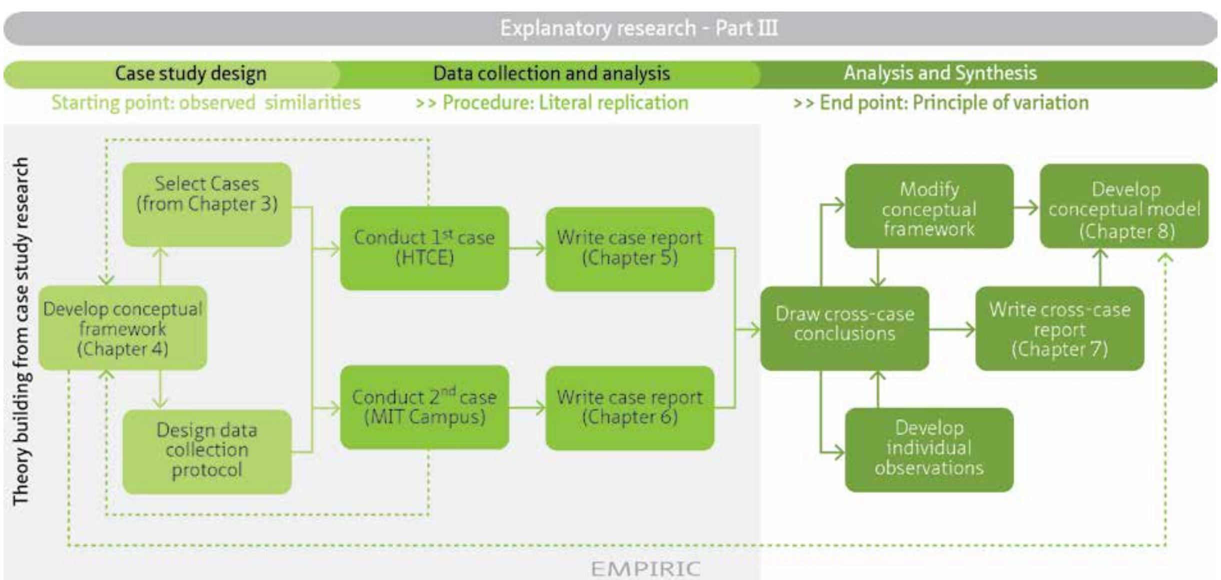


Figure 7.1 Explanatory research: design and methods.

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CASE STUDIES	DATA SOURCES								
	In-person interviews			*Direct observations*		*Documentation*		*Mapping*	
	Experts	*Key informants*	*Total*	*Events*	*Examples*	*Types*	*Examples*	*Apps*	*Examples*
HTCE	4	10	14	6	Site visits; guided visit to special facilities; Informal talks	4	Maps' collections; official reports; existing empirical research; news	3	Google Earth; Esri Maps; Google maps
MIT CAMPUS	4	8	12	9	Seminars; site visits; guided visit to special facilities; attendance to events; informal meetings and talks.	4	Maps' collections; official reports; existing empirical research; news	4	Google Earth; Esri Maps; Google maps; and Mapnificent
Total	8	18	26	15	n.a.	4	n.a.	4	n.a.

TABLE 7.1 Overview of data collected in both case studies

§ 7.1.3 Two technology campuses in two cities aiming to stimulate innovation: the nature of their differences and similarities

The two cases compared in this chapter are ideal to explain the proposition because they are similar in addressing 'stimulating innovation' as a goal in campus development. Moreover, they are different in the ways this goal is perceived by the stakeholders involved in their developments and the physical and functional ways in which these campuses have developed. This research refers to these similarities and differences as the strategic- and operational nature of campus development.

EXEMPLARITY OF THE CASES		HTCE	MIT CAMPUS
DIFFERENCES *Focus on context*	Demand-driven conditions	R&D businesses	Scientific/fundamental research, and R&D
	Supply-driven conditions	Touches: The city 'touches' the campus	Overlaps: the city and the campus share common points
	Hosting city/region	Eindhoven, North Brabant, The Netherlands (NL)	Cambridge, Massachusetts, The United States (US)
SIMILARITIES *Focus on object of study*	City/Region's vision	Eindhoven, Leading in Technology. Brainport, Top Economy Smart Society	Cambridge, The heart of innovation!
	Campus' vision	Open Innovation Ecosystem (HTCE Zoning Plan's concept) – Turning Technology into businesses (HTCE brand)	Innovation and Collaboration (MIT 2030 concept)

TABLE 7.2 Evident similarities and differences between HTCE and MIT campus to stress in the case comparison

As shown in Table 7.2, the evident differences between these campuses are context related. For instance, the demand-driven conditions differ from the primary orientation of each campus' research activities supporting the goal of stimulating innovation (business and scientific). Likewise, the supply-driven conditions distinguish two types of physical/functional relationships between the campus and the city (Touches and Overlaps)[177]. These campuses are hosted in cities with different socio-economic and

177 More information about the types of relationships between the campus and the city can be found in Chapter 3.

geographic settings shaping the demand- and supply-driven conditions of both technology campuses. This table outlines the evident similarities between these campuses are related to analytical frame of this research. Thus, there is an alignment in the visions of both, the campuses and their hosting cities, in stimulating innovation as a goal. This is evidenced in the concepts used to frame the future of both cities' and campuses' developments. The following paragraphs discuss in brief the evident differences between HTCE and MIT campus, which are context dependant.

The strategic campuses

The demand-driven aspects shaping campus development define the strategic nature of technology campuses. This demand relates to stakeholders involved in the developments of technology campuses over time. Those are the main users with their core activities or businesses accommodated on campus and the decision makers with their goals supported by the campus as one of the organisational resources. Stimulating innovation is differently perceived by the stakeholders.

As shown in Table 7.3, there is a list of indicators outlining the strategic differences between HTCE and MIT campus. For instance, the difference in the nature of the research activities accommodated on each campus is pretty much influenced by the campus' end-user. In HTCE, the nature of the research activities is R&D businesses because most of the campus' end-users are R&D firms, which are for-profit private companies. In contrast, MIT campus accommodates mainly scientific or fundamental research carried out by the university and its affiliated research institutes, which are non-profit private institutions[178]. This evident difference makes 'stimulating innovation' a goal with different perceptions and the campus an instrument serving the purposes of the different organisations.

An important indicator outlining a strategic difference between HTCE and MIT campus is the degree of variety in the fields of research activities accommodated on campus. HTCE accommodates research activities that specialise in three narrow fields while MIT campus does it in five diverse fields related to the MIT's schools. The research institutes and the R&D firms accommodated on MIT campus' properties are also in three different and complementary industries adding to this diversity.

The two campuses are considered to be bold examples of two concepts of geographical concentrations explaining a favourable environment for innovation. As mentioned in Chapter 3, two types of externalities are recognised to play a major role in the process of knowledge creation and diffusion: specialisation or localisation externalities and diversity or urbanisation externalities. Accordingly, the first operates within one or similar industries while the second works across sectors. Not surprisingly, the evident differences in the operational nature between HTCE and MIT campus (Touches and Overlaps) coincide with the respective geographical units of these two concepts: the region and the city.

Next to these differences, the strategic nature of the campus marks important similarities between HTCE and MIT campus, which are related to the changing accommodation demand in history. Although these campuses emerged in different periods, both are the result of an accommodation need to cope with the growth of their founding organisations, which were coincidentally established to support industrial research. This similarity indicates the importance of research as source for industrial growth and development in two different contexts over time. Both campuses were initially meant to accommodate a single organisation. They have grown to accommodate hundreds of organisations, which core businesses or activities are different than originally planned to be on campus.

178 However, in the commercial properties MIT campus accommodates several R&D firms.

THE STRATEGIC CAMPUS Demand-driven indicators	HTCE	MIT CAMPUS
Nature of research activities accommodated in campus	R&D businesses (Fundamental research in the past)	Scientific or fundamental research (in academic properties); R&D (in commercial properties)
Year of campus' emergence as an accommodation demand	1963 (Complex-W) 1999 (Philips Hight Tech Campus)	1916
Initial accommodation need	Expansion of research plant because of the growth of a former industrial laboratory established in 1914 (Royal Philips' Nat Lab)	Expansion of the academic plant because of the growth of the former School of Industrial Science established in 1861 (MIT)
Campus main end-user / Type of organisation	R&D firms (larger campus' resident is Philips Research) / For-profit private companies	Research University (Massachusetts Institute of Technology) /Non-profit private institution
Mission founding organisation (current main user)	'Improve the quality of people's lives through technology-enabled meaningful innovations – as co-creator and strategic partner for the Philips businesses and complementary open innovation ecosystem participants.'	'Advancing knowledge and educating students in science, technology, and other areas of scholarship that will best serve society.'
Secondary end-user's organisation	Research institutes, specialised services firms	Research institutes, R&D firms, service firms
Fields of research activities / Knowledge externalities	Health, energy, and smart environments / Specialisation (Related variety)	Scientific research: architecture; engineering; management; science; humanities, arts, and social sciences R&D: Biotechnology, Pharmaceutics, and IT / Diversity
Number of organisations in campus	Current: 125+ [A]	Current: 200+ [B]
Campus' governing body	HTCE Site Management B.V.	The MIT Corporation
Campus' ownership	The Chalet group (since 2012); Royal Philips (1940s-2012)	Massachusetts Institute of Technology (MIT)

[A] Until 2003, HTCE was home of Philips only.
[B] Since the 1960s MIT has been involved in developing commercial property housing other organisations on MIT campus as defined in this research.

TABLE 7.3 Indicators outlining the strategic differences and similarities between HTCE and MIT campus

Last, this comparison of strategic nature indicates both campuses are important assets for the organisations that own them. Next to their instrumental role supporting the accommodation needs of their end-users campuses are valuable financial resources for organisations. Their management is a crucial aspect of campus development. In both cases it is observed that there are special governing bodies in charge of campus decisions, which main task and also challenge is balancing the demands of campus' end-users and campus' owners.

The operational campuses

The supply-driven conditions shaping campus development define the operational nature of technology campuses. This supply relates to the physical and functional characteristics of the developments over time. The evident operational difference between HTCE's and MIT campus' developments are their location characteristics. They distinguish two types of physical and functional relationships between the campuses and their hosting cities (Touches and Overlaps). Next to it, there are a number of indicators outlining other differences but also similarities in the operational nature of these two campuses.

As shown in Table 7.4, HTCE and MIT campus have bold differences in their location characteristics. HTCE has been developed as an isolated area from an urban context, while with MIT campus has been quite the opposite. Indeed, the spatial features of their immediate contexts (peripheral in HTCE and inner-city in MIT campus) defined as well the built density of these campuses, which marks even more their differences although they are similar in size. HTCE's development has a great deal of green and water surfaces in its clearly defined plot with its own road structure. MIT campus is not clearly identified as a single plot but it consist of different areas integrated in the inner city fabric, although the campus built density is different in each of the campus zones.

THE OPERATIONAL CAMPUS Supply-driven indicators	HTCE	MIT CAMPUS
Location characteristic / Type of physical & functional relation with the city	Isolated area from urban context / Touches: The city 'touches' the campus	Integrated area with urban context/ Overlaps: the city and the campus share common points
Land use area	103 hectares	104 hectares [A]
GFA (Gross Floor Area)	280.000 m^2	1,8 million m^2 [B]
FSI (Floor Space Index)	0,27	1,7
Planning Zones or Development Areas	4	8
Number of users on campus	10.000+	22.000+ [C]
User per m^2 (GFA) [D]	28 people/m2	54 people/m2 [E]
Development phases	1999 (redevelopment phase I) 2012 (redevelopment phase II)	1960s (growth and redevelopment) 1990s (redevelopment)
Functions on campus [D]	Mixed (office, laboratory, parking, retail, conference, sports & leisure)	Mixed (office, laboratory, parking, retail, conference, sport & leisure, and housing)
Campus' connectivity and accessibility (external)	Road transport (car and bus lines); and bike paths.	Metro line; bike paths; bike sharing system; and Road transport (car and bus lines)
Campus' connectivity (internal)	Bike sharing system; and open air pedestrian paths; Road transport (on campus' periphery)	Bike paths; open air pedestrian paths; internal corridors interconnecting buildings; road transport (Exclusive shuttle service on campus' periphery)

[A] There are two types of properties at MIT campus, from which the land use area distinguishes 68ha in the academic property, and 36ha in the commercial property.
[B] The GFA of MIT campus distinguishes 1,2 million m^2 of academic, and 650.300m2 of commercial properties.
[C] This figure includes only MIT's population (students, professors, and staff members)
[D] This figure differs per campus zone
[E] This figure is calculated based on MIT's population/academic built area

TABLE 7.4 Indicators outlining the operational differences and similarities between HTCE and MIT campus

Likewise, the differences in the location characteristic between HTCE and MIT campus define their connectivity and accessibility at urban and regional scale. For instance, MIT campus has more transport modes connecting the campus with the hosting and neighbouring cities as well as with international airports. The peripheral condition of HTCE campus limits its accessibility and connectivity at those scales.

The operational nature of the campus outlines two similarities between HTCE and MIT campus. The first is related with the functional offering of these campuses, since both accommodate a mix of uses, which only differ in the provision of housing. The second is related to the long-term evolution of these campuses, which have already been through different development phases in accommodating the dynamic demands of their end-users.

The hosting cities

The campuses examined are hosted in cities with different socio-economic and geographic backgrounds. These backgrounds have contributed in shaping the strategic and operational components of both technology campuses.

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Strategically, the stakeholders defining the demand-driven indicators of these technology campuses perform their activities and frame their visions in a local context (region or nation-wide) regardless of the global focus of these organisations' core businesses. The end users of technology campuses are research-based organisations strongly identified with their respective contexts using their hosting city/region representing their brand image. Each hosting city has distinctive characteristics framing the social, cultural and administrative contexts in which organisations perform their activities.

Operationally, these two technology campuses are part of larger regional and urban spatial systems defining the physical/functional context in which they develop. The supply driven indicators of campuses relate to such systems.

As shown in Table 7.5, HTCE and MIT are hosted in cities that locate in different countries and even in different continental regions. Both, Eindhoven and Cambridge are relatively small cities compared to their respective European and North American contexts. However, they locate in regions that differ vastly in the size and density. For instance, Cambridge is almost three times denser than Eindhoven because it is located at the heart of one of the largest metropolitan regions of the US.

THE HOSTING CITY	Eindhoven | HTCE	Cambridge | MIT campus
Region	North Brabant, The Netherlands	Massachusetts, The United States
City's Population	219.173 (CBS, 2013)	106.471 (USCB, 2012)
City's Density	2.438/km2	6.361 /km2
Region's economic base (Consolidated)	High-tech industrial clusters including mechatronics, the automotive industry and electronics.	Education, Life sciences, IT, and Technology businesses.
Region's economic base (Emergent)	Industrial distribution, environmental technology, medical technology, and information technology.	Systems, Energy
Knowledge base (consolidated)	Engineering, applied sciences and design.	Sciences, Engineering, Life Sciences, Social Sciences, and Design.
City's profile in history	Past: Company town Present: High-tech businesses' location	Past: College town Present: Biotech businesses' location

TABLE 7.5 Differences and similarities between the cities hosting HTCE and MIT campus respectively

These regions have similarities too. They concentrate technology-focused knowledge-and economic base, which are important at national level in each context. For instance, both areas have industries relevant for their respective national economies. Similarly, they concentrate a relative high number of higher education institutions that complement the consolidated economic sectors. Other similarities and differences that relate to the hosting city/regions of these technology campuses are discussed further in the next section since they deserve special attention according to the analytical framework of this research.

§ 7.2 Conditions stimulating innovation in HTCE and MIT campus

This section compares the six aspects proposed as necessary and interdependent conditions to stimulate innovation in a conceptual framework, which was used to explain the research proposition in each case study (Chapters 5 and 6). As summarised in Table 7.6, the case comparison helped to identify similarities and differences of the conditions stimulating innovation between in HTCE and MIT campus.

These similarities and differences relate directly to the contexts of these campuses. The comparison indicates there are a number of unexpected similarities in the context considering these campuses locate in different places. Although the similarities outlined in these conditions are very general to make sense of the analytical framework of this study, there are specific context-related details that make each of these conditions distinctive. The following paragraphs briefly elaborate on it by addressing each condition in a comparative way.

CONDITIONS STIMULATING INNOVATION		HTCE	MIT CAMPUS
SIMILARITIES	Concentration of innovators	Research and development as the engine of a high-tech industrial cluster	University research leading a prestigious science and technology cluster
	Innovation climate	Reinvention of Eindhoven based on its natural strengths	Massachusetts adapting the shift of technology over time
	Flow of incentives	The synergy of the Triple Helix in Brainport Eindhoven	The synergy of the Triple Helix in Massachu-setts
	The presence of a catalyst	The development of HTCE	The development of MIT campus
DIFFERENCES	Innovation area	Brainport Eindhoven area (peripheral)	Cambridge-Boston area (inner-city)
	Density of functions	Immature	Mature

TABLE 7.6 Summary of the conditions stimulating innovation outlining the differences and similarities between HTCE and MIT campus.

§ 7.2.1 Concentration of innovators

Both campuses and their hosting cities provide a relative strong and complementary knowledge- and economic basis in their regional contexts. The presence of these complementary types of innovators is an essential condition enabling the creation of technology-based knowledge and its application to develop new technologies.

As illustrated in Table 7.7, HTCE and MIT campus accommodate a good number of innovators or organisations engaged on R&D activities and in technology fields. An important difference in the context is the extraordinary concentration of universities and colleges in Massachusetts compared to Brainport Eindhoven region. Even though the large surface of Massachusetts compared to the Southeast Netherlands could be addressed as an unfair comparison at first sight, the truth is 80% of the Massachusetts' concentration is within the inner belt of Boston's Route-128. This area is at least five times smaller than the Southeast Netherlands and has eight times more higher education institutions. The amount of research institutes and R&D multinationals and start-ups is higher in the context of the MIT campus compared to HTCE. When comparing the knowledge- and economic base of these campuses in relation to their own contexts, a similarity is observed. For instance, although the number research institutes differs greatly between the cases, they are different in size and representative of their contexts.

CONCENTRATION OF INNOVATORS		HTCE Brainport Eindhoven region	MIT campus Cambridge-Boston area
Knowledge base	HEIs[A] in the campus	1	1
	HEIs[A] in the city	3	4
	HEIs[A] in the region	8	65
	Research institutes [B] in the campus	5	56[C]
	Research institutes [B] in the city	9	70+
	Consolidated fields	Engineering, applied sciences and design.	Sciences, Engineering, Life Sciences, Social Sciences, and Design.
Economic base	Multinationals with R&D focus in campus/city	2/3	3/8+
	Start-ups with R&D focus in campus	60+	200+
	Consolidated R&D fields	High-tech industrial clusters including mechatronics, the automotive industry and electronics.	Life sciences, IT, and Technology businesses.
	Emergent R&D fields	Industrial distribution, environmental technology, medical technology, and information technology.	Systems, Energy

[A] Higher education institutions include research universities, colleges (in the US) and universities of applied sciences (in NL)
[B] This figure includes only well-know or prestigious research institutes
[C] This figure includes all MIT research centres and laboratories

TABLE 7.7 Cases' comparison - Concentration of innovators.

§ 7.2.2 Innovation area

The innovation areas where these two campuses locate are different [See Table 7.8]. In first place, the innovation area, which is defined by the high concentration of innovators around the campus, indicates few differences in the spatial distributions of these innovators. The concentration around MIT campus is denser than in HTCE since R&D firms and knowledge institutions are distributed in a smaller surface. This is perhaps explained by the inner city's location of MIT campus in contrast to the peripheral location of HTCE.. Therefore, these two innovation areas have different scales to perceive such concentration. At the scale of the region, which is the case of HTCE, the concentration of innovators is partially focused in specific zones within the peripheral setting of this innovation area. In contrast, at the scale of a metropolitan area, the concentration of innovators is more fluently distributed across the inner-city setting of the innovation area.

In second place, the connectivity and accessibility across and within these areas also differ in some aspects. This difference is indicated by the availability of diverse transportation systems connecting the area internally, but also at regional, national and international scales. For instance, the Cambridge-Boston area provides more modes of transport systems. This is perhaps explained because of its metropolitan scale serving a densely populated area. Nevertheless, this connectivity difference makes the accessibility to MIT campus more efficient compared to HTCE. This is indicated by the travelling distances allowing contacts among innovators in the area, which is less in MIT campus compared to HTCE when using public transport.

INNOVATION AREA		HTCE Brainport Eindhoven region	MIT campus Cambridge-Boston area
Geographic Identity	Geographic scale	Region	Metropolitan area
	Setting	Peripheral	Inner-city
	Concentration of innovators - Radius from campus	9 km	5 km
	Natural feature across the area	The Klotputten ecological zone and the Dommel stream's route	The Charles River and its mouth to Boston Harbour
Accessibility / Connectivity	Rail infrastructure across the area	Intercity railway connecting Eindhoven at regional and national level	Intercity railway connecting Cambridge at regional and national level Subway line connecting Cambridge at regional level
	Road infrastructure across the area	National and international motorways	Interstate highways, U.S. and State Routes.
	Transport systems within area	Bus lines; bike sharing	Subway line; bike sharing; and bus lines
	Transit oriented development strategy	National spatial policy - A2 motorway - Knowledge axis (Brainport Avenue)	Regional TOD initiative – Subway Red Line - Life Science Corridor
	Traveling distance campus to international airport	40-60 min /public transport 10-15 min / car	35 – 45 min / public transport 10 – 15 min / car
	Maximum traveling distance within campus radius from central point	30-40 min / public transport 10-15 min / car	10 – 25 min / public transport 10 – 12 min / car

TABLE 7.8 Cases' comparison - Innovation area.

§ 7.2.3 Density of functions

These two cases differ in the density of functions offered by their respective contexts. Similar to the previous condition, this difference is related to the scale and the setting of the innovation area in which the campus locate. As expected, the density of functions is higher in the Cambridge-Boston area because of the metropolitan scale and the inner-city setting of this innovation area compared to the Brainport Eindhoven area. As indicated in Table 7.9, two main aspects indicate the difference in the density of functions of both innovation areas. First, it is the diversity of people and amenities ensuring the frequency of informal interaction between the innovators in the area. And second, it is the quality of life attracting innovators to the areas.

The case comparison indicates the degree of diversity of people in these campuses and their hosting cities relates to the abundance of amenities and the ways they are distributed in each case. For instance, the share of (young) international students and expats in relation to the city's population and density is higher in Cambridge than in Eindhoven. Similarly, the abundance of attractive amenities in Cambridge is sufficient and distributed in eight commercial districts across the city, while Eindhoven's amenities are still regarded as insufficient and concentrated mostly in the city centre. Correspondingly, the campuses replicate the patterns found on their hosting cities, both in the degree of diverse people and the distribution of their amenities.

The case comparison also indicates there are a number of interrelated indicators of the quality of living that make Eindhoven and Cambridge more or less attractive to knowledge workers compared to each other depending on the aspects addressed. The more access to culture, shops, cafés and restaurants makes Cambridge a city with a more attractive profile than Eindhoven as a place to live in an international context. In the same line, the wages in Cambridge are higher than in Eindhoven , which makes it at first sight more attractive for working. However, living in Boston is (at least 33%) more expensive than Eindhoven while the social inequality of Eindhoven is lower than in Boston. These aspects combined illustrate a major difference in the contexts of these campuses in relation to the density of functions.

DENSITY OF FUNCTIONS		HTCE Brainport Eindhoven region	MIT campus Cambridge-Boston area
Diversity of people and amenities	City's Population	219.173 (CBS, 2013)	106.471 (USCB, 2012)
	City's Density	2.438/km2	6.361 inh./km2
	City's university students	23.000+	36.000+
	City's International students	1.190+ A	9.500+
	Expats	13.000~ (region)	27.000~ (city)
	International schools	1 (city)	1 (city)
	Amenities in city	Insufficient attractive amenities for young people. In Eindhoven, the average travelling distance to a restaurant is 0,6km and to a café is 0,9km. The city is joining efforts to improve its offering, which is now concentrated in the city centre.	Sufficient attractive amenities s for young people. Only in Cambridge, there are 8 commercial districts and 3 corridors offering a variety of restaurants, cafés, nightspots and specialty stores.
	Distance to large urban agglomeration with sufficient and attractive amenities	The Randstad is the largest urban agglomeration in the Netherlands. Eindhoven is 90 – 120km away from the main cities in the Randstad= 60+min driving.	Cambridge is next to Boston, only 3 – 6km away from the main downtown=15 – 20 min using public transport and within 15 min driving.
	Campus' Population	10.000+	22.000+ (11.000 students)
	Nationalities of Campus' users	85+	115+ (3.220 international students)
	Amenities on campus	Central place with retail, conference, and leisure facilities. Dedicated sport area, and outdoors in the four campus' zones.	Retail, conference, and leisure distributed in the different campus zones. Dedicated sport and housing area.
Quality of living	City's International image	Immature – There is an international brand strategy since the early 2000s	Mature – cosmopolitan and touristic metropolitan area
	City's costs of living[A]	Rank 65 (Eindhoven)	Rank 12 (Boston)
	City's average annual wage per person	€31.600 (CBS, 2012)	US $93.600 (EOLWD, 2013)
	City's poverty rates	According to a research by the national statistics office CBS and the government's socio-cultural think-tank SCP, 7,1% à 7,8% of the population in Eindhoven is living below the poverty line.	According to the 2010 - 2012 American, Community Survey 14.4% of all persons and 9.9% of all families in Cambridge had incomes below the poverty line in Cambridge.

[A] The costs of living are compared using a Cost of Living Index value that lists over 1940 cities in different regions across the globe, using the prices of house, clothing, food, transport, personal care and entertainment as indicators. Cambridge is not listed in the rankings but Boston is used as a reference for the MIT case. CBS (Het Centraal Bureau voor de Statistiek); USCB (The United States Census Bureau); EOLWD (Executive Office of Labor and Workforce Development).

TABLE 7.9 Cases' comparison - Density of functions.

§ 7.2.4 Flow of incentives

The developments of HTCE and MIT campus have taken place in contexts where a synergy between stakeholders in the Triple Helix has been achieved. The comparison between the cases indicates a similarity in the actions and the roles assumed by the University-Industry-Government spheres, whose relationships determined the actions that will trigger interaction between the innovators. Even thought each of these spheres has its own interests on innovation, they maintained a good relationship because their goals are complementary in attaining socio-economic development.

Overall, the similarities between the two cases refer to the collaboration between the University-Industry-Government spheres to get these actions done. This collaboration consists of five recurrent activities: (1) investing in research, (2) creating firm and job opportunities, (3) strengthening local networks, (4) funding real estate to accommodate R&D and (5) facilitating the promotion of the region as an attractive place to work, live and study. Although the flow of incentives is similar in general, there are also differences in particular aspects.

FLOW OF INCENTIVES		HTCE Brainport Eindhoven region	MIT campus Cambridge-Boston area
Role-taking in five key activities : (1) investing in research (2) creating firm and job opportunities (3) strengthening local networks (4) funding real estate to accommodate research (5) promoting the region as an attractive place	University	(5) Supporting role providing the complementary and required knowledge base to attract and prepare the skilled knowledge workers in the region. (5) Promoting role building identity of the region and acting as ambassadors of Brainport Eindhoven.	(2) Entrepreneurial role in firm formation emerging from MIT's research and contributing to Massachusetts' social and economic development. Thus, MIT is active in setting up programs, projects and incentives focusing on creating and capturing new technologies and businesses as they emerge from MIT's research. (3) Leading role strengthening the local networks involving industry-government spheres. (4) Funding role investing in real estate development conducting to strengthen R&D in collaboration with private and public parties. (5) Supporting role providing the required knowledge base to attract and prepare the skilled knowledge workers in the region.
	Industry	(1, 4) Funding role investing in R&D and real estate development conducting to advance economic development in the region. (3) Leading role strengthening the local-based network, well known because of the trust developed between public and private stakeholders over time. (5) Promoting role building identity of the region and acting as ambassadors of Brainport Eindhoven.	(1) Funding role investing on universities' research to attain economic growth out of the new technologies from sponsored research projects. (2) Entrepreneurial role in firm formation by a community of venture capitalists committed to Massachusetts' economic development.
	Government	(2) Supporting role providing national, regional, and municipal policies aimed to spur the region's economic development based on its knowledge and research strengths. (2) Entrepreneurial role partnering with-and involving industry-university spheres in regional planning, to align their goals and to join forces and commitment in attaining a shared regional vision. (5) Promoting role of national, regional, and municipal governments in building and marketing the identity of the region.	(5) Promoting role enhancing the working opportunities that emerge from research in Massachusetts. There is an alignment in the national and municipal ambition to generate a lively and attractive environment that retains skilled workers and young entrepreneurs. Thus, the local and regional governments actively promote and support collaborative initiatives involving the university-industry spheres. (1) Funding role of the national government investing on universities' research in advancing technology trough subsidies.

TABLE 7.10 Cases' comparison - Flow of incentives.

As shown in Table 7.10, each of the three spheres have distinct roles triggering the flow of incentives in each case. In the case of HTCE it is observed that Industry-Government spheres have played more active roles than University spheres, whose roles seem to be more facilitating. In the case of MIT the University's sphere has played a more proactive and non-traditional roles such as creating firms and generating working opportunities over time as well as industry-government's spheres. This difference can be attributed to the traditions in which universities in these two countries evolved. Clearly, the foundation of MIT was explicitly aimed to advance industrial processes in New England, a major industrial and academic centre in the US for more than two centuries.

It is observed that different spheres have assumed the leadership strengthening the local networks in each case. This difference is deeply related to the historical presence of organisations within these spheres in their regions. The leading roles of multinationals in Brainport Eindhoven region and universities in the Cambridge-Boston area are evident.

§ 7.2.5 Innovation climate

The comparison between the two cases has uncovered important similarities in the social, economic and technological developments of the contexts in which these campuses evolved. These context-related developments preserved the flow of incentives and/or increased the actions needed for innovators to carry on their processes over time. In general, the most important similarities observed between these two contexts are 1) the need to reinvigorate the regional economies because of the shifts in technological paradigms over time; and 2) the use of the regions' natural advantages (research organisations) to adapting the shift and re-orientating their economic activities.

As illustrated in Table 7.11, in both cases the interrelated developments enriching the innovation climate in their contexts related to three important periods of technological advancements, which were recognised as key in the emergence and development of technology campuses worldwide (Chapter 3). Such advancements are interrelated to common historical events influencing the social and economic landscape of these two industrialised countries during the 20th century (e.g. the WWII, the decline of traditional manufacturing activities, the entering of Asian firms in the global market, the focus on the knowledge-based economy).

These major events affected each context differently because of the relative involvement of the regions or specific organisations in these events. For example, WWII had a major impact on the technological development of both countries but at different pace. During and after the WWII period the US federal government funded large research projects at universities to advance military and space programmes. During the WWII, the Germans occupied the Netherlands limiting the activities in universities and research organisations. Only after the WWII, it was evident to improve the technical oriented education in the Netherlands with less urgency and amount of resources compared to the US

All in all, this singular event in this specific period had positive consequences for the innovation climate in both contexts since these two regions housed important technology-based knowledge organisations for their national interests of advancing technologies. Likewise, more events related to other periods shaped the developments of both regions to high-tech business locations, referred nowadays as innovation ecosystems

INNOVATION CLIMATE		HTCE Brainport Eindhoven region	MIT campus Cambridge-Boston area
Periods of technological advancement	The post-war period *1945 - 1960*	Eindhoven progressively developed from being an agricultural town to be the most important industrial centre of the Netherlands. *Interrelated developments:* • Improvement of the technical-oriented education in the Netherlands after WWII favouring the knowledge base of the city: creation of polytechnic school in Eindhoven • Diversification path of fundamental research activities at the Philips' Nat Lab.	1st wave of economic revitalisation in Massachusetts boosting the technological capacity in research and manufacturing after the decline of traditional industries. *Interrelated developments*: • Advancements of technologies at MIT supporting space and military programs during and after the WWII • Establishment of advanced laboratories and electronic companies working in military research and manufacturing • The modern concept of venture capital emerged in Massachusetts involving stakeholders of universities' and business' communities.
	The space age and the ICT industrial revolution *1961 - 1989*	Eindhoven consolidates its profile as an industrial town powered by the image and presence of Philips among other large manufacturing firms. *Interrelated developments:* • Growth of R&D efforts and scientific cooperation at European level because of the emergence and consolidation of Japanese companies on the global market. • Upgrading of Eindhoven's polytechnic school to University (TU/e) • Beginning of specialisation path of market-oriented research activities at the Philips' Nat Lab.	2nd revitalisation's wave aka the Massachusetts Miracle focusing on high-tech businesses after a severe loss of manufacturing jobs. *Interrelated developments:* • Advancements in microelectronics brought by competitive space programs in the US • Increasing competition of national and foreign industrial bases (Asian markets). • Recession of military spending on research created the need to business to growth independent from the Defense establishment • Establishment of a fast changing industrial network based on computers and a geographic agglomeration aka the Boston's Route 128- Spin-off from the area's research and academic institutions • Government's support with incentives targeted to creating new jobs and attracting R&D
	The digital and information age *1990 – present*	Eindhoven faced a period of economic revitalisation after an economic and social decline in the late 1980s, establishing as a high-tech business location. *Interrelated developments*: • Reorientation of the economic sectors based on the knowledge strengths of the region, involving local stakeholders in developing a shared vision for the region • Setting-up of various programmes and policies aimed at strengthening Eindhoven's economy- EU focuses on the knowledge economy. • Re-structuring of Philips' activities including the moving of HQ to Amsterdam and the concentration of R&D activities in one location in Eindhoven • Adoption of Open Innovation research in Philips' R&D activities • Several R&D firms and research institutes moved to and/or established in Eindhoven	Massachusetts developed as a major cluster of biotech, medical equipment, and AI coming from the advancements in technologies in the many universities, and research institutes concentrated in the area. *Interrelated developments*: • Biotechnology establishes as a new entirely industry evolving from basic research in the life sciences • The deployment of technology transfer mechanisms in universities enabled by government policies tracing back to the 1980s and giving property rights to universities from federally funded research • The increase of patents issued, technology transfer licensed, and firms formed by universities, hospitals and research institutes resulted from the advancements in research and the facilitating legal frameworks. • A decrease of federal-funded research in universities stimulating partnering between industry and academia. • The increased number of venture capitalist moving to Massachusetts • The fast increased number of students at research universities such as MIT • The number of graduated students surpassed the undergraduate student population since the 1980s

TABLE 7.11 Cases' comparison - Innovation climate.

§ 7.2.6 The presence of a catalyst: campuses' developments facilitating the conditions for innovation

The analysis of the case studies (Chapters 5 and 6) indicates both campuses' developments are catalysts facilitating the previous conditions for innovation in their contexts. According to the analysis of each campus development, there are five campus' interventions supporting organisational goals and activities, which illustrated the role of the built environment as a catalyst for innovation. However, there are general differences and similarities between HTCE and MIT campus in the ways each intervention facilitates specific conditions for innovation, depending on two types of demand-driven circumstances.

As indicated in Table 7.12, the campus' interventions facilitating the conditions of innovation in these cases are different for those interventions that focus on supporting organisational goals, while those focusing on supporting organisation activities are similar. This case comparison outlines the major influence of two different interventions supporting organisational goals, which have facilitated all the conditions for innovation in their different contexts: 'intended accommodation strategy' in HTCE and 'urban area development' in MIT campus. Both interventions were conceived and implemented in collaboration with their respective municipalities focusing on redevelopment and renewal of the areas in each context.

<table>
<tr><th colspan="2">CONDITIONS FOR INNOVATION
CAMPUS' INTERVENTIONS</th><th>Concentration of innovators</th><th>Innovation area</th><th>Density of functions</th><th>Flow of incentives</th><th>Innovation climate</th></tr>
<tr><td rowspan="4">Focus on organisation's goals</td><td rowspan="2">HTCE</td><td colspan="5">Intended accommodation strategy – focus on redevelopment</td></tr>
<tr><td colspan="2">Representative facilities</td><td></td><td></td><td></td></tr>
<tr><td rowspan="2">MIT campus</td><td colspan="2">Incremental land acquisition</td><td></td><td></td><td></td></tr>
<tr><td colspan="5">Urban area development – focus on renewal</td></tr>
<tr><td rowspan="3">Focus on organisation's activities</td><td rowspan="3">HTCE & MIT campus</td><td colspan="3">Shared facilities</td><td></td><td></td></tr>
<tr><td></td><td></td><td colspan="3">Flexible facilities</td></tr>
<tr><td></td><td colspan="2">Physical connectors</td><td></td><td></td></tr>
</table>

TABLE 7.12 Summary of campuses' interventions facilitating the conditions for innovation outlining the differences and similarities.

The differences between HTCE and MIT campus in interventions that focus on supporting organisational goals can be seen as the result of the contrasting characteristics of the innovation areas in which these campuses have been developed. The details of these and all intervention in each case are compared in Table 7.13. For instance, HTCE developed to intentionally concentrate the research activities of Philips in an area outside the city, which still has a peripheral setting. Correspondingly, the redevelopment of this area aimed at strengthening its park-like image with a high-tech appeal. MIT campus developed to expand MIT's academic activities by incrementally acquiring land in the vicinity of its Cambridge's academic plant securing the future growth of the Institute. The inner-city setting where MIT evolved from having an industrial character towards a mixed uses area with a focus on an R&D business location is partly the result of urban renewal interventions of MIT in collaboration with public and private parties.

Table 7.13 shows that the interventions with a focus on supporting organisational activities are rather similar in both campuses, especially those concerned with shared and flexible facilities. However, the contrasting location characteristics of these campuses stress few differences in role of the physical connectors as a catalyst for innovation at regional and neighbourhoods' scales. The physical connectors at these scales facilitate the contact between innovators in the area and beyond, by ensuring the accessibility to the campus and the innovation area and by enabling the connectivity between the different functions on campus and the innovation area.

CATALYSTS FOR INNOVATION	(INTERVENTIONS)	HTCE's development	MIT CAMPUS' development
Focus on organisation's goals	Intended accommodation strategy	Concentration as separate area in peripheral setting planned in collaboration with the municipality	
	Incremental Land acquisition		Expansion in different neighbouring zones integrated in urban setting
	Representative facilities	High tech and sustainability as brand image of the campus matching the peripheral setting	
	Urban area development		Urban renewal of former industrial districts in the vicinities of the campus to R&D and mixed uses business locations in collaboration with the municipality and private parties.
Focus on organisation's activities	Shared facilities	• Central mixed uses facility as place to be and meet • Special laboratories as collaborative work space • Business centres as shared work space for start-ups • Parking garages strengthening campus unity	• Main campus building as place to meet and exchange knowledge • MIT's magical incubator as shared lab- and office space for various users • Cambridge Innovation Center as shared office space for start-ups
	Flexible facilities	• Functional buildings • Horizontal buildings • Modular building structures	• Functional buildings • Horizontal buildings • Modular building structures
	Physical connectors	• Public space (campus' scale) • Landscape design (neighbourhood's scale) • The road infrastructure (regional scale)	• Internal corridors interconnecting buildings (campus' scale) • Pedestrian oriented infrastructure (neighbourhood's scale) • Public transport system (regional scale)

TABLE 7.13 Comparison of campus interventions as catalysts for innovation between HTCE and MIT campus.

In the case of HTCE (located in a peripheral setting) the main physical connector at regional scale is the road infrastructure, while in MIT campus -located in an inner-city setting- the main connector is the metropolitan public transport system of subway and bus lines. Correspondingly, these differences are observed at neighbourhoods' scales where as HTCE connects with its immediate surroundings through landscape design (bike and pedestrian paths in the green surroundings) and MIT campus does it by following the pedestrian-oriented (and also road-) infrastructure of the existing urban fabric.

The individual analysis of each case allowed the identification of specific conflicts among stakeholders that act as inhibitor for innovation in their contexts. These conflicts are related to supply- and demand-driven aspects in which these campuses have been developed. The comparison of these conflicts ratifies the importance of the context enabling the catalyst role of the built environment in innovation - i.e. the physical/functional settings in which campus locate and the ambitions of the stakeholders involved in their developments.

Table 7.14 indicates that each of the conflicts in both cases deal with demand-driven conditions. In other words, there is an observed pattern of opposing ambitions among the different stakeholders involved in campus development, which according to the analyses of chapters 5 and 6 relies on the different perceptions of innovation among these stakeholders. In both cases the view of innovation as a market driven by the exchange of capital is dominant and in conflict with the view of other stakeholders. Specially those who perceive innovation as a process driven by the exchange of ideas. Overall, the conflicts in both cases derive mostly from a combination of both supply- and demand-driven conditions.

<table>
<tr><th colspan="2">NATURE OF THE CONFLICTS OBSERVED ON CAMPUS INTERVENTIONS</th><th>Supply-driven condition</th><th>Demand-driven condition</th></tr>
<tr><td rowspan="7">Stakeholders' conflicts on campus' interventions (Inhibitors)</td><td rowspan="3">HTCE</td><td colspan="2">The campus in the city vs. The campus as the city</td></tr>
<tr><td></td><td>Autonomy vs. Dependency in strategy implementation</td></tr>
<tr><td colspan="2">Arranged vs. Spontaneous collaboration dynamics in R&D activities</td></tr>
<tr><td rowspan="4">MIT campus</td><td colspan="2">Commercial development Vs. Academic accommodation</td></tr>
<tr><td colspan="2">Attracting firms Vs. Retaining talent</td></tr>
<tr><td colspan="2">Competitiveness vs. Collaboration</td></tr>
<tr><td></td><td>Form vs. Function</td></tr>
</table>

TABLE 7.14 Summary of stakeholders' conflicts observed on campus' interventions outlining the nature of the conflicts in each case study.

This systematic comparison shows the explanatory power of the context-related aspects in testing the conceptual framework and validating the proposition of the built environment as a catalyst for innovation depending on context-related aspects. For instance, the differences between the campus' interventions that focus on supporting organisational goals in these two cases ratify the importance of the contexts shaping the ways in which the built environment acts as a catalyst for innovation. The similarities found in particular interventions supporting the organisational activities suggest paying attention to physical and functional aspects that are relevant for the design and planning of technology campuses and similar built environments in which the conditions for innovation are present. The following section discusses these and the overall findings of the case comparison.

§ 7.3 Discussion

This section discusses the findings of the case comparison and evaluates the conceptual framework used to analyse the case studies towards the construction of an interpretative model of the built environment as a catalyst for innovation. The framework discussed as follows can be seen as a preliminary version of a model in which this research builds upon. In this framework, the proposition of the built environment as catalyst for innovation is demonstrated in terms of input-processes-output (i.e. local conditions – the primary processes driving the key organisations in this study – performance measures for innovation in the knowledge economy). The attention is placed on the input of the processes required for innovation, which happen in a certain local context.

Conceptual framework: verification and revision

The comparison served to validate the conceptual framework based on the explanations offered by the interrelationships between contexts-related aspects in each case. This framework suggested six mutually dependent conditions required to carry out the processes leading to innovation: (1) concentration of innovators, (2) innovation area, (3) density of functions, (4) innovation climate, (5) flow of incentives and (6) the built environment as catalyst. A distinction is made in one of these conditions, which positions the built environment (e.g. campus development) as a catalyst facilitating the other conditions through specific interventions. Thus, the proposition of the built environment as catalyst for innovation depends upon the presence of all the other interdependent conditions.

The systematic comparison of the cases found similarities in four of the six conditions in the two different contexts [See Table 7.6]. The two conditions found to be different in each context were input conditions related to physical and functional characteristics of the contexts in which these campuses have been developed. This difference validates the second purpose of this comparison, which is to illustrate the importance of demand- and supply-driven aspects in explaining the research proposition.

These findings suggest that although all the conditions in the conceptual framework are interdependent and necessary for stimulating innovation, there is room for variation within these conditions. Thus, a distinction should be made between these two different conditions and the others proposed in the conceptual framework. The revision of the conceptual framework is based on observed patterns in the practice of developing technology campuses, which are outlined as follows.

Pattern 1: Common goals and primary processes in different organisations explain the similarities in some local conditions for innovation. These are defined as demand-driven conditions in the model.

The starting point in selecting the case studies was an evident similarity: organisational contexts that address stimulating innovation as a goal in campus development. Besides, this study observed common phenomena between the cases, which are related to the goals and/or the primary processes of the different organisations involved in campus development. Although the campuses studied emerged and developed in different local contexts, there are four similarities in the local conditions for innovation proposed in the framework.

First, these cases have a relevant concentration of innovators. In both cases, there is a concentration of organisations, whose primary processes involved technology-based research. These organisations are linked to the historical development of their hosting cities/regions. Second, there has been a corresponding innovation climate in each context. In both cases, there has been the need of (or opportunity to) adapting the region's economic activities to the shifts of technology over time based on their existing technology-based research strengths. Third, their contexts have ensured appropriate flow of incentives. In both cases, there is a strong entrepreneurial tradition in at least two of the spheres of the Triple Helix (University-Industry-Government) leading to increase the number of innovators in the area. Last, there have been similar built environments as catalyst for these conditions. In both cases, the deliberate development of technology campuses has facilitated and/or strengthened the conditions stimulating innovation proposed in the conceptual framework of this research.

These four conditions are the result of deliberated activities conducted to support the goals and primary processes of the three organisational spheres involved in campus development (universities of technology, R&D firms and local governments).

Pattern 2: Distinct locations within particular geographic settings explain the differences in some local conditions for innovation. These are defined as supply-driven conditions in the model.

An important contextual difference making the cases exemplars to explain the research proposition was that they have different types of locations in relation to their hosting cities on the supply-side (Touches and Overlaps). Indeed, this study observed individual phenomenon between the cases, which relate to the distinct locations within particular geographic settings (inner city or peripheral). Accordingly, there are three main differences in the local conditions for innovation proposed in the framework.

First, the concentration of innovators and their location choices shaped different innovation areas in the two cases. These two campuses locate in areas with very different geographic scales (region/metropolitan area), settings (peripheral/inner city) and connectivity (car oriented/public transport oriented). The definition of each innovation area is given by the relative concentration of innovators around the campus, which varies from five up to nine kilometres between the cases. Second, their distinct innovation areas contain different density of functions. These two campuses locate in areas with very different population characteristics in terms of density and diversity. Besides, the more dense and diverse the area, the more sufficient is the area offering attractive amenities and an international attractive environment to live and work. These differences correspond to the geographical differences of each the innovation areas. Third, the similar built environments as catalyst for these conditions developed differently. In each case, the singularity of the geographic settings in which these campuses locate shaped specific decisions and interventions.

These differences are the result of the unique historical and geographical settings of the cities hosting the campuses. For instance, they are linked to the multiple events shaping the emergence and development of the each campus.

Overall, the common and individual phenomena observed in these previous patterns (1 and 2) suggest a more clear distinction between the six conditions for innovation in the conceptual framework. For instance, all conditions are necessary for innovation but not all of them are mutually dependent among each other. Therefore, only conditions within each category (demand-driven and supply-driven conditions) are interdependent except for 'concentration of innovators'. This one is the basic condition for innovation because the other five depend upon its existence. The built environment as catalyst for the other five conditions is both, a demand- and supply-driven condition. In brief, these empirical findings illustrate the explanatory power of both supply- and demand-driven circumstances as context-related aspects conditioning the role of the built environment as catalyst for innovation.

Pattern 3: Common primary processes in different organisations explain the similarities in campus interventions facilitating some conditions for innovation. However, the distinct location characteristics and geographic settings explain the differences in their implementation. These interventions can support campus decisions in the planning and design phases of campus development.

This research observed five interventions in each campus development facilitating different conditions for innovation as proposed in its conceptual framework. Three of these five interventions are the same in the cases studied: (1) shared facilities; (2) flexible facilities; and (3) physical connectors. These interventions focus on supporting the primary processes of campuses end-users – i.e. technology-based research organisations. However, the implementations of these common interventions vary according to the distinct location characteristic and geographic settings of the hosting cities. Correspondingly, each of the three interventions facilitates both supply-driven conditions in the framework (i.e. innovation area and density of functions) among other conditions.

These interventions and their variations according to the type of campus can be collected as a repertoire of design solutions that can be used to support campus decisions in existing or future technology campuses accommodating similar primary processes. However, the implementation of any design solution should be carefully corresponding to unique the supply-driven conditions of each campus.

Pattern 4: Distinct campus interventions facilitating all the conditions for innovation are the result of strategic goals of end-users organisations and local governments. They have been implemented in collaboration between different organisations. These interventions can support campus decisions in the management phase of campus development.

This research observed one intervention in each case studied facilitating all the conditions for innovation as proposed in the conceptual framework, showing a great potential as catalyst for innovation. Each of them is a different intervention per campus: (1) an accommodation strategy involving a site's re-development and (2) the development of three areas involving urban renewal. These interventions focus on supporting the goal of the end-users' organisations and the local governments (e.g. municipalities and regions) in stimulating innovation. Indeed, they aimed at the economic revitalisation of their contexts and were executed in collaboration between campus and city managers and planners.

Similar to the previous pattern, they have been strategic responses to the different supply conditions of each campus. These findings illustrate how collaborative strategies can direct efforts to develop built environments as catalyst for innovation. For instance, the necessity of strategic alignment, alliance and commitment in envisioning and developing built environments that can facilitate innovation, when there is an existing potential for it. However, as shown repeatedly, that is only possible if all the necessary conditions for innovation are present in the area.

The implementation of these interventions according to the type of campus can be mapped as management information that can be used to support campus decisions in existing or future technology campuses with similar strategic goals. However, the use of such management information should be carefully corresponding to the unique the supply-driven conditions of each campus.

Overall, the common and individual phenomena observed in these previous patterns (3 and 4) suggest a distinction in the conceptual framework. For instance, the built environment as a catalyst for innovation has a dependent position in this framework because its presence facilitates the other five conditions through specific interventions. However, the observations from these patterns suggest that the potential of campus interventions as catalyst for innovation depends upon the ability to match the existing demand-driven conditions to the unique supply-driven conditions in each local context. Thus, the existence of the three demand-driven conditions in the framework (which were consistent in both cases) is essential to trigger the role of the built environment as catalyst. Conversely, the other two supply-driven conditions determined the way in which the built environment facilitated (and might hinder) the previous three conditions for innovation. In this context, the built environment as catalyst for innovation is directly dependent on supply-driven conditions.

Pattern 5: Distinct perceptions of innovation explain conflicting ambitions among the different stakeholders involved in the practice of campus development. These conflicts inhibit the role of the built environment facilitating some conditions for innovation.

This research observed specific issues generating conflicts among stakeholders that act as inhibitor for some of the conditions necessary to stimulate innovation in their contexts. For instance, in both cases innovation is perceived by different stakeholders either as (1) a process driven by the exchange of ideas and (2) a market driven by the exchange of capital. In both cases, the later perception has become dominant among some stakeholders when making campus decisions or justifying campus interventions. This results in conflicts that derive from a combination of both supply- and demand-driven conditions in the context where each campus has developed. In most cases, these conflicts are shaped by the physical/functional settings in which campuses locate on the one hand and the demands of the stakeholders involved in their developments on the other hand. In fact, all the conflicts are strongly related to the contrasting demands of the stakeholders, which derive from their different perspectives on innovation as a goal.

In this context, the lack of balance between the different ambitions placed on innovation can create the opposite effect of the built environment in the framework. In other words, the built environment can be both a catalyst and an inhibitor for innovation. Thus, the steering of the built environment as a resource becomes critical.

Pattern 6: The distinct times of emergence and developments of technology campuses explain the differences in the influential links between theoretical concepts of innovation and the practice of campus development.

The framework used to analyse the cases is based on a collection of theoretical concepts of innovation from economic geography in the context of the knowledge economy. The common phenomena observed in the three demand-driven conditions[179] of the two cases validate the importance of historical links and path-dependency for innovation as addressed in evolutionary economic geography and supported by other sources outlining the relevance of specific organisations in the knowledge economy (See Chapter 4). Nevertheless, the individual phenomena observed in the supply-driven conditions[180] of each case strengthen the open debate about the concept of proximity in economic geography.

In both cases, the concepts of physical proximity and diversity of people are persistent in the discourse of stimulating innovation of both campus developments. For instance, stakeholders involved in the development of both campuses (e.g. designers, planners, managers, controllers, developers and policy makers) stand on the idea that these two concepts are essential for two primary processes of campuses' end-users. First, stakeholders acknowledge proximity and diversity of people as a requirement for sharing ideas that create new knowledge by means of the social interactions among interdisciplinary knowledge networks. And second, these stakeholders recognise proximity and diversity of people as essential for boosting the entrepreneurial environment because of the trust developed by face-to-face contact.

These arguments are largely used in both campuses to promote interventions such as the development of shared facilities and mixed-use areas. However, the explicit influence of these theoretical concepts is more evident in recent interventions. For instance, there is a time-correspondence between specific campus interventions and the establishment of particular theoretical concepts (e.g. 'concentration' as an advantage in organisation' location choices as well as for regional economic development and 'open innovation ecosystems' favouring growth in firms and economic developments in regions).

Surprisingly, the distinct geographical setting in which these campuses have emerged and developed might strengthen the theoretical concepts on the multiple dimensions of proximity. Simultaneously, the patterns observed in these two campus developments reinforce the ambiguous theoretical debate on whether urban or regional environments are more or less favourable for innovation as a learning process.

179 These are concentration of innovators, innovation climate and flow of incentives.

180 These are Innovation area and density of functions.

Overall, these last two patterns (5 and 6) give to the local context a prominent role in the framework, because it shapes both the demand- and supply-driven conditions for innovation. These and the other suggestions outlined above are the basis to revise this framework and propose a model that is presented as follows.

§ 7.4 Conclusions

This section draws the conclusions of this chapter and how its findings can be used to further answer the main question of this research. This chapter compared the developments of HTCE and MIT campus aiming to uncover common and distinct patterns of the built environment as a catalyst for innovation in two particular contexts in which 'stimulating innovation' is a goal successfully attained. The comparison of these two cases in different contexts has also a twofold instrumental/illustrative purpose for this research to validate its conceptual framework on the one hand and to expose the importance of context-related aspects in validating its research proposition.

The guiding questions of the case comparison presented in this chapter will be answered as follow.

What are the similarities and differences in the contexts of the cases?

The answers given in these paragraphs rely on the analysis presented in §7.1.3 and §7.2. As stated before, a common similarity is the starting point of this research: these two campuses locate in organisational contexts that address stimulating innovation as a goal in campus development. This is expressed in the visions of each campus and its hosting city/region. This case comparison found out four important similarities in the context-related aspects proposed in this research as conditions stimulating innovation:

- Concentration of innovators: in both cases, there is a concentration of organisations focused on technology-based research and linked to the historical development of their hosting cities/regions.
- Innovation climate: in both cases there has been the need/opportunity to adapt the region's economic activities to the shifts of technology over time based on their existing technology-based research strengths.
- Flow of incentives: in both cases, there is synergy among the spheres of the Triple Helix (University-Industry-Government).
- The presence of a catalyst: in both cases the development of technology campuses has facilitated and/or strengthened the conditions stimulating innovation proposed in the conceptual framework of this research.

In addition, this research addresses two important contextual differences making these two cases exemplars to explain its proposition: these two campuses accommodate different type of organisations on demand-side (business and academia) and they have different types of locations in relation to their hosting cities on the supply-side (Touches and Overlaps). Moreover, this case comparison uncovers two important differences in the context-related aspects proposed in this research as conditions stimulating innovation, which are in fact supply-driven conditions:

- Innovation area: these two campuses locate in areas with very different geographic scales (region/metropolitan area), settings (peripheral/inner-city) and connectivity (car oriented/public transport

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oriented). The definition of each innovation area is given by the relative concentration of innovators around the campus, which varies from 9km in HTCE to 5km in MIT campus.

- Density of functions and diversity of people: these two campuses locate in areas with very different population characteristics in terms of density and diversity. Besides, the more dense and diverse the area, the more sufficient is the area offering amenities and an attractive environment to live and work. These differences correspond to the geographical differences of each the innovation areas.

How have HTCE and MIT campus been developed compared to each other?

These technology campuses emerged in different periods, having a difference of almost half a century of interrelated developments between the two [See Figure 7.2]. The analytical frame used to study both campuses' developments helped identifying a set of relevant campus interventions as catalyst for innovation in each case. These interventions are linked to periods of technological developments affecting the research activities accommodated in each campus.

These interventions are perceived as more or less incremental or intended strategies when comparing the developments of these two campuses. In the case of the MIT campus, the interventions are being incremental since its emergence throughout important periods of technological change and advancements in its context. In the case of HTCE, the interventions are mainly related to the redevelopment of an existing built environment as the result of an intended accommodation strategy at a specific time of technological and economic changes in its context. The difference in the way these campuses have been intervened is the result of the time difference between their developments and the multiple interrelated events in time and place shaping the accommodation processes of both organisations.

These findings give to the context a prominent role in the way the built environment facilitates conditions for innovation. Today, these campuses share the deliberate intention to stimulate innovation in their current regulatory development frameworks.

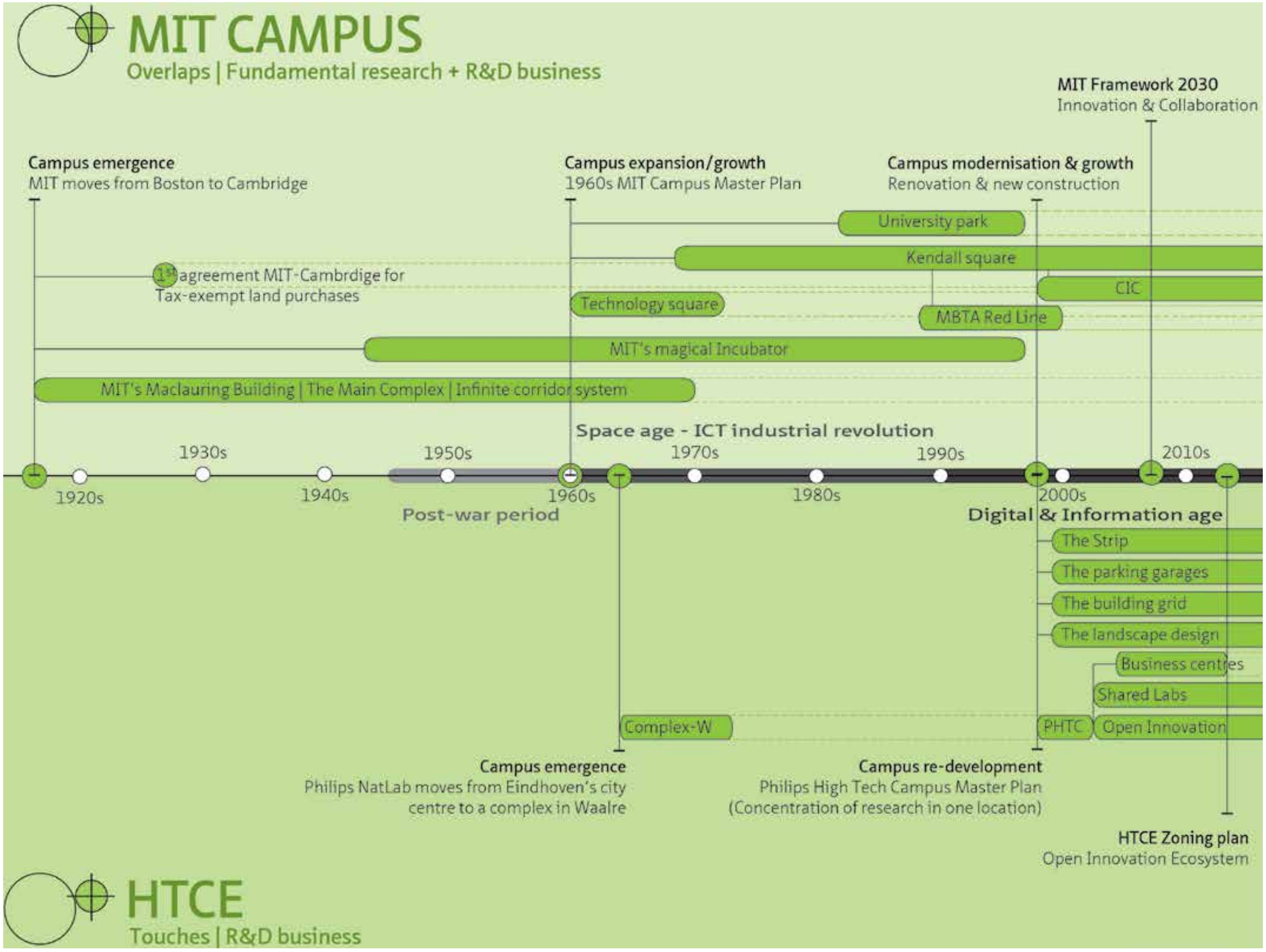


Figure 7.2 Developments of HTCE and MIT campus compared to each other.

Why are their evident location characteristics in relation with the city different?

In an international comparison of 39 technology campuses (Chapter 3), it has been observed that HTCE and MIT campus have different characteristics in relation to their hosting cities regarded as 'Touches' and 'Overlaps' respectively. Accordingly, Eindhoven touches HTCE and Cambridge and MIT campus share common points. Overall, HTCE is perceived as a separated area, which is located at the southwest edge of the city of Eindhoven while MIT campus is integrated in Cambridge's urban fabric.

The study of both campus developments as a historical phenomenon helped to understand the multiple events shaping the ways in which these two built environments developed in relation to their hosting cities. Eindhoven and Cambridge have developed and grown at different paces. For example, at the beginning of the 20th century, Eindhoven was still small agricultural town in the South of the Netherlands that has started growing because of industrialisation processes. Simultaneously, Cambridge was already a major industrial city at the heart of New England, during the industrialisation period of the US and housing the oldest university of this country since 1636. These historical differences and other events related to periods of economic revitalisation and technological change have shaped the ways in which these two cities developed and so these two technology campuses.

Next to the historical settings, the different geographical settings between Cambridge and Eindhoven have made an important difference explaining the evident location characteristics between HTCE and MIT campus. For instance, Cambridge grew next to Boston to be one of the most densely populated cities and in the middle of an attractive metropolitan area of the US, while Eindhoven still is a medium size city in the Dutch context and quite distant from the major urban agglomeration of the Netherlands.

Correspondingly, the chosen sites where these two campuses locate are examples of the different historical and geographic settings of these two cities. On the one hand, industrial sites surrounded the initial landfill where MIT campus established. Over the 20th century, these industrial districts were targets of renewal projects by the municipality of Cambridge and incrementally acquired by MIT to accommodate its growing activities. On the other hand, the site where HTCE established was an available property of Philips in the outskirts of Eindhoven, which fitted an urgent corporate strategy aimed at saving costs and improving image in time of crisis. Such strategy involved the moving of Philips HQ from Eindhoven to Amsterdam, the selling of several properties owned by Philips in Eindhoven's city centre of Eindhoven purchased by the municipality and the concentration of all the dispersed Philips' research activities in one location in the outskirts of Eindhoven. This location eventually became isolated from their immediate surroundings with the construction of the A67 (a national motorway) and the designation of the surroundings' campus land as areas environmentally protected.

Overall, the distinctive location characteristics of HTCE and MIT campus are the results of the different historical and geographical settings of the cities hosting them. Besides, these characteristics are linked to multiple events that shaped the emergence and development of both campuses in such contexts.

To what extent have HTCE's and MIT campus' developments been influenced by theoretical discourses of stimulating innovation? Is this influence explicit or accidental compared to each other? Which theoretical concepts influencing campus development arise from the case comparison?

As explained in Chapter 4, the proposition of the built environment as a catalyst for innovation is based in a collection of theoretical concepts of innovation from economic geography. The empirical information analysed in both cases points out that there is a link between theory and practice in the development of HTCE and MIT campus. In both cases, the concepts of physical proximity and diversity of people are persistent in the discourse of stimulating innovation of both campus developments. For instance, stakeholders involved in the development of both campuses (e.g. designers, planners, managers, controllers, developers and policy makers) stand on the idea that these two concepts are essential for:

- Sharing ideas that create new knowledge by means of the social interactions among interdisciplinary knowledge networks; and,
- Boosting the entrepreneurial environment by means of the trust developed by face-to-face contact.

These arguments are largely used in both campuses to promote the development of shared facilities in both campuses and mixed-use developments in the case of MIT campus.

While it was difficult to generalize the explicit or accidental influence of these theoretical concepts in practice, studying the developments of HTCE and MIT campus uncovered some indications linking theory and practice over time. However, compared to each other, the influence of these concepts seems more explicit in HTCE than in MIT campus.

For instance, there is a time-correspondence between the intended interventions on HTCE and the establishment of theoretical concepts favouring concentration as an advantage in organisation' location choices as well as for regional economic development. In fact, the influence of theoretical concepts on

HTCE's development has become more explicit with the adoption of the Open Innovation model as leading concept in campus development and in regional spatial planning.

In the case of MIT, the design and planning principles favouring physical proximity and diversity of people occurred long before these concepts were discussed and established in theory. Nevertheless, lately it has been used to promote –if not justify- the development of mixed-use urban areas around the campus in favour of economic development.

Moreover, the difference in the geographical setting in which these campuses have developed might be supporting two important theoretical discourses about physical proximity. As mentioned in §7.3, the development of each campus is strengthening the debate between specialisation externalities and urbanisation externalities in the process of knowledge creation and diffusion, which has been extensively discussed in agglomeration economies. In theory both provide concepts explaining a favourable environment for innovation and economic development. In practice, the developments of HTCE and MIT campus sustain each one of these concepts.

What campus' interventions have facilitated the conditions leading to innovation in HTCE and MIT campus compared to each other? How do the mechanisms leading to these interventions differ in each case?

As shown in §7.2.6, there are five interventions in each campus development facilitating different conditions for innovation as proposed in the conceptual framework of this research. Three of these five interventions are the same in HTCE and MIT campus, with variations in their implementations according to the different supply-driven conditions of their contexts. These interventions focus on supporting organisation's activities and are:

- Shared facilities
- Flexible facilities
- Physical connectors

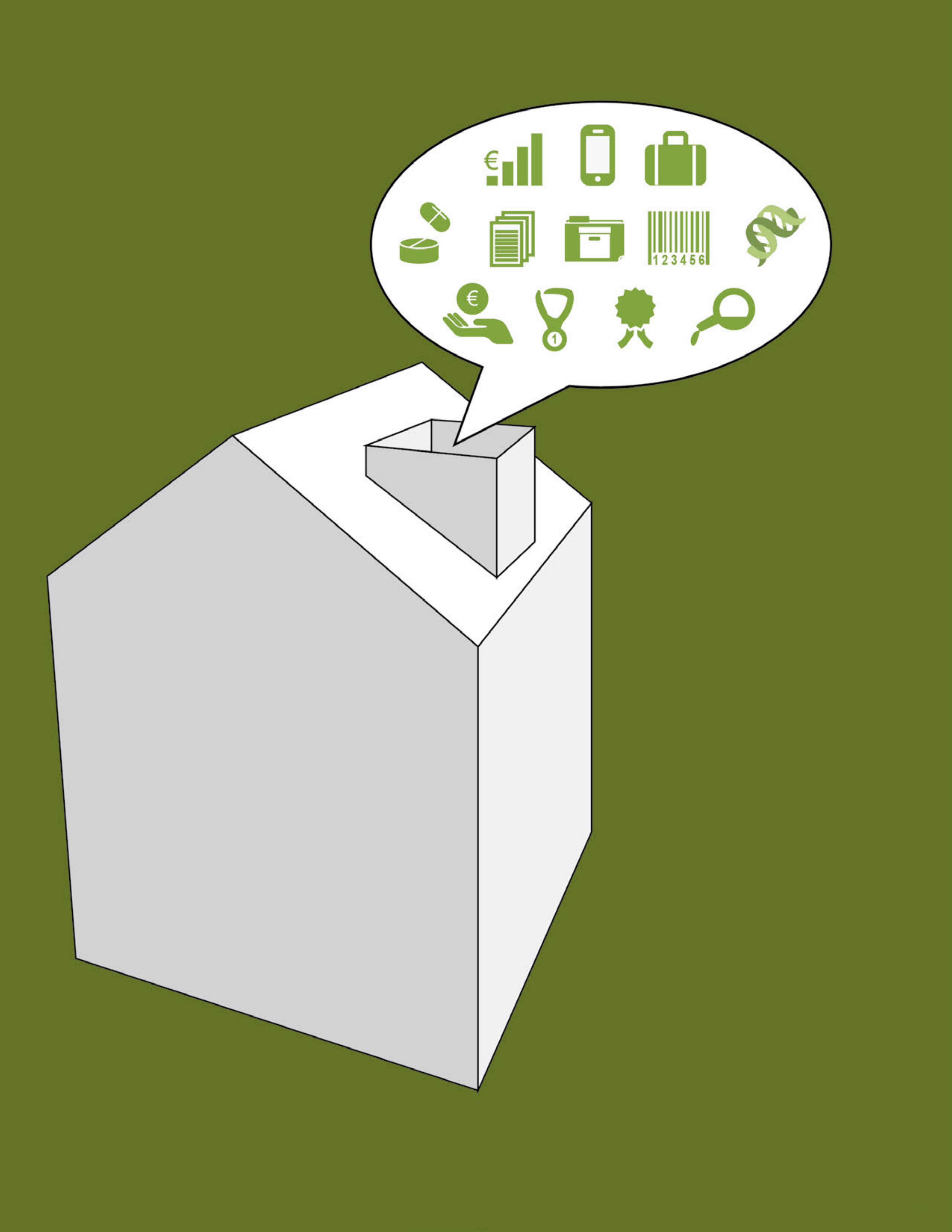
Accordingly, these campus interventions can be observed as common phenomenon found in these two different contexts. Therefore, this finding suggests planners and designers of the campus and the city should pay attention to these three aspects in the brief of technology campuses, as these interventions focus on supporting the activities of research organisations. However, the ways in which these interventions facilitate conditions for innovation in each case is limited to the supply-driven aspects of the contexts. Thus, the implementation of this type of interventions should be carefully corresponding to unique the supply-driven conditions of each campus.

On the contrary, the interventions found to be different between HTCE and MIT are those focusing on organisation's goals. Correspondingly, these interventions are strategic responses to the different supply conditions of each campus. According to the empirical information collected, some had a great potential as a catalyst for innovation because they have facilitated all the conditions for innovation in each campus' context:

- Intended accommodation strategy in HTCE (redevelopment); and
- Urban area development in MIT campus (urban renewal).

These two interventions aimed at the economic revitalisation of their contexts and were executed in collaboration between campus and city managers and planners. These findings indicate another common phenomenon found in these two different contexts regardless their distinct supply-driven conditions. Indeed, this finding indicates collaborative strategies can direct efforts to develop built environments as a catalyst for innovation. However, as shown repeatedly, that is only possible if all the necessary conditions stimulating innovation are present in the area. Thus, managers and planners of campuses and cities should acknowledge the necessity of strategic alignment, alliance and commitment in envisioning and developing built environments that can catalyse innovation, when there is an existing potential for it. Similarly, these stakeholders should carefully acknowledge the unique supply-driven characteristics influencing the developments of technology campuses, which can also inhibit the facilitating role of the built environment for innovation.

The findings discussed in this chapter validates the conceptual framework used in this research and suggests improvements based on the observations discussed here. These suggestions serve as basis to propose a model of the built environment as a catalyst for innovation. The model is described and discussed further in Chapter 8.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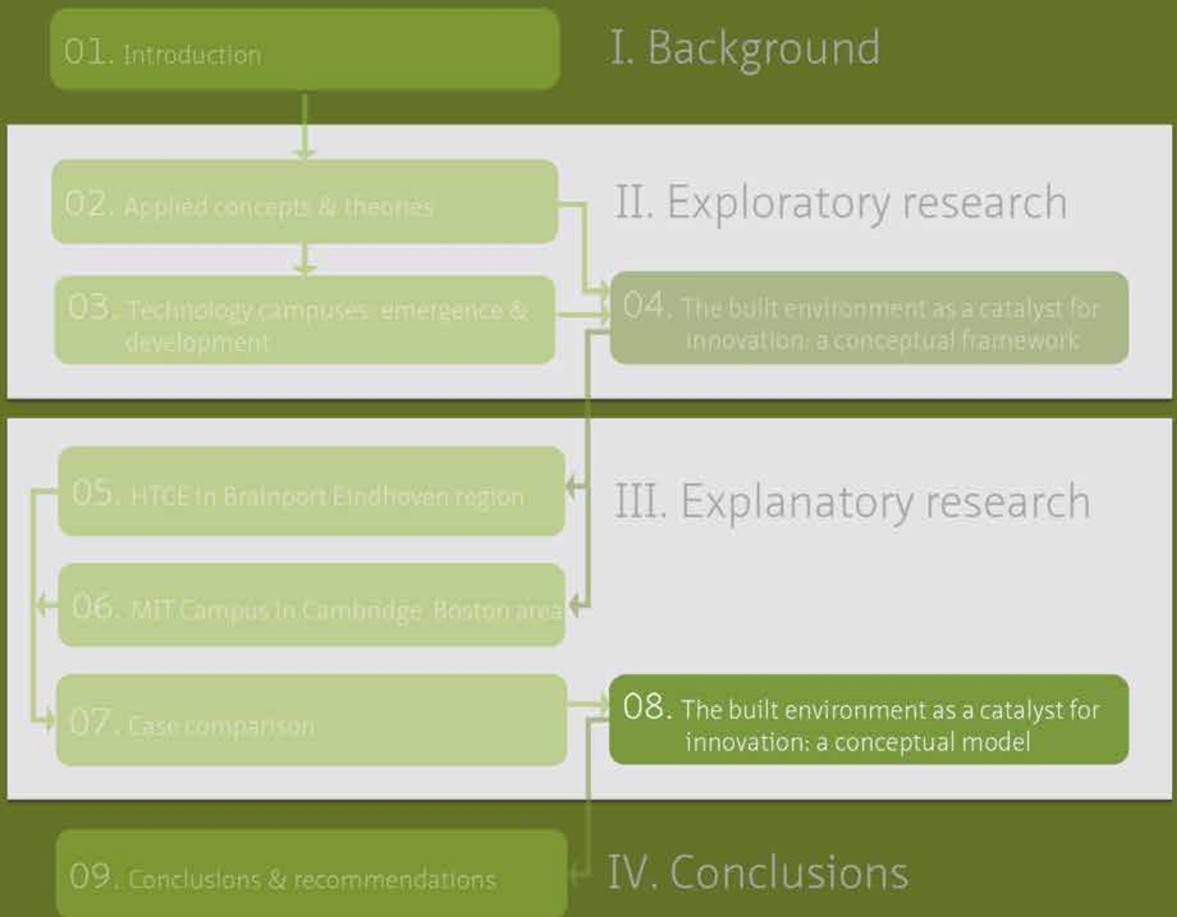
Chapter 8. The built environment as catalyst for innovation: a conceptual model



The previous chapter presented the comparison of empirical information from two case studies gathered by using a proposed conceptual framework. This comparison allowed for uncovering common and distinct patterns of the built environment as a catalyst for innovation between the cases studies. The findings suggested a logical evaluation and revision of the conceptual framework towards the construction of a conceptual model explaining the relationship between innovation and the built environment. Therefore, this chapter elaborates on the discussions and findings of the explanatory research (Part II), which contributes to answering the question: ***What can be concluded on the built environment as a catalyst for innovation from the observed patterns in the two case studies? How can we use this knowledge to improve future outcomes and challenges in the practice of developing technology campuses and similar built environments?***

This chapter presents the main outcome of this research, with the aim to explain its proposition of the built environment as a catalyst for innovation based on empirical findings. Accordingly, Section 8.1 begins with introducing the logic of this chapter. Section 8.2 presents a conceptual model explaining the research proposition and outlines important conclusions in the grounding field of corporate real estate management. Section 8.3 provides insights for stakeholders involved in the development of technology campuses based on the integration of these findings. Last, Section 8.4 draws the chapter conclusions by answering its central question.

8 The built environment as catalyst for innovation: a conceptual model

§ 8.1 Introduction

§ 8.1.1 Chapter aim and questions

This chapter aims to develop knowledge and understanding of the relationship between innovation and the built environment based on the patterns identified in the empirical findings. These findings confirmed the research proposition of the built environment as a catalyst for innovation. Accordingly, this explanation has a twofold purpose. First, it aims to provide general understanding of the role of the built environment in stimulating innovation. Second, it aims to facilitate the use of such knowledge to stimulate specific campus interventions that effectively conduct to attain this goal.

This chapter addresses two main questions as a synthesis of this explanatory research: ***What can be concluded on the built environment as catalyst for innovation from the observed patterns in the two case studies? How can we use this knowledge to support decision-making and improve future outcomes in the practice of developing technology campuses and similar built environments?***

Besides, the following set of sub-questions guided the process of answering such questions:

- How can we provide understanding on the role of the built environment in innovation based on the lessons learned from the case study research?
- What do campus decision-makers need to know to effectively attain their goal of stimulating innovation?

§ 8.1.2 Approach and methods

These questions will be answer by providing a conceptual model, which is the main outcome of the explanatory research or Part III of this dissertation [See Figure 8.1]. The analysis and interpretation of data followed as much as possible the explicit process of 'theory building from case study research' (Eisenhardt, 1989; Eisenhardt & Graebner, 2007). For instance, the use of rich and extensive descriptions, tables, maps and figures was central to the generation of insights and helped to cope with the analysis process and the enormous amount of data collected.

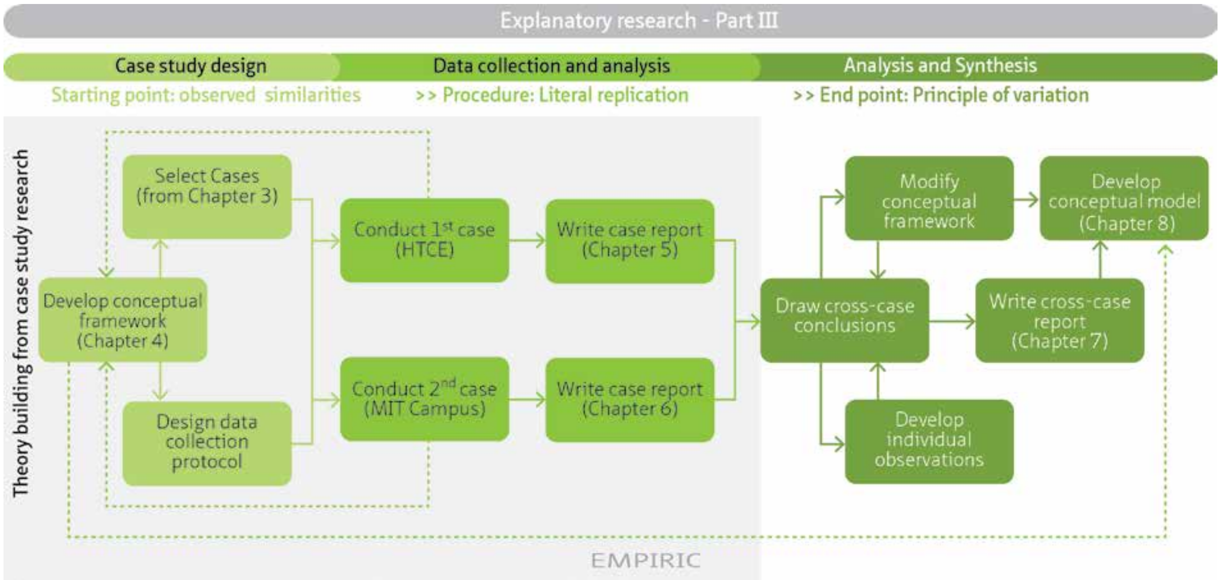


Figure 8.1 Explanatory research: design and methods. The content of this chapter is indicated as the final outcome or synthesis of this research.

The use of replication logic in case study research contributed to compare two cases that confirmed existing and emergent relationships (See Chapter 7). This approach presented an opportunity to refine and extend the theoretical constructs in the conceptual framework that developed into a model. These constructs will be elaborated in this chapter.

§ 8.2 Towards a conceptual model of the built environment as a catalyst for innovation

This section revises and presents a conceptual model explaining the relationship between the built environment and innovation. A preliminary version of this model –based on theoretical concepts- was used to studying the practice of campus development in two cases located in different contexts. The validation of theoretical concepts with empirical information from the cases is used to revise this model as main outcome of this study.

The discussion in Chapter 7 suggests improvements regarding the distinction between the six different conditions for innovation and their interrelations. Besides, a more precise terminology is used to improve the readability of the conceptual model that can facilitate its use either in practice or in future research.

§ 8.2.1 Purpose of the model

This model has a twofold purpose. On the one hand, it aims at providing understanding about the role of the built environment in innovation in a broad context. On the other hand, this model aims at encouraging interventions that effectively facilitate the fulfilment of 'stimulating innovation' as

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an organisational goal in the practice of campus development. Thus, this model is targeted both to researchers developing knowledge about the impact of the built environment on organisational performance and to practitioners involved in the development of technology campuses and similar built environments. This last group includes stakeholders who are involved in decision-making processes and at different phases of campus development – i.e. campus and city's planners, designers, managers, end-users' organisations, municipalities, among others.

§ 8.2.2 Logic of the model

As described above, this model is mainly descriptive and/or explanatory. It provides an explanation of how the built environment in combination with other elements works as a catalyst for innovation. Corresponding to its preliminary version, the proposition of the built environment as catalyst for innovation is demonstrated in terms of input-processes-output (i.e. local conditions – the primary processes driving the key organisations in this study – performance measures for innovation in the knowledge economy). The model is described as follows.

In general, the knowledge economy of cities and regions in industrialised countries provides a wide contemporary context for this model. Hence, this model assumes two states framing the system defined in terms of input-processes-output [see Figure 8.2]. An initial state named stimulating innovation, which is a strategic goal of the organisations involved in campus development. And a desired state named competitive advantage, which is the common outcome pursued by these key organisations, or the main reason why these organisations want to stimulate innovation. In other words, this is also the reason why organisations are willing to spend resources in built environments such as technology campuses. The model is fully illustrated in Figure 8.3.

According to this model, the fulfilment of stimulating innovation as an organisational goal is widely measured by using various output indicators. These are the most common ways of measuring the development of new or improved products, processes or services. The relevance given to these output indicators vary according to the type of organisation. This model maps the most common indicators used by different organisational spheres involved in campus development (e.g. academia, industry and governments). These indicators corroborated the exemplary of the cases selected in this research to apply the preliminary version of this model. Although these output indicators and the processes leading to innovation are an important part of the system, they are illustrated in the model for the purpose of understanding the position of the built environment as one of the input conditions required to accomplish both processes and output. Therefore, this model emphasises the input conditions required to carry on the processes of knowledge creation and its application advancing technologies used to develop such output. Indeed, the creation and application of new knowledge is a core process of technology-based research organisations, which are the main end-users of technology campuses.

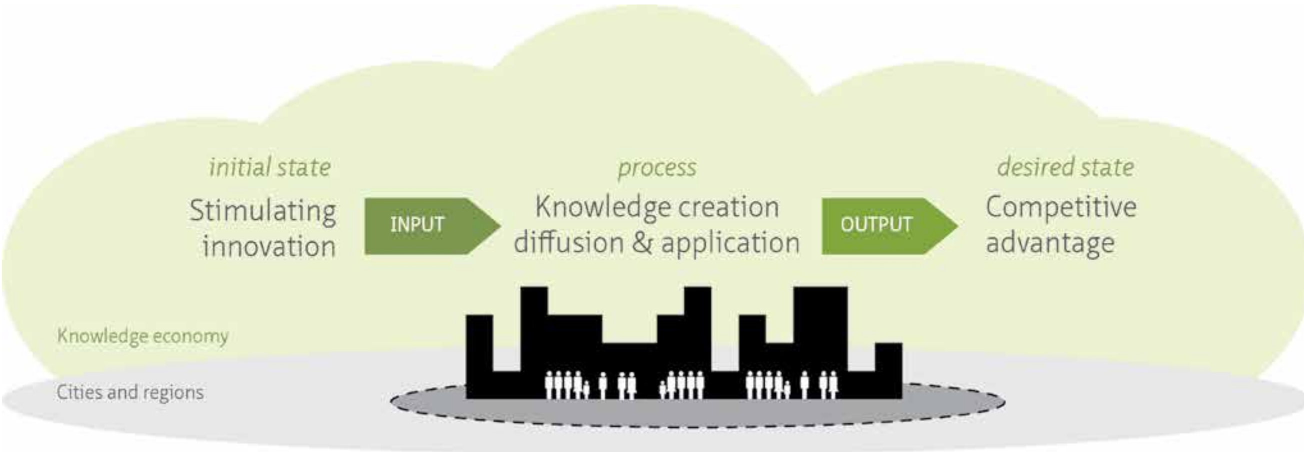


Figure 8.2 Basic structure of the model's system defined in terms of input-process-output in the context of the knowledge economy

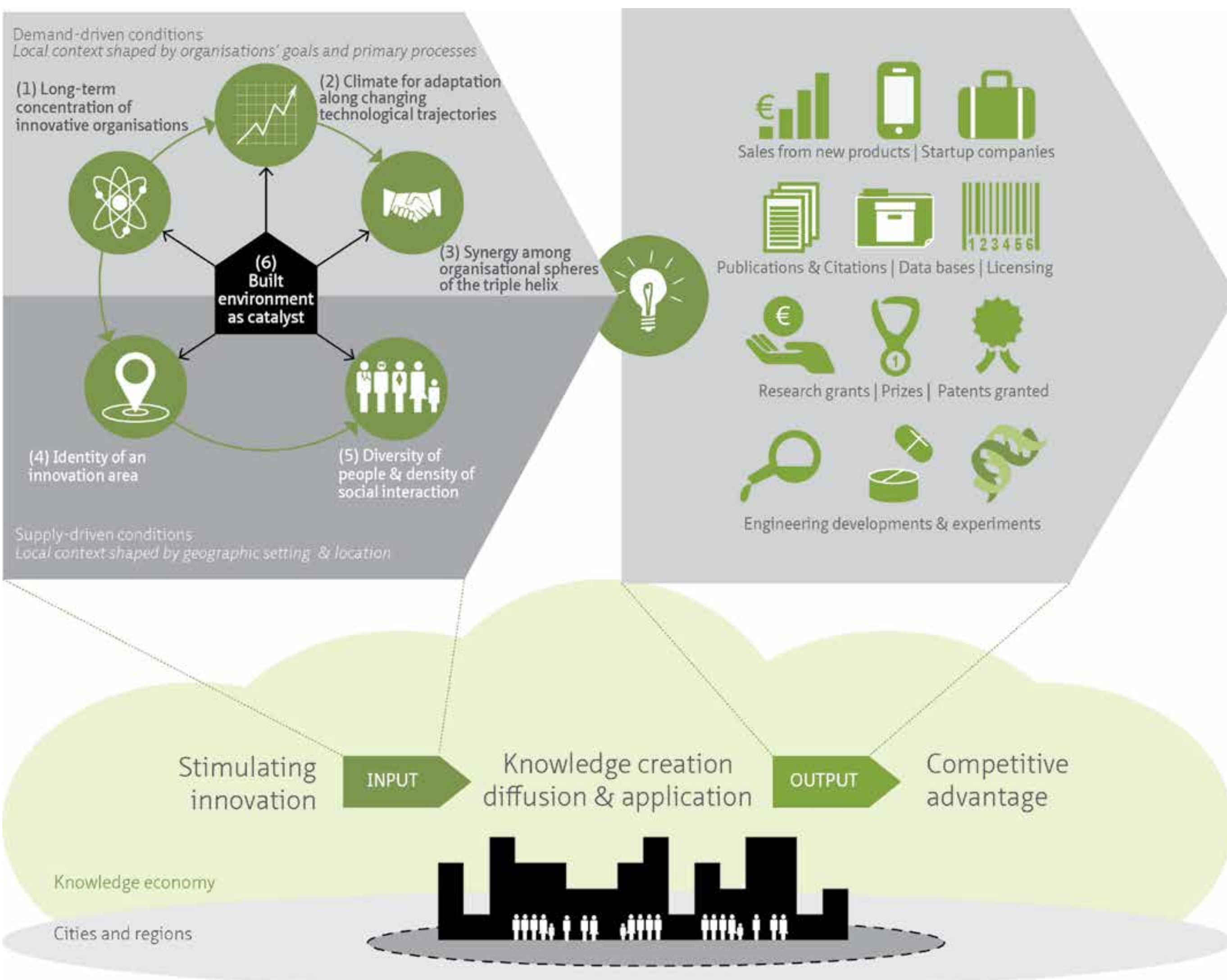


Figure 8.3 Conceptual model explaining the role of the built environment in innovation (Bottom: the system and its general context. Top: Input-conditions and output-indicators of innovation)

§ 8.2.3 Hypothesis and propositions

This model contains the hypothesis that 'the built environment is a catalyst in the process of knowledge creation and its application. Its function in the entire system is demonstrated through interventions facilitating other required conditions for innovation. Thus, *its function as catalyst for innovation cannot be isolated from the functions of other conditions, which all together are required for innovation'*.

This model proposes six conditions required to stimulate innovation in organisations involved in the development of technology campuses - e.g. universities of technology, R&D companies and cities/regions. Each condition has a different function in the process of knowledge creation and its application, which is relevant for the competitive advantage of these organisations. These conditions are distinguished into demand-driven conditions and supply-driven conditions [see Figure 8.4]

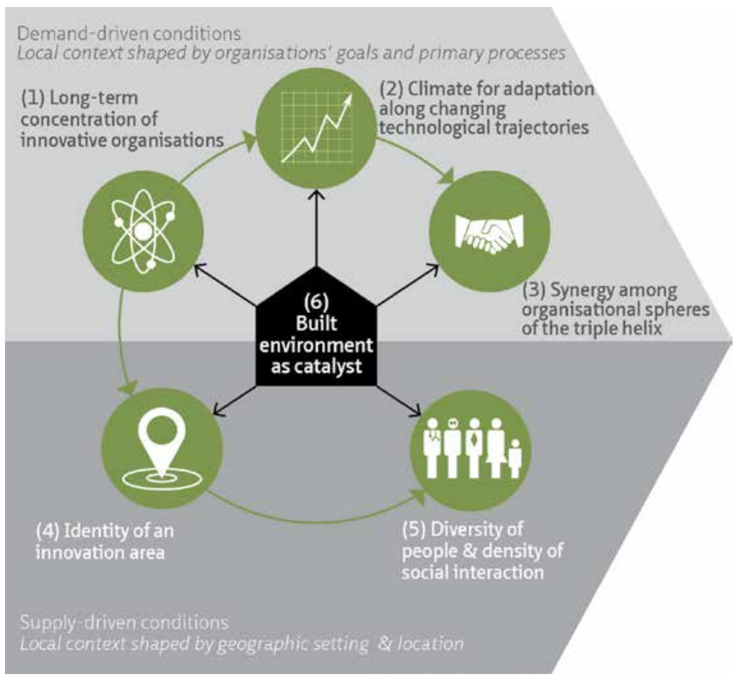


Figure 8.4 Input conditions in the conceptual model explaining the built environment as catalyst for innovation

The first type refers to conditions that resulted from deliberated activities of local stakeholders within the three organisational spheres involved in campus development (universities of technology, R&D firms and local governments). Demand-driven conditions for innovation are (1) Long-term concentration of innovative organisations; (2) Climate for adaptation along changing technological trajectories over time; (3) Synergy among organisational spheres. These local conditions are likely to be similar across industrialised regions regardless the different contexts in which innovative organisations locate.

The second type refers to conditions that are shaped by physical and functional characteristics of the region in which the organisations above locate and conduct their activities. These conditions are shaped by the geographic settings of the hosting city/region and ultimately by the location characteristics of technology-based research organisations within such city/region. Supply-driven conditions for innovation are: (4) Identity of the innovation area; (5) Diversity of people & density of social interaction. These local conditions are likely to be unique in each context.

A last condition is distinguished as a facilitator for all these conditions and positioned in between demand- and supply-driven conditions: (6) the built environment as catalyst. In fact, built environments like campuses are the result of both, deliberated organisational goals supporting primary process and the singular geographic settings in which organisations locate. Thus, the facilitating role of the built environment as catalyst for innovation is strongly dependant on the other five conditions – i.e. the built environment can facilitate conditions for innovation if interventions are steered in a way that matches specific organisational demands with the unique supply conditions of their local contexts.

Proposition 1. Location decisions and area development facilitate the long-term concentration of innovative organisations in cities/regions.

The long-term concentration of innovative organisations is the very basic condition for innovation in competitive cities and regions in the knowledge economy. Without this condition, the other conditions addressed in this framework are meaningless. Innovative organisations are distinguished because their primary processes deal with technology-based research (e.g. universities of technology, R&D firms, research institutions, etc.). These organisations are essential parts of the system because they are the source of the knowledge required to advance technologies applied to developed new or improved products, processes and services. The function of this condition is to make these processes happen.

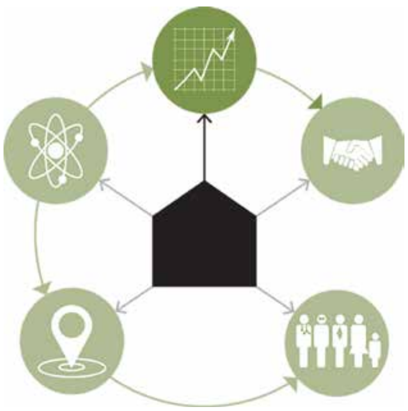
The case study research provided empirical evidence that the location decisions of anchor organisations (e.g. prestigious universities and multinational firms) to concentrate their research activities have played a significant role defining where innovation takes place in particular local contexts (Chapter 5 & 6). The empirical evidence suggested that organisations' location decisions have defined the concentration of innovative activities in particular places unintentionally. In the two cases studied, organisations' location decisions have been shaped by multiple factors such as the availability of land relatively convenient to accommodate growth, expansion or change needed to support these organisations primary processes in combination with minimising costs or improving image required at particular times. Over the years, these areas and their hosting cities have developed in different ways creating unique conditions for campus development, which may be more or less favourable for the concentration of innovative activities. These empirical findings corroborate existing studies outlining the relevance of interconnected innovators in one location as sources of competitive advantage, especially in the knowledge economy (Porter, 2008; Van Den Berg et al., 2005). In general, it adds to the theoretical assumption that knowledge spillovers are geographically bounded.

Through the re-development of areas in collaboration with local governments, these organisations have attracted other innovative organisations to locate in their vicinities. This facilitating role has been enhanced through the development of mixed-use shared facilities (e.g. laboratories, mixed uses facilities and co-working office space) strengthening the attractiveness of these locations for specific organisations because of the potential access to knowledge networks. The role of location decision facilitating the long-term concentration of innovative organisations in cities/regions is crucial because this condition is primordial for innovation.

Other campus interventions facilitating this condition have been found but depending on the particular setting of each campus. For instance, the development of representative facilities in remote locations and the long-term land acquisition plan in urban locations that were once industrial and unattractive places are examples of interventions facilitating the concentration of innovative organisations. Indeed, the specific geographic settings of their local contexts shaped the facilitating role of each intervention.

Overall, the long-term presence of these innovative organisations in a city/region has influenced all the other conditions for innovation. Directly, it has allowed a climate for innovation in their regions and it has shaped the geographic scale of the innovation area. The former is discussed as follows.

Proposition 2. Interventions enabling the transformation of the built environment at area and building levels facilitate the climate for innovation over time.



The long-term presence of innovative organisations favouring the concentration of technology-based research activities has been a natural advantage for cities/regions in economic resets. During the 20th century, many regions in industrialised countries have experienced a transition from manufacturing to knowledge-intensive activities shaping their economies. This transition has been largely influenced by technological advancements, in which technology-based research activities have been essential shaping technological shifts over time – e.g. from electronics in the post war period, to ICT in the space age, to software in the digital and information age and to energy and life sciences lately. These shifts created a need for adaptation of regional economies in industrialised countries where manufacturing was a leading activity. Thus, the climate for adaptation is a condition for innovation that functions as the initial state that makes innovation a prerequisite for growth.

This research demonstrates how two regions in different industrialised countries experienced this transition and how the long-term presence of innovative organisations facilitated the economic adaptation along technological trajectories. For instance, these two regions experienced severe declines of their economies, which enforced their governments to take different revitalisation or re-industrialisation measures in different periods. In both cases, the leaders of these regions (including governments, industry and academia) had a proactive role in sorting the economic crisis while pulling together the natural advantages of their regions – i.e. having a presence of innovative organisations helped these regions to re-orientate their economies to specific sectors taking advantage of their technological developments over the time.

These empirical findings support a core concept defining evolutionary economic geography that 'views institutions as primarily influencing innovation in a generic sense and as co-evolving with technologies over time and differently so in different regions' (Boschma & Frenken, 2006). Similarly, it strengthens the theoretical concept of related variety (Frenken et al., 2007) and those approaches explaining the different dimensions of proximity from a dynamic perspective (Balland et al., 2015). This research shows how the innovative organisations located in the different regions studied in this research developed along existing technological trajectories, which turned out to be successful in the long term because the local institutional context allowed change.

In campus development, two real estate interventions have facilitated the climate for adaptation in both cases and in two different ways. First, the transformation of built environments (urban renewal or redevelopment) facilitated the regions' resolutions for change in attracting innovative activities in new- targeted sectors that reinvigorated their economies. These large-scale interventions brought together the combined effort of different stakeholders, who collaborate to reach their shared ambition to revitalise their economies.

Second, the development of flexible facilities in campuses accommodated the changing demands of end-users' organisations that adapted their activities along with changes in the technological trajectories they continued. The adaptive re-use of existing buildings with particular design and building qualities (e.g. modularity, standardisation and openness) facilitated the dynamic climate required for innovation. The development of flexible facilities has also enabled the adaptation of activities among changing end-users over time. For example, in one of the cases the renewal of former industrial districts has accommodated the activities of changing industries along significant periods of technological development since the 1960s up to date.

This climate for adaptation along changing technological trajectories over time brought together different stakeholders, who had the need to collaborate ensuring a continuous flow of incentives or a third condition for innovation as follows.

Proposition 3. Large-scale real estate interventions facilitate the synergy among organisational spheres.

The institutional climate for innovation described above resulted from the ability of the regions to take advantage of- and to exploit the technological developments of their local innovative organisations. Reaching this climate demanded collaborative efforts among regional stakeholders in the three organisational spheres: governments, industry and academia. Most of the efforts took the form of incentives targeted to reach their shared vision on competitive advantage driven by innovation. The success in implementing such incentives relied largely in the synergy among the stakeholders in these three spheres to assuming and playing different and unconventional roles.

Universities, firms and governments have assumed multiple and complementary roles such as leaders, entrepreneurs, funders and promoters when implementing the different incentives (e.g. investing in research, creating firms and jobs, strengthening local networks, funding real estate development and marketing the region as a place to work, live and study). This synergy among organisational spheres functions as the activation energy required to carrying on the processes of knowledge creation and application in the entire system of the model.

This research demonstrates how a concerted agenda created synergy among organisational spheres that were able to play non-traditions roles to accomplishing their goal of stimulating innovation to remain competitive – i.e. depending on the context universities or governments assumed non-traditional roles as entrepreneurs and become increasingly proactive in the creation of firms and job opportunities. These empirical findings validate existing theoretical concepts outlining this required synergy and role-taking ability, such as the organising capacity of cities in the knowledge economy (Van Den Berg et al., 2005) and the triple helix relationships in regions (Etzkowitz, 2008).

Empirical evidence from the cases suggested that these interventions facilitated the synergy among the triple helix in three ways. First, these interventions were set up as ad hoc collaborations among different organisations aiming to encourage economic development. They involved long-term processes that demanded strategic alignment, agreements and commitments between the different organisations involved in such interventions. Second, this strengthened the relationships and trust among stakeholders in these organisational spheres, who worked together for decades pursuing mutual benefits. And third, developing these areas was a way to channel incentives (e.g. public and private investments) that work in retaining and attracting economic activities in each particular context and during different periods. In this regard, the development of flexible facilities played a secondary role facilitating the implementation of other incentives for innovation. For instance, re-using and adapting existing facilities when changing research programs and end-users over time may helped to channelling R&D investments to other targets rather than building new infrastructure. This research provided specific examples of adaptive re-use of functional buildings in both cases. Although the impact as cost saving resource was not measured in this research, some examples suggested this because in some case there was no need for further renovations in adapting these changes.

The synergy among stakeholders in different organisational spheres is the last of the interrelated demand-driven conditions facilitated by the built environment, which role as catalyst has been shaped by common organisational goals and core processes in local contexts.

Proposition 4. Location decisions and interventions supporting image and accessibility define the innovation area by emphasizing its distinct identity, scale and connectivity features.

The innovation area is the settlement hosting the concentration of innovative organisations and their activities. This settlement is defined by the spread of the concentration of certain innovative organisations in a certain territory (i.e. geographical and cognitive proximity among innovative organisations).

Depending on the spread of this concentration, the innovation area could be an urban area, the city, a metropolitan area, or the region. In this model, the innovation area functions as the geographical surface allowing face-to-face contacts among people working in organisations, whose primary processes are correspondent or complementary.

In this context, the spread of such concentration is defined by the geographic scale and connectivity of specific locations (e.g. innovative organisations locate in inner city or peripheral settings, which define the city or the region as the scales for such concentration. Likewise, these scales determine differences in the connectivity of these areas since inner city locations offer more variety of transportation modes than peripheral locations). Furthermore, unique features on both the geographic scale and the connectivity of these different settings give a unique identity to the innovation area, which sometimes represents the innovative organisations too (e.g. the valley, the hub, the roundabout, the road, the district, etc.). Thus, the innovation area is unique in each case (i.e. face-to-face contact among people is partly determined by the existence of unique site characteristics, natural features, provision of infrastructure, etc.).

The empirical evidence from the case study research demonstrates that the long-term presence of innovative organisations determined the identity of the innovation area. Similarly, their distinct settlement in relation to an existing infrastructure and geographic features determine the scale and connectivity of these areas. These findings suggest that location decisions in organisations might facilitate this condition for innovation regardless the fact that such decisions were shaped by other factors.

The case study research corroborates how the different identities, scales and connectivity of the areas in which innovative organisations locate have created favourable conditions for concentration but in varying degrees and changing over time. Peripheral locations were perceived as beneficial for R&D businesses in the past because of privacy reasons, transport and cost minimisation. The knowledge economy has diminished their importance. The access to people and amenities -provided abundantly in cities- is becoming more relevant for technology-driven organisations. Representation and building image has become more important for organisations located in peripheral rather than in inner-city settings. Cities have also changed with urbanisation and locations that were considered peripheral are now at the core of urban areas or close enough to take advantage of this condition.

The case study research outlined specific interventions that have defined the innovation area via supporting image and improving accessibility. The redevelopment and renewal of areas in both cases had the explicit intention to change the image of the area highlighting the character of specific innovative activities at different times (i.e. from industrial districts to high-tech and R&D sites). This supporting role is replicated on a smaller scale with the development of particular shared facilities benefiting the various organisations that have become landmarks and brands identifying its end users. Last, the development of physical infrastructure favouring walk-ability and the use of public transportation show a turn towards transit-oriented development rather than the use of cars to improve the accessibility of these areas. These interventions have contributed to improve the accessibility required for face-to-face contact according to the geographic setting of each innovation area. The effectiveness of this last type of intervention depends on the unique features of the location enabling accessibility within and beyond the innovation area. Developments in both, inner city and peripheral locations have emphasised the implementation of pedestrian oriented infrastructure (e.g. public space, bike-paths and landscape design) to improve the connectivity within the innovation area. However, in the inner city location this infrastructure is part of a larger transit-oriented development improving also the accessibility to the innovation area, while in the peripheral location this infrastructure is limited since the accessibility to the area is car-oriented.

These empirical observations build upon existing studies that outline -in a broad sense- that geographical proximity facilitates the other four dimensions of proximity as relevant for innovation because of its crucial role facilitating the flows of tacit knowledge by means of face-to-face interactions and collaborations among knowledge networks (Audretsch & Feldman, 1996; Boschma, 2005; Lagendijk & Lorentzen, 2007; McCann, 2007; Torre & Rallet, 2005). Those studies emphasising the importance of multiple spatial scales and the roles of transportation and mobility infrastructure in their approaches support this proposition.

The identity, scale and connectivity of the innovation area is directly determining a second supply-driven condition, which is controversial in the theoretical debate about the geography of innovation and the role of cities as engines for growth.

Proposition 5. Real estate interventions enabling the access to amenities increase the diversity of people & density of social interactions regardless the distinct geographical settings in which the concentration of innovative activities takes place.

Diversity of people and ideas is believed to facilitate the processes of knowledge creation and its application leading to innovation in cities and regions. This condition has an important social component because knowledge sharing and idea generation are strongly tied to social interaction and trust developed among innovators through frequent interaction (i.e. socially proximity). The more amenities, the more mix of uses and then, the more chances for interactions that can generate ideas and knowledge spillovers. Furthermore, providing sufficient and varied amenities increases the attractiveness of a location for individuals and organisations next to other quality of living indicators. Thus, this condition functions as an invisible force that allows frequency of collisions or accidental encounters among people concentrated in the innovation area.

This condition differs according to the geographical setting in which innovative activities concentrate (i.e. inner city or peripheral locations determine differences in population, density of amenities and thus, the diversity of people). Accordingly, cities are recognised as natural sources of innovation because the abundance of these aspects. The empirical evidence from the cases studied, which locate in different settings, supports that indeed this condition differs between peripheral and inner city locations. More amenities as well as more diversity of people are found at the scale of the city compared to the region. These findings support the theoretical viewpoints that see cities as engines of growth, creativity and innovation because of the diversity of people, ideas and functions inherent to urban areas (Florida, 2002, 2008; Glaeser et al., 1992; Jacobs, 1961; Pentland, 2014; Van Den Berg et al., 2005). However, both environments (i.e. peripheral and inner-city) have provided favourable conditions for innovation overcoming unique challenges about these aspects in different ways.

The concentration of innovative activities studied in the peripheral location showed that the lack of amenities and diversity of people is compensated by concentrating functions in central facilities in particular areas (e.g. R&D parks). The distribution of the amenities and diversity of people becomes limited to these areas strengthening their isolated identity. This can decrease the attractiveness of these areas for particular people and organisations. The main challenge for this type of locations is to improve their integration with nearby cities using efficient connectivity.

The concentration of activities studied in the inner city location showed this area has abundant amenities as well as more diversity of functions and people compared to the peripheral location. However, the limited space in urban areas poses challenges concerning affordability and congestion. These issues can be detrimental to innovation because they can drive away key actors of the knowledge network and decrease the attractiveness of the innovation area in the long term.

These findings reinforce the important role of the social dimension for knowledge networks and the need for controlling its advantages and associated problems for learning addressed in economic geography (Boschma, 2005; Boschma & Frenken, 2010).

Studying the developments of campuses revealed a combination of real estate interventions facilitating this condition for innovation worked in different ways depending on their respective peripheral or inner city location. For example, the concept of mixed-use in shared facilities was implemented when redeveloping areas in both cases. This allowed to accommodate a functional mix ensuring diversity of people under one single roof and more chances for social interaction However, the implementation of this concept varied in its distribution from centralising all functions in one shared facility in the peripheral campus, to spreading different functions in various shared facilities in the inner city campus. The degree of these interventions facilitating the diversity of people varied per location. In the peripheral campus, the central facility became exclusive for campus end-users because of the lack of neighbours in their vicinity. Only in case of temporary events (i.e. conference, congress, symposia, etc.), these facilities enable the diversity of external users. In the inner city campus, the distribution and use of shared facilities within and beyond the campus allowed the use of end-users and citizens at large, because there are no formal boundaries between the campus and the city.

A similar pattern occurs with the development of physical infrastructure (e.g. indoor and outdoor paths) connecting the different functions on campus and allowing different opportunities to have more and diverse people under one single roof with chances for interaction. For instance, the physical connectors in the peripheral campus enabled diversity of people and density of social interaction by connecting the shared central facility with the rest of the campus through landscape design and an internal system of outdoor pathways for pedestrians and bikes. Conversely, the physical connectors in the inner city campus facilitated this condition by giving (indoor or outdoor) continuity to the transit-oriented system of the city through the campus (e.g. pedestrian paths, bike-lanes, bus and subway corridors). The indoor continuity of pedestrian paths through the campus' facilities is a unique intervention in this case because it keeps a continuous flow of people moving- and information displayed in different facilities that accommodate mixed uses. In this case, physical connectors become not only channels that increase the opportunities to meet diverse people but also to keep people informed.

In this context, these findings outline that the geographic setting of the innovation area shapes the ways in which specific real estate interventions can facilitate the diversity of people and density of social interaction required for innovation. Indeed, these findings pose some questions about the rise of the so-called 'innovation districts' and a stream of research underestimating the potential of peripheral locations for innovation. This research has shown that both peripheral and inner city locations provide enough diversity of people distributed in a different way. However, the two cases studied here represent only two of the five different types of locations categorised in this research according to the formal and functional relationship between campuses and cities described in Chapter 3 (e.g. Equals, Disjoints and Touches as peripheral locations and Contains and Overlaps as inner city locations).

The progression of these typologies from more peripheral to more inner city may represent degrees of diversity of people and density of social interaction in the concentration of research activities. Since the cases studied do not represent completely the extremes of both inner city and peripheral locations, the question remains how peripheral or inner city is the optimal location for concentrating innovative activities? This research has shown that peripheral areas, which are not completely isolated, have opportunities to explore and to improve this condition. Similarly, it has also shown that inner city locations are facing other types of issues that can harm innovation in the long term [See §6.4]

§ 8.2.4 Discussion

The knowledge developed above builds upon the existing knowledge that focuses on the contribution of real estate to organisational performance (i.e. the fulfilment of organisational goals according to the judgement of various stakeholders and their perspectives on real estate) within a larger research field called corporate and public real estate management (CREM/PREM). Previous studies in this field identified different aspects of organisational performance through which real estate strategies can be aligned to organisational strategies (e.g. Costs, Real estate value, Risk control, Flexibility, Productivity, Users' satisfaction, Image, Innovation, Culture and Sustainability). The present research explores innovation as an aspect of organisational performance in the practice of campus development, which has been intended to accommodate technology-based research activities. Developing knowledge in this field by studying both, the practice of campus development and innovation as an aspect of organisational performance, made this research a complex one while revealing an emergent perspective in the CREM/PREM field.

First, most studies in this field focus on specific activities in the practice of real estate management at the scale of the building and/or portfolio (e.g. developing real estate strategies, developing building projects and/or maintaining and managing the built space in the portfolio of an organisation). Studying the practice of campus development using the CREM/PREM approach challenged this research because it addresses other activities besides campus management at portfolio level (i.e. campus planning and campus design at the scale of the urban area). Indeed, campus development was studied as a process of accommodating the activities of innovative organisations while transforming specific places over time. This process involved real estate decisions and interventions in different phases of the accommodation cycle (i.e. initiation, preparation, realisation and use) in specific spatial contexts (i.e. the city and/or the region). Thus, this research builds upon a least explored application scale of core concepts in the CREM/PREM field, which expands its empirical scope from activities at building and/or portfolio levels towards activities in the urban domain.

Second, most of the existing empirical studies in this field focus on a specific type of organisations, from which organisational performance can be easily defined within the boundary of specific real estate end-users (e.g. higher education institutions, firms in specific businesses, governmental agencies, etc.). However, not all real estate objects are the exclusive resources of a single type of organisations as end-users. Recently, the accommodation process of organisations is growing in complexity while challenging the CREM perspectives since built environments -especially at the scale of urban area- are developed and used by multiple and changing organisations with different core processes and objectives. Undoubtedly, technology-campuses are good example of 'hybrid' real estate objects from the CREM/PREM perspective since their developments involve the objectives and accommodation processes of multiple and different organisations (e.g. universities of technology, research institutes, R&D firms and municipalities and/or regions). Indeed, these organisations have different values and cultures but a similar driving force that resides in the creation of new knowledge and its application to develop new technologies in order to remaining competitive in the knowledge economy. In this context, this research demonstrates that the contribution of real estate to organisational performance can be studied simultaneously in multiple areas if organisations have common driving forces. Therefore, this research suggests that the knowledge developed in the CREM/PREM field is versatile and can be applied to multiple areas depending on a specific driving force studied. This is especially important because the driving forces in organisations may change over time according to developments influencing the contexts in which they operate.

Third, most of the studies building knowledge on this field studied the contribution of real estate to organisational performance from a broad perspective through different but interdependent real estate strategies or added values. In fact, by attempting to isolate innovation this study ratifies its interdependence to other aspects of organisational performance such as image and users' satisfaction. This is demonstrated by real estate interventions identified in this research as catalyst for innovation and simultaneously supporting image and or increasing users' satisfaction or quality of place. For example, developing shared- and flexible facilities can facilitate the required diversity of people and density of social interaction for innovation because they allow accommodating different functions and users and thus, increasing the chances for collisions. Simultaneously, the same interventions enable the provision of amenities that can increase the attractiveness of a place for its end-users (individual and organisations). In this context, this research suggests that a single real estate intervention has the potential to impact multiple aspects of organisational performance that may be linked among each other. Thus, organisations that focus on stimulating innovation should consider the potential of supporting image and increasing users' satisfaction strengthening each other's impact on organisational performance (i.e. the combined effect of real estate strategies).

Last, when attempting to measure the effect of real estate on innovation, the existing research in this field points out to decisions and/or interventions that focus mostly on workplace design. That is because most of these studies relate innovation to users' processes such as learning and/or knowledge sharing and at building or portfolio level. However, this research has demonstrated that there are more perspectives on innovation brought by the complexity of accommodating these processes in today's knowledge economy. Indeed, attracting, retaining and inspiring knowledge workers are as important as enabling them to create and share new knowledge. In this context, this research suggests that location and the provision of amenities are powerful real estate decisions when it comes to stimulate innovation in campuses. In clarifying the path to attain organisational goals through real estate, this research identifies a number of real estate interventions that can be seen as implemented choices of real estate decisions (e.g. transforming areas, developing and adapting flexible facilities, implementing shared facilities and physical infrastructure connecting functions). These empirical findings are illustrated in Figure 8.5.

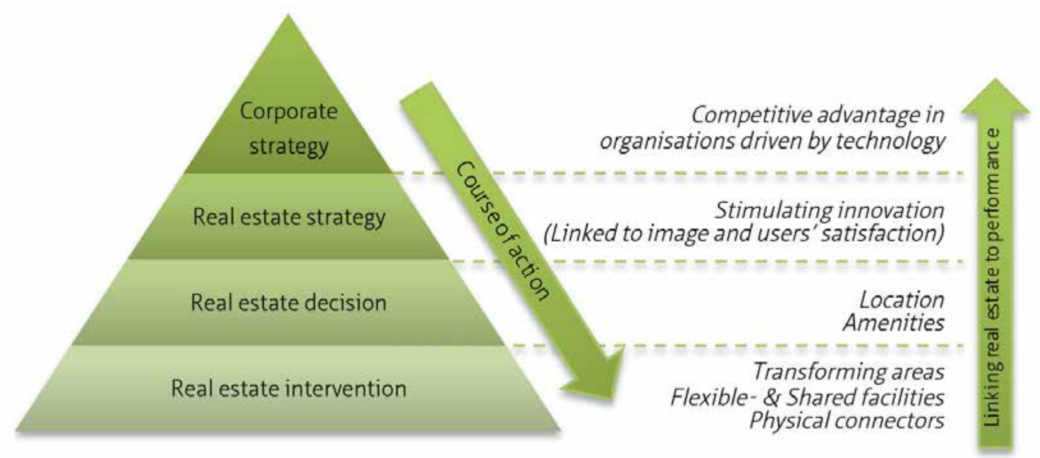


Figure 8.5 Path to attain organisational goals through real estate by studying the practice of campus development and innovation as an aspect of organisational performance

Although this path seems to be straight in theory, setting real estate strategies that guide decisions is easier than implementing them in practice. Indeed, this research shows how the different perspectives on innovation by the multiple stakeholders making campus decisions can generate conflicts, which in turn have the risk to inhibit the role of the built environment as catalyst for innovation. This is demonstrated when implemented choices that do not integrate and/or balance these different views on innovation. Accordingly, this research suggests that the four CREM perspectives and CREM domains can be used to identify the different views on innovation and finding out the possible ways to integrate them in implementing real estate strategies respectively.

When linking these real estate interventions to organisational performance in practice, this research suggests to use the conditions in the model to derive key performance indicators (KPIs) according to the relationship between the built environment and innovation suggested in this model. Figure 8.6 summarises key performance indicators that technology-driven organisations can use to measure the long term impact of real estate in their competitive advantage when stimulating innovation. The link of innovation with image and user's satisfaction as interdependent aspects of organisational performance becomes evident when looking at the KPIs derived from these conditions.

Generally, this research have demonstrated how the specific geographic settings in which organisations decide to locate (e.g. inner city and peripheral locations) have influenced the ways in which real estate choices are implemented in technology campuses. Decision makers of campuses and similar built environments have a challenging task in effectively stimulating innovation through the built environment. This requires not only skills but also knowledge on the complexity of planning, designing and managing these built environments while involving the objectives and accommodation processes of multiple and different organisations. The following section provides information to support real estate decisions in the practice of campus development and similar built environments.

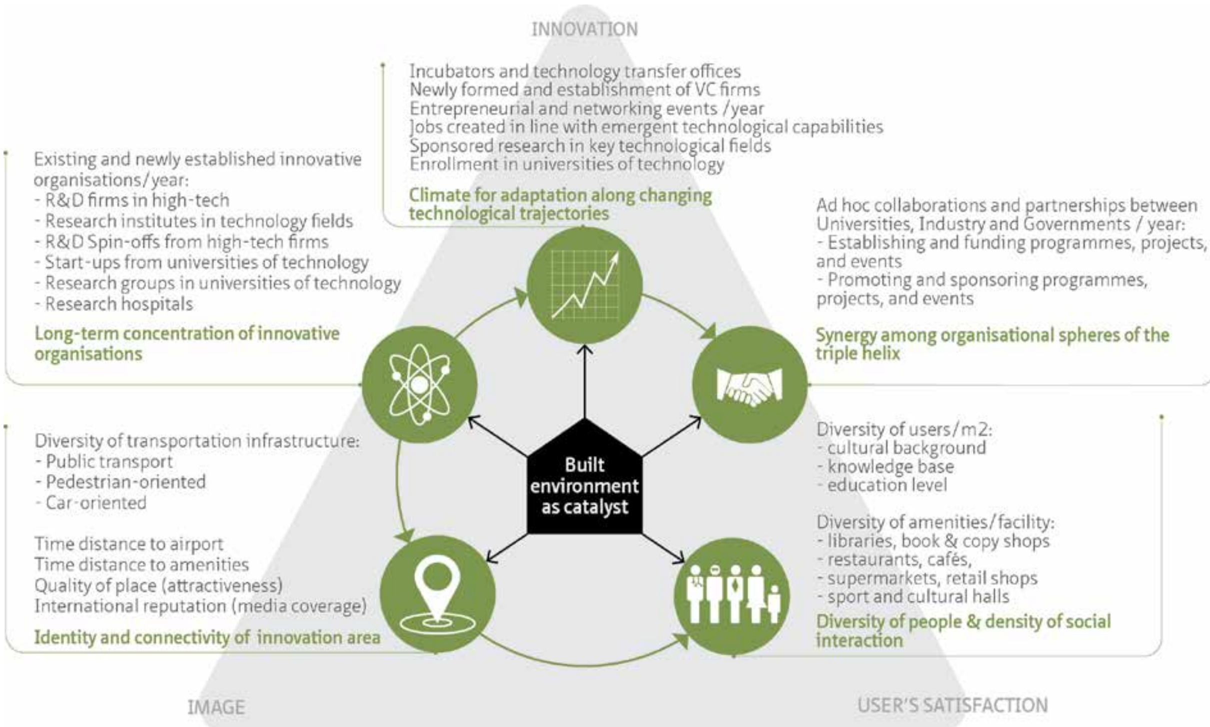


Figure 8.6 Summary of key performance indicators for campus development linked to three aspects of organisational performance leading to competitive advantage in technology-driven organisations.

§ 8.3 The campus decision-maker toolbox

This section provides insights for stakeholders making decisions in the development process of different types of technology campuses. These insights add to the body of information available to decision makers in this practice, which is relevant because decision makers often rely on limited information, time constraints and other pressures (i.e. bounded rationality). Thus, the knowledge developed in this research has been converted into information that can be useful for campus decision makers involved in planning, designing and/or managing these built environments.

§ 8.3.1 The need for campus-specific information

The results of this research has outlined the complexity of developing technology campuses since it involves the objectives and accommodation processes of multiple and different organisations in unique places. Indeed, it is not new that in problem solving (and/or problem setting) practitioners deal with uncertainty, uniqueness, instability and value conflict (Schön, 1983). Thus, the knowledge developed in this research is integrated in this section with the aim to helping campus decision makers to dealing with such complexity. Therefore, this research provides a toolbox to inform campus decision makers who aim at stimulating innovation through the built environment.

A so-called campus decision-maker toolbox is a repertoire of information organised in three tasks targeted to different decision makers and in different stages of the accommodation cycle of the campus development process. Accordingly, this tool describes campus categories and exemplars of campus interventions helping to build repertoires, which these practitioners can bring to unique situations. These repertoires accumulate exemplary decisions taken by specific professionals. For instance, the empirical information that emerged from the cases seems to be useful to planners, designers and managers of both campuses and cities. As a result, the information collected in this toolbox is depicted in a way that is useful for different campus decision-makers and they ways they approach a situation[181]. Overall, the usefulness of this toolbox depends on the linkages between context, outcome and actions clarifying the path to attain organisational goals (i.e. stimulating innovation) through the built environment.

§ 8.3.2 Information to support decisions in technology campuses

The campus decision-maker toolbox proposes three tasks for specific professionals in the practice of developing technology campuses (planners, designers and managers). Similarly, a tool with specific information is provided to accomplish each of these tasks and targeted to strengthen the link between the built environment and innovation through specific products containing campus decisions (e.g. campus vision, campus brief and campus strategy). As shown in Figure 8.77, each of these tasks and its respective tool is key at specific stage of the campus development process as seen in this research. These tools and their usefulness to specific decision-makers are described as follows.

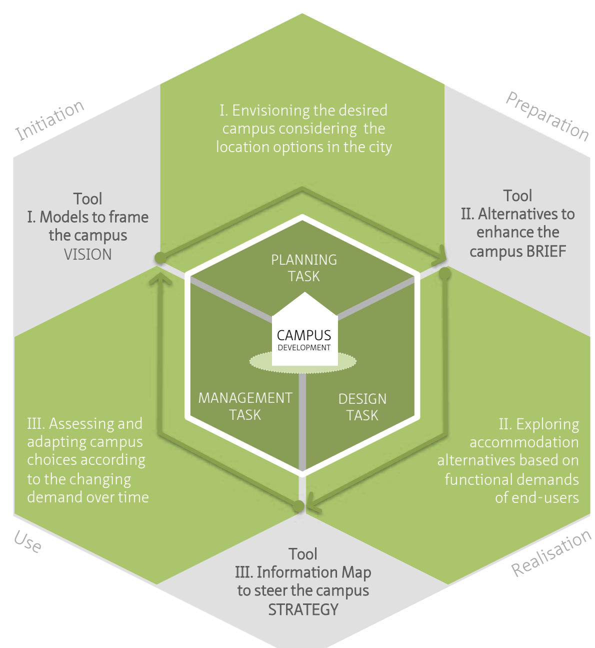
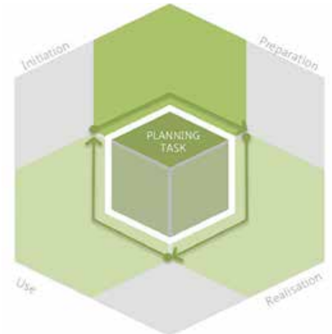


Figure 8.7 Campus decision-maker toolbox ((Information to support decisions aimed at stimulating innovation in technology campuses)

181 This researches framed these recommendations by using an approach called reflection-in-action (Schön, 1983) that outlines 'repertoire-building research' as one of the types of researches likely to be useful to practitioners. Thus, this research considers the core concepts addressed by the author on how professionals such as planers, designers and managers think in action (i.e. know-how when setting or solving problems).

Tool I. Models to frame the campus vision.



This tool contains information useful to campus and city planners involved in the development of technology campuses. Their main task (i.e. Planning task) as proposed in this research is envisioning the desired campus considering the location options in the city. This task is key during the initiation stage of the accommodation cycle of campuses when ideas and development goals are framed. Indeed, the planner's know-how system deals with framing goals and imagining a desirable future, while identifying alternative strategies to take action and the consequences of such actions. Hence, this tool suggests two models based on facts in which planners can frame their goals for the desired campus.

In the case of technology campuses, pursuing the built environment that best accommodates the creation and application of new knowledge is the planners' mission. This research has demonstrated that attracting, retaining and inspiring the people who perform innovative activities (organisations and individuals) is central in the process of knowledge creation and its application, which can be facilitated by the built environment. Accordingly, two crucial decisions need to be considered by planners in pursuing their mission: location and access to amenities. Indeed, providing easy and quick access to other functions besides working environments is vital in planning these built environments (e.g. leisure, housing, shopping, etc.). The location of the campus in relation to the city will determine the access to amenities that are attractive for knowledge workers (e.g. the location determines the amount and distribution of amenities provided in campus). The advantages of locating in- or close to inner city areas are evident since the provision of amenities is abundant in cities compared to peripheral locations. However, since location decisions are not always the result of a choice, connectivity becomes an important aspect in campus/city planning because the access to amenities is determined by the travelling distance from the campus to specific functions available elsewhere. The connection of the campus to main transportation nodes and hubs provided by the hosting city/region is an important issue in peripheral settings. In both cases, the planning of the desired campus needs cooperation between campus end-users (innovative organisations) and municipal or regional authorities.

In this context, the inner city or peripheral location of a campus matters when shaping the vision of the desired campus because other campus interventions will be determined by this decision. Furthermore, the location will determine a boundary for planning partners necessary to attain the vision of the desired campus. Based on the diverse reality of technology campuses in terms of location and these insights, this research provides two campus models that can be used by planners to frame their goals and visions of the future [See Table 8.1]. Accordingly, these two models are distinguished because of either the peripheral or inner city characteristics of their locations. Indeed, these two models comprise in total four types of campuses categorised by their formal and functional relationship with the city[182]. These typologies are positioned in a scale that ranges from more peripheral to more inner city - i.e. Disjoints (1); Touches (2); Contains (3); and Overlaps (4). These two campus models have the ability to nurture liveable environments for innovation as described as follows.

182 Chapter 3 identifies five types of location characteristics categorised by the formal and functional relationships between campus and the city (i.e. Equals, Disjoints, Touches, Contains and Overlaps). The first two types are merged into one so-called Disjoints since their main difference is the scale of the development, which is not relevance for the purpose of this tool.

	CAMPUS MODELS *DESIGNATION*	**Campus as the city** ***Tech-park***	**Campus in the city** ***Tech-district***
LOCATION CHARACTERISTICS	Setting	Peripheral 	Inner-city 
	Types of campus-city relationship	Disjoints (1) & Touches (2)	Contains (3) & Overlaps (4)
	Geographic scale	Region	City
CONNECTIVITY	Distance to urban area with sufficient amenities	Over 30 minutes (Public Transport*) *Less frequent schedules	Within 15 minutes (Public Transport^) ^More frequent schedules
	Travelling distance to international airport	Over 40 minutes (Public Transport*) *Less frequent schedules	Within 40 minutes (Public Transport^) ^More frequent schedules
	Primary transportation mode	Car-oriented	Transit-oriented
PLANNING FRAME	Choices for the desired campus	Provision of enough amenities in campus and effective connectivity to cities	Balancing the provision of amenities between the campus and the city
	Key partners	State-Provincial authorities	Municipalities
	Consequences for the city	The concentration of innovative activities can shape the growth of cities and urban development towards those areas.	The concentration of innovative activities can lead to an increase of real estate and rental prices of the urban land in the vicinities of campus

TABLE 8.1 Models to frame the campus vision by the planner.

The Tech-park: campus as the city model

The so-called 'Tech-park' is a campus model in which planners can frame their objectives when the desired campus is located in peripheral areas. This model comprises technology campuses, which locations' characteristics are identified in this research as 'Disjoints' and 'Touches' [See Figure 8.88]. Existing campuses in these categories accommodate research activities that were meant to be concentrated outside cities. Indeed, their isolated formal and functional condition from cities has not changed regardless the urbanisation process. Thus, this model has the region as the geographical scale in which the concentration of innovative activities is perceived. Similarly, the regional authorities are key stakeholders for attaining the desired vision of the campus.

In attracting, retaining and inspiring knowledge workers, the strategic choices for this model are providing enough amenities in campus and effective connections to those functions available elsewhere. In practice, Tech-parks are referred to as research silos. Indeed, the provision of amenities of amenities in campus might strengthen this perception. However, it can be the case that the activities accommodated in these built environments require isolation and/or the need to provide the required amenities in campus. However, this does not mean they are sterile environments for innovation. Indeed, the concentration of innovative activities in peripheral areas can shape the growth of cities and urban development towards their locations if the impact of such activities is relevant for the economies of their hosting city/region.

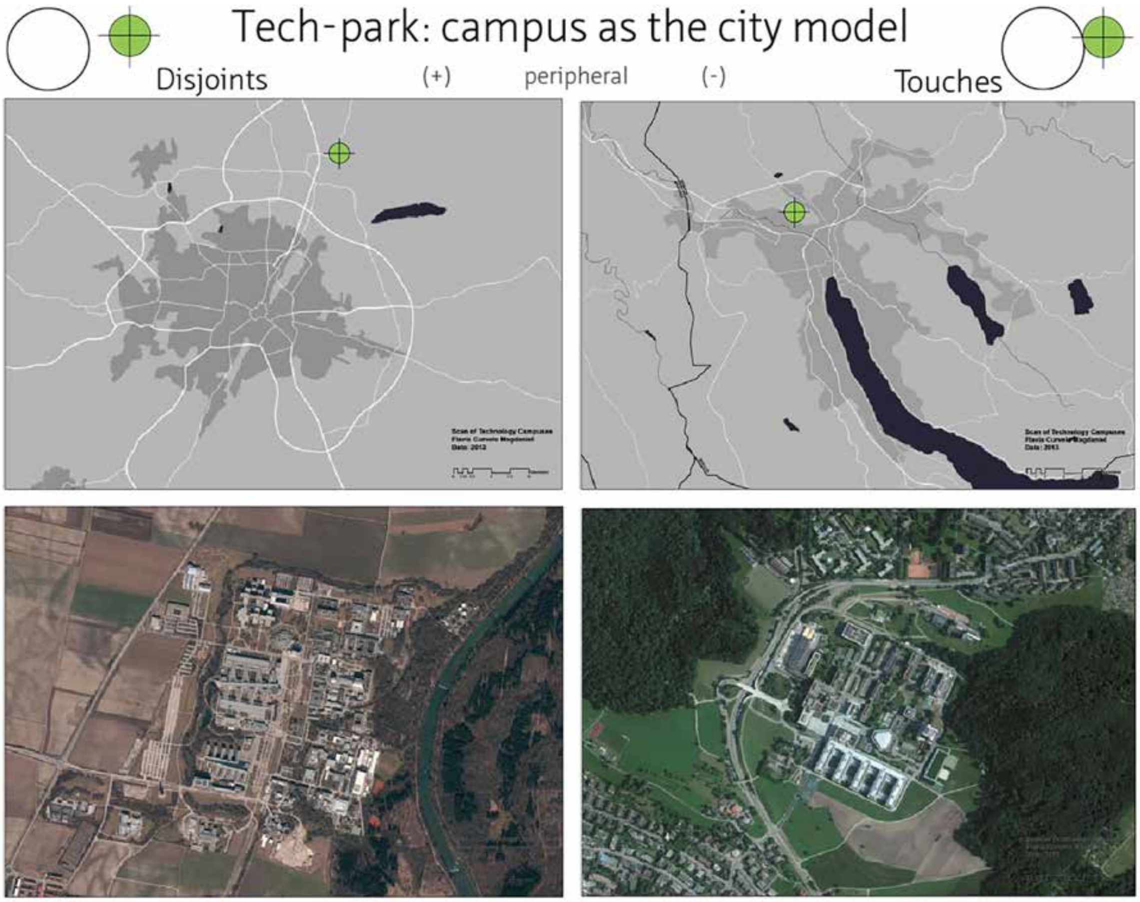


Figure 8.8 Examples of existing technology campuses that can be potentially framed into the Tech-park model. Left: Research Campus Garching, Technical University of Munich in Garching, Munich Metro Region (Germany). Right: ETH Hönggerberg Science City in Zurich (Switzerland).

Tech-district: campus in the city model

The so-called 'Tech-district' is a campus model in which planners can frame their objectives when the desired campus is located in inner city areas. This model comprises technology campuses, which locations' characteristics are identified in this research as 'Contains' and 'Overlaps' [See Figure 8.99]. Existing campuses in these categories accommodate research activities that were perhaps meant to be concentrated outside cities but their former isolated formal and functional condition from cities has changed with the urbanisation process. Thus, this model has the city as the geographical scale in which the concentration of innovative activities is perceived. Similarly, municipalities are key stakeholders for attaining the desired vision of the campus.

In attracting, retaining and inspiring knowledge workers, the strategic choices for this model are providing a balanced distribution of amenities in campus according to those available in the city and a suitable integration between both formal and functional systems. In practice, Tech-districts are mostly perceived as vibrant locations because of their inner city location but it is not the case in all campuses. Indeed, the formal and functional integration of some campuses with their urban surroundings is not achieved regardless their location characteristics. This point deserves attention especially for those campuses that still have physical boundaries while seeking integration (e.g. fences or road infrastructure barriers blocking the flow between the campus and the urban fabric). However, it can be the case that the activities accommodated in these built environments require a controlled integration because of the diversity of functions and people cities offer. Indeed, concentration of innovative activities in Tech-districts can lead to an increase of real estate and rental prices of the urban land in their vicinities if the impact of such activities is relevant for the economies of their hosting city/regions.

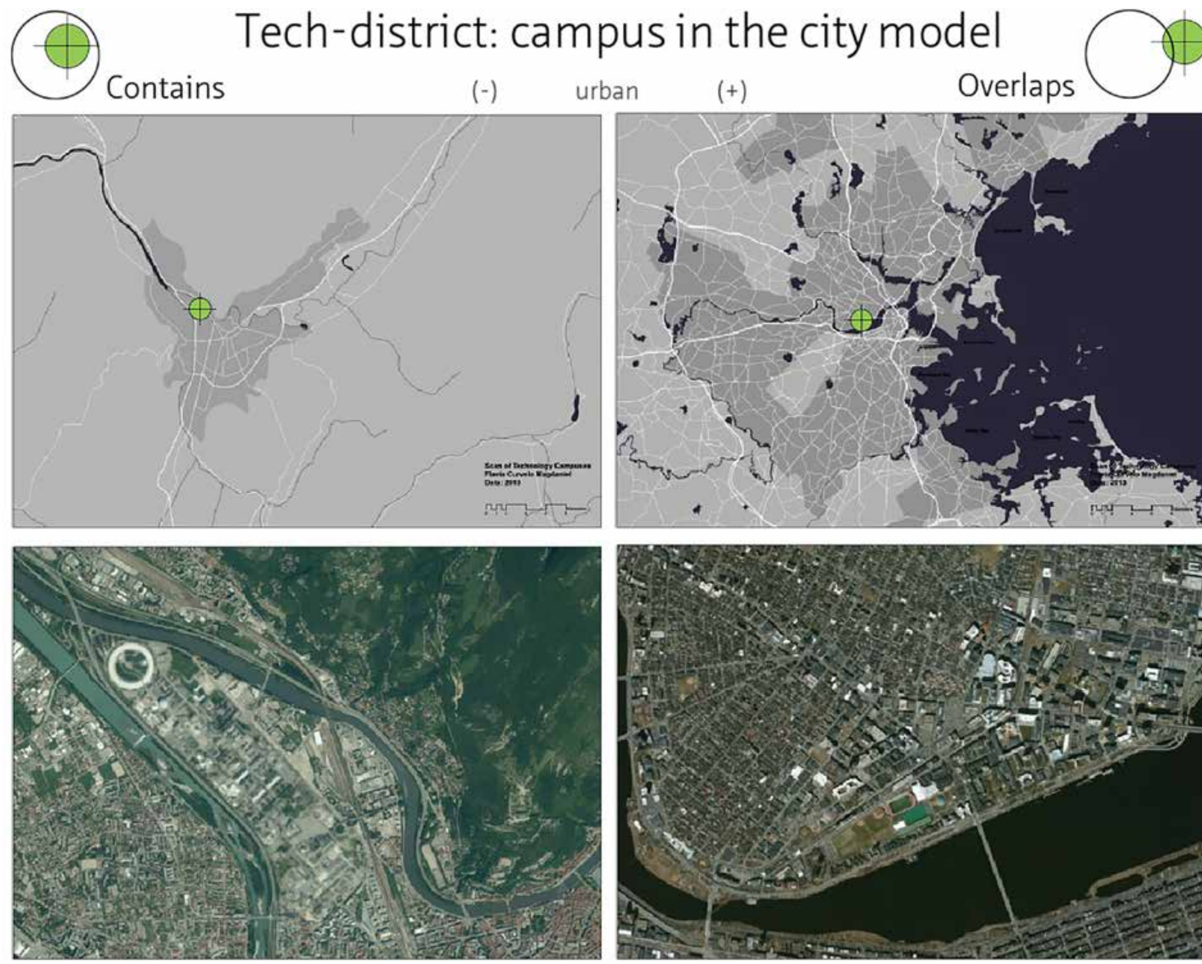
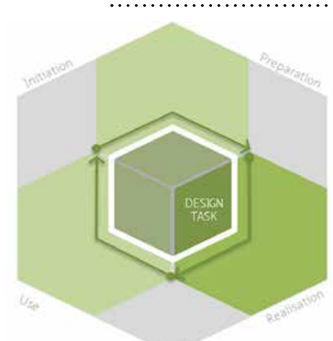


Figure 8.9 Examples of existing technology campuses that can be potentially framed into the Tech-district model. Left: GIANT Innovation Campus (Grenoble Innovation for Advanced New Technologies) in Grenoble, Isère, Rhône- Alpes (France). Right: MIT campus (Massachusetts Institute of Technology) in Cambridge, Massachusetts (the United States of America).

Tool II. Alternatives to enhance the campus brief



This tool contains information useful to campus and urban designers involved in the development of technology campuses. Their main task (i.e. Design task) as proposed in this research is exploring accommodation alternatives based on the functional demands of end-users. This task is key during the preparation stage of the accommodation cycle of campuses when ideas take shape in built forms. Indeed, the designer's know-how system is iterative and deals with exploring, making and testing new models of a situation by using past experiences. Thus, this tool provides a repertoire of experiences that designers can use as models to reframe similar situations.

In the case of technology campuses, facilitating the core processes of campuses' end-users is where the designer's skill is challenged in attaining the physical campus. Indeed, in getting the physicality of 'stimulating innovation' campus designers must explore what end-users actually do in campus to innovate. This research has outlined the processes of knowledge creation and its application as central for innovation. From the end-users' perspective, innovation can be seen as a learning process driven by the exchange of ideas. Indeed, end-users of technology campuses carry-on these processes mainly by doing research and by interacting with other people. In other words, people (within- and across organisations) learn in campus by working and socialising. Accordingly, the types of activities that designers can facilitate in campus are distinguished as working- and non-working activities. For both types of activities, especially for the last, physical proximity is essential.

On the one hand, working activities in technology campuses involve individual- and team research (e.g. learning, experimenting, meeting, concentrating, networking, producing, etc.). Thus, the types of space that best facilitate working activities for innovation are those enabling intellectual interaction (e.g. offices in team and individual settings, labs, meeting rooms, conference rooms and libraries). On the other hand, non-working activities in technology campuses support the different individual- and group needs (e.g. eating, drinking, relaxing, meeting, sporting, playing, etc.). Therefore, the types of spaces that best facilitate non-working activities for innovation are those enabling social interaction (e.g. restaurants, cafés, bars, shops, public space, circulation paths, corridors, sport facilities and other amenities).

In this context, a physical campus stimulating innovation seems to be a mixed-use campus that encourages different types of interactions through the provision of facilities that accommodate working and non-working activities. Experiences from the empirical world in two types of technology campuses suggest three interventions in which design could facilitate these activities: (1) enabling encounter and meeting via sharing facilities; (2) formal and functional transformation via flexible facilities; and (3) accessibility to functions via physical connectors. Accordingly, these three interventions have demonstrated to support the accommodation of working and non-working activities in the two technology campuses studied in this research.

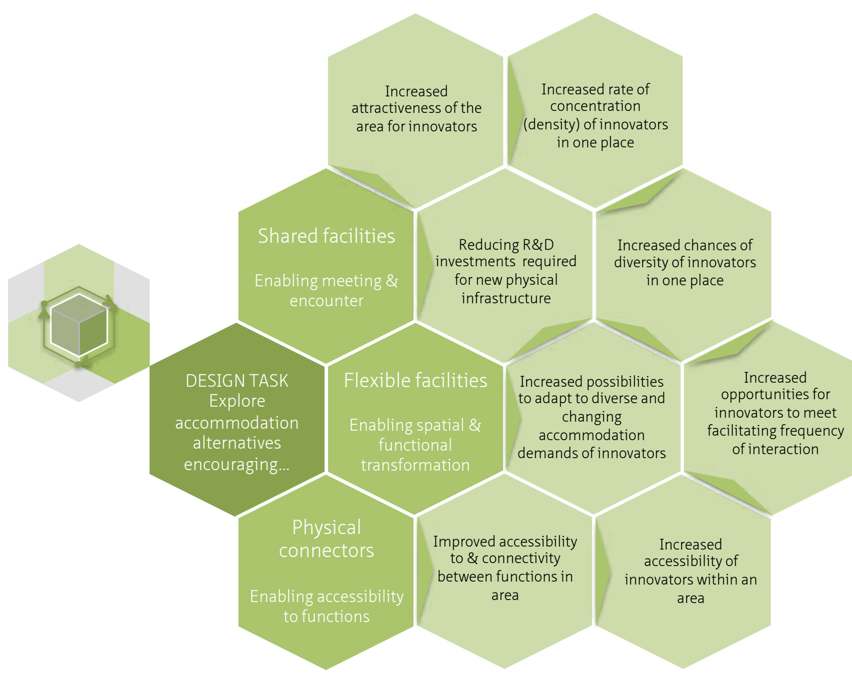


Figure 8.10 Cloud describing the paths through which three design interventions facilitate the accommodation of working and non-working activities of end-users in technology campuses.

Figure 8.10 illustrates the pathways through which this happens and how each of these interventions strengthens each other's impact. For instance, each of these interventions contributes in different ways to increasing the opportunities for people to meet and thus, facilitating the frequency of potential intellectual and/or social interaction. However, the combination of these three interventions increases their effectiveness in supporting the end-users' activities required for innovation. Furthermore, some of these interventions might facilitate innovation by having effects in other aspects besides the users' perspective (e.g. developing flexible and shared facilitates can reduce R&D investments required for physical infrastructure).

Although designers can use these interventions to facilitating activities in technology campuses, the ways in which they are implemented vary from Tech-parks to Tech-districts. Accordingly, this study suggests different alternatives to be explored in each of these interventions according to the campus model. For instance, designers should consider crucial determinants when shaping the physical campus for innovation. Table 8.2 provides a summary of these determinants in each of the three interventions per campus model, which will be discussed as follows.

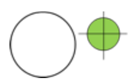
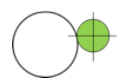
	CAMPUS MODELS	Campus as the city *Tech-park*	Campus in the city *Tech-district*
	Location setting	Peripheral  	Inner-city  
SHARED FACILITIES	**Repertoire of workspaces and amenities supporting end-users' activities and processes**		
	Amount	Single (for mixed-use facilities)	Multiple (for mixed-use facilities)
	Use	Mostly exclusive	Non-exclusive (for mixed uses facilities)
	Distribution	Central / Easy access within campus area	Spread / Along campus urban axis
FLEXIBLE FACILITIES	**Repertoire of design languages/concepts enabling change in the accommodation of end-users' activities**		
	Shape & structure	Allowed by regulations in peripheral land (loose building)	Allowed by regulations in urban land (tight building density)
PHYSICAL CONNECTORS	**Repertoire of physical infrastructure connecting functions (activities and end-users)**		
	Configuration	Centralised network (connecting campus parts to specific central nodes).	Distributed network (connecting multiple nodes distributed in campus & city)
	Distribution	Campus fabric (internal logic)	Campus-City fabric (internal/external logic)

TABLE 8.2 Alternative interventions to enhance the campus brief per campus model

Shared facilities

Accommodating the (working and/or non-working) activities of end-users in shared facilities enables the concentration of many and diverse people in one place. This increases the chances for meeting and encounter among people, who might be willing to share ideas and knowledge. Indeed, having mixed uses in shared facilities increases the chances for both intellectual and social interaction among diverse groups of people. However, not all campus activities require the same amount or type of interaction and therefore, this study do not suggest developing every single facility in campus as a shared one. Instead, this research provides a repertoire of workspaces and amenities that can be considered as alternatives in the development of shared facilities in technology campuses [See Table 8.3].

As shown in Table 8.2, the amount, use and distribution of shared facilities varies between Tech-parks and Tech-districts especially for those accommodating mixed uses. For instance, the peripheral setting of Tech-parks requires the recreation of lively areas within the campus boundary. In the case of accommodating mixed-use, a single and central shared facility might be more appropriate to enable density and diversity of people, which are limited to campus end-users and eventual visitors. On the contrary, the inner city setting of Tech-districts provides sufficient concentration of functions and people –especially for those fully integrated in the urban fabric. In the case of accommodating mixed-use, multiple shared facilities can be distributed between the campus and the city to balance the existing density and diversity of people, which are not exclusive to campus end-users. The repertoire of spaces with their considerations for each campus model is summarised in Table 8.3 and Figure 8.11.

	CAMPUS MODELS	Campus as the city *Tech-park*	Campus in the city *Tech-district*
SHARED FACILITIES	Location setting	Peripheral	Inner-city
	Repertoire of spaces supporting end-users' activities related to innovation as a process		
WORK SPACE FOR MULTIPLE USERS (e.g. Office and laboratory facilities for researchers)	Open office for start-ups (1-3 people company) Flex & ready to use multidisciplinary lab space Flex Meeting-conference rooms Flex Team rooms Work lounges – coffee corners Brainstorm rooms Libraries – Study rooms Break areas - Game rooms Print / Copy areas Waiting areas	• Exclusive for internal campus users (magnet for tenants) • Possibility to work in collaboration with regional authorities to develop & manage facilities	• Open to external users besides campus users • Possibility to work in collaboration with municipalities and urban partners to develop & manage facilities
AMENITIES FOR MULTIPLE USERS (e.g. Mixed-use facilities, special facilities and open spaces for retail and leisure)	Restaurants, Cafés, Bars, student clubs Food- drink terraces at street level Shops (book stores, services, supermarkets, banks, etc.) Auditoriums – large halls for networking events Mobile Food tracks Fitness and sport courts Open space for temporary events (squares for exhibitions, outdoor cinema, sports competitions) Periodical markets (food, flea market, books, music, etc.)	• Central mixed-use facility with easy access by foot within campus area • Open to external users at regional and city levels • Use of green and open areas in public space -Possibility to work in collaboration with regional authorities to develop & manage facilities	• Multiple mixed-use facilities spread in nodes across the campus network of buildings • Open to external users at city and neighborhood levels • Use of public space along campus urban axes • Possibility to work in collaboration with municipalities to develop & manage facilities

TABLE 8.3 Alternative shared facilities with considerations per campus model

Figure 8.11 Example of alternative shared facilities per campus model. Each campus model has a range of geographic- and organisational scales defining the exclusive or non-exclusive use of shared facilities and potential partners for developing the campus

Flexible facilities

Accommodating the different types of activities of campus' users in one facility requires formal and functional flexibility. Indeed, developing flexible facilities increases the possibilities to adapt the form and function of these facilities to the diverse and changing accommodation demands of campus end-users. In this view, developing flexible facilities increases the chances to have different users in one place and then, the opportunities for them to meet and to interact. In this context, flexibility can be the channel for designers in their conversation with the materials of stimulating innovation.

This research suggests a repertoire of design concepts enabling change in the accommodation of end-users' activities in two types of facilities. These are functional buildings and horizontal buildings [See Table 8.4]. The first type results from an architectural movement dominated by the efficient realisations of both, the program of requirements (functionalism) and architecture as a material structure (rationalism). The second type is the particular shape of most functional buildings found in this empirical research. Indeed, shape is determinant enabling flexibility and change in campus facilities. However, the possibility to fully explore the shape of flexibility varies between Tech-parks and Tech-districts. For instance, these types of facilities required space that is not always available in inner city locations. Indeed, inner city areas can be more restricted in terms of land use and building permits. On the contrary, peripheral locations can be exploratory settings for designers since the immediate contexts of Tech-parks are hardly built. Thus, natural features become more important in shaping the physical campus for innovation; where as large footprint becomes an environmental issue.

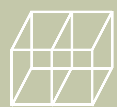
	CAMPUS MODELS	Campus as the city *Tech-park*	Campus in the city *Tech-district*
FLEXIBLE FACILITIES	Location setting	Peripheral	Inner-city
	Repertoire of design concepts enabling change		
Functional buildings 	Modular structure with standardized dimensions (e.g. framed system with light and non-structural partitions)	• Free setting for designers due to autonomy from immediate context.	• Controlled setting for designers due to the relevance of immediate built environment in urban context
	Central and double-loaded corridors layout for efficient circulation		
	Ample space in interior layout – high ceilings		
	Unpretentious language – easy to tailor according to needs		
Horizontal buildings 	Large footprint for building density rather than tall buildings. For instance, four to six storey buildings for keeping the visual contact with ground floor and street life	• Autonomy in land occupation due to loose regulations and low land prices in peripheral location • Footprint becomes an environmental issue	• Restriction in land occupation due to tight regulations and high land prices in urban location. Attention should be pay to mechanisms to cope with interaction in tall buildings. For instance, street life and events allowing people to move vertically.
	Long and continuous hallways interconnecting stances		
	Linear and straight shaped building forming bounding spaces (e.g. Courtyards and patios) for natural light and ventilation.		

TABLE 8.4 Alternative flexible facilities with considerations per campus model

The suggestions above are based on common phenomenon found in the empirical world while studying two types of technology campuses. However, it does not mean developing functional or horizontal buildings is the only way to accommodate change in technology campuses, although it has been done this way for decades. In some cases, horizontal buildings has been taken to the extreme where a single large facility has become the corporate campus of tech-based organisations (e.g. Googleplex, Apple Campus 2, Samsung Campus in Silicon Valley), which are highly criticized because of their disconnected and introverted urbanism changing the urban landscape of their hosting city/region. Overall, this research has shown that horizontal shapes can work when well integrated in their contexts and that vertical shapes can be explored with the help of technology and functional strategies.

Physical connectors

Accommodating the different types of activities of campus users often requires more than one facility. Indeed, in a traditional technology campus the cluster of facilities -with specific built forms and configuration at unique locations- shapes the physical campus. These facilities are the parts of a whole called campus but they only work as a whole because of the space in between defining connections among them. In some cases, these spaces are just leftovers of careless campus planning neglected by poor urban design. However, this research has collected lessons from the empirical world that demonstrates the relevance of the physical infrastructure connecting the different activities accommodated in multiple campus facilities and also across the innovation area as described in this research.

Accordingly, this infrastructure is important because physical connectors provide easy and efficient access to specific functions for campus users. Hence, they also increase the chances for diverse people to meeting and having potential interaction out of the frequent and incidental contacts. This happens because physical connectors enable people moving either within one facility, from one to another facility, across- and beyond campus. In this context, this research distinguishes two systems of physical infrastructure connecting functions and predominantly promoting walk-ability. These are pedestrian-oriented systems and transit-oriented systems, which configuration and distribution vary between Tech-parks and Tech-districts.

In Tech-parks the physical infrastructure connecting functions and people is configured as a centralised network that connects campus facilities to specific central nodes within the campus boundary. This results from the absence of functions outside the campus making the distribution of this connecting infrastructure independent from the immediate context and following its own internal logic. Instead, existing natural features are more likely to affect the configuration and distribution of physical connectors in Tech-parks. Likewise, because of its peripheral setting, the physical infrastructure that connects the campus with the nearest functions in the region is limited to specific access points between two independent systems (e.g. dedicated and controlled access points for cars, pedestrians and bikes to campus, connected to existing roads, motorways, or paths in the surroundings of the campus).

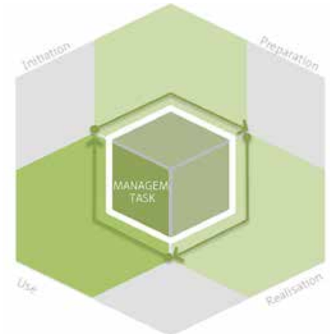
In Tech-districts the physical infrastructure connecting functions and people is configured as a distributed network connecting multiple facilities spread between the campus and the city. This result from the abundant functions that exist in inner city areas making the distribution of this connecting infrastructure integrated with that existing in the urban fabric. In some cases, formal integration between both systems is difficult because not all Tech-districts are the same (e.g. Some type of campuses located in inner city locations like the so-called 'Contains' have formal barriers for integration in the shape of fences or high traffic roads). However, since campus users move across functions between the campus and the city, there is a need for functional integration that pushes forward to overcome the existing formal barriers.

In this context, the repertoire of physical infrastructure connecting functions and people in both pedestrian- and transit oriented systems are detailed in Table 8.5, which contains considerations per each of the campus model proposed in this research.

	CAMPUS MODELS	Campus as the city *Tech-park*	Campus in the city *Tech-district*
PHYSICAL CONNECTORS	Location setting	Peripheral	Inner-city
	Repertoire of physical infrastructure connecting functions & promoting walk-ability		
Pedestrian-oriented systems	**Outdoor pathway systems** *as direct routes connecting functions distributed across the campus inside and outside buildings. The system supports the repertoire of open spaces for retail and leisure such as terraces, squares, and green areas. Efficient connector in good weather conditions.*	A sounded balance between outdoor and indoor pathways system is required due to the suggested amount and distribution of functions in shared facilities (specific-central). Thus, the quality of the landscape design is essential to invite the use of public space (wide pedestrian paths with good quality of pavements and urban furniture, trees, and sufficient traffic signs).	The balance between outdoor and indoor pathway systems must respond to the logic of connecting functions distributed across the campus and the city. Attention should be paid to the quality of the outdoor-pathways that the campus shares with the city, as well as the open spaces crossing access points of indoor-path-ways.
	Indoor hallway systems *as direct routes interconnecting related functions at different levels. The system is accessed through entrance halls, elevators and staircases. Effective connector for extreme climate conditions during winter time.*	Both pathway systems become an exclusive infrastructure for internal campus users due to internal isolated logic of campus. For instance, gates and controlled entrances can be a barrier for external users of public space.	Both pathway systems become an open infra-structure for citizens and campus users due to the integrated fabric between the campus and the city. For instance, the quality of the street life along campus-city axes (commerce in the ground floors of the buildings and etc.) might invite the use of public space. Attention should be paid to geographic features (roads with traffic, water, mountains, forests).
Transit-oriented systems	**Bike pathways system and bike sharing schemes** *as fast-connectors within campus and between the campus and the city. The system is supported with parking (an bike repair-) stations close to public transport nodes, and buildings accommodating main functions. Efficient connector to complement outdoor pathways systems*	This system might become an exclusive infrastructure for internal campus users due to internal isolated logic of this campus model. For instance, gates and controlled entrances can be a barrier for external users of the bike system. Attention should paid to the connection between internal and external bike pathways infrastructures, and the partnering of private bike-sharing scheme with public transportation.	There are plenty opportunities to integrate the campus pathways with urban system of bike pathways. Also, the location is an advantage for bike-sharing schemes provided in partnership with public transportation, and reinforces the concept of TOD.
	Public transportation systems *as fast routes connecting the campus with other functional locations at city and regional level (bus, subway, tram, and train lines and stations). Effective connector maximising the access to pedestrian-oriented systems.*	Disadvantage of peripheral location where public transport is limited. The effectiveness of this connector depends on the involvement of regional and municipal authorities in improving the quality of a public transportation that benefits the connectivity of the campus.	Advantage of inner city location that benefits from the diversity of existing public transport infrastructure in cities.
	Dedicated shuttle services targeted to campus users *as periodical programmed routes connecting the distant zones in campus, and the campus with main public transport nodes in the city. The system includes programmed routes at specific times and bus stations. Efficient connector to complement outdoor-pathways systems in winter time.*	Depending on the size of the campus and its distance from the city this can be provided as a public transport	Due to the location of the campus in the city, this service is provided privately and exclusive for internal campus users.
	Carpooling system *as alternative route connecting the campus with other functional locations at city and regional levels. The system is accessed through motorways.*	Due to the availability of land in peripheral locations, this system can be supported by non-exclusive parking garages within campus buildings (shared facility for multiple users)	Due to scarcity of parking space in urban areas, this system can be supported Park + Ride for commuting with public transport between the campus and other locations in the city-region.

TABLE 8.5 Alternative physical connectors with considerations per campus model

Tool III. Information map to steer the campus strategy



This tool contains information useful to real estate managers involved in the development of technology campuses. Their main task (i.e. Management task) as proposed in this research is assessing and adapting campus choices according to the changing demand on innovation over time. This task is crucial during the use stage of the accommodation cycle of campuses after ideas have been realised and the development goals of the campus need to be sustained and/or adapted in line with the strategic direction of organisations and the dynamic environment in which they operate.

Accordingly, campus managers deal with situations of uncertainty, change and uniqueness based on their experienced phenomenon within a certain organisation. Indeed, the managers' know-how system is intuitive and deals with questioning, restructuring and assessing a present situation by using the stock of 'organisational knowledge' in which their practice (i.e. the mission, identity, strategy, objectives, facts, techniques, perspectives and/or procedures of an organisation influence the managers' learning system). Essentially, this is why in house rather than outsourced management units are highly appreciated in real estate management because in aligning real estate strategy to organisational strategy the managers' skills rely on their knowledge of the core business of the organisation in which they practice.

This tool provides information building upon the stock of organisational knowledge that campus managers can use when steering campuses in the pursuit of stimulating innovation. Indeed, this research has demonstrated that stimulating innovation is a common organisational objective in universities of technology, R&D institutes, R&D firms and municipal/regional governments, which are involved in the development of technology campuses.

In the case of technology campuses, demonstrating the effectiveness of real estate strategies on organisational performance is where the managers' skills are challenged. This is particularly complex because the organisations that address innovation as an important aspect of their performance are technology-driven organisations. They operate in a dynamic environment in which their competitive advantage relies on their (often joint) capacity to advance knowledge and technologies, especially in the knowledge economy. Accordingly, this covers different types of organisations with different values and cultures, which are subject to change with the knowledge economy. For instance, both universities and R&D firms are driven by the creation of new knowledge and its application to advance technologies for the use of society.

However, the traditional mission of universities is to educate people and advance research while R&D companies advance technologies with the aim to increase return or profit. Nevertheless, there is an increasing cooperation between these two types of organisations -often encouraged by governments ensuring the competitiveness of their cities and regions- in which they perform overlapping functions beyond their own missions. Indeed, the dynamic context of the knowledge economy has expanded the traditional scope in which these organisations operate playing non-traditional roles. In coping with this dynamic context, managers need to clarify their path in attaining the specific organisational objective of stimulating innovation through real estate.

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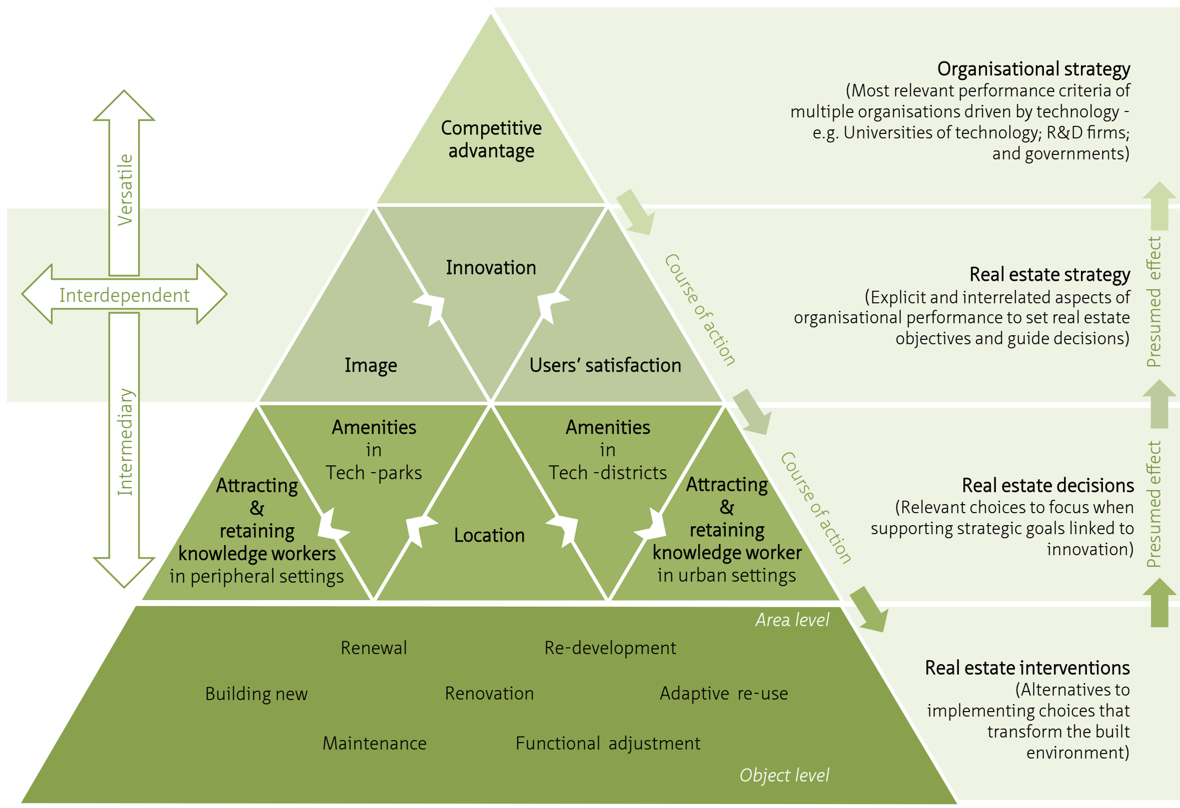


Figure 8.12 Information map indicating paths to link organisational performance and real estate through four hierarchical levels.

The information map illustrated in Figure 8.12, indicates the straightforward path linking organisational performance and real estate through four different and hierarchical levels. These are organisational strategy on top, real estate strategy, real estate decisions and real estate intervention at the bottom. Accordingly, innovation is a central aspect to focus real estate strategy in an explicit way. Thus, this map can be used for campus managers to guide the course of action from strategic to operational decisions in stimulating innovation. Also, it can be used to justify real estate decisions and interventions by its potential effect on competitive advantage. Similarly, this map makes explicit three important attributes of stimulating innovation as a real estate strategy, which are useful to managers in aligning real estate strategy with organisational strategy.

First, *stimulating innovation is a versatile real estate strategy*. As explained above, competitive advantage is the common performance criterion of the different organisations involved in campus development. These organisations are driven by technology but have different values and cultures influenced by the specific markets or areas in which they operate. Therefore, in order to remain competitive each organisation focuses its strategy depending on its core business and mission. However, the creation and application of new knowledge to advance technologies is major driving force for theses organisations in the knowledge economy.

In this context, stimulating innovation is a real estate strategy contributing to organisational performance by means of competitive advantage in universities of technology, R&D companies and municipal/regional governments and regardless the focus of their corporate strategies leading to either distinctiveness, profitability and/or productivity. In the end, the effectiveness of real estate decisions and interventions on organisational performance is measured by the judgement of stakeholders and their values, which are strongly influenced by a specific organisational context. This research has shown that even within the same organisation innovation is seen differently by campus stakeholders (e.g. policy makers, controllers, planners, designers, users, among others). The challenge for campus managers is to balance the different perspectives of these individual stakeholders in line with the organisational strategy. The hierarchical structure of this tool eases this dilemma by making precise the priority directing the path that might lead to stimulating innovation through real estate.

Second, *stimulating innovation is an interdependent real estate strategy*. Theoretically, the impact of real estate on organisational performance is understood as the combined effect of interdependent strategies. Indeed, the empirical information of this research demonstrate that innovation relates to users' satisfaction and image as relevant aspects of organisational performance in technology-driven organisations. Certainly, attracting and retaining high-skilled individuals and/or groups of individuals is essential for these organisations in order to carry out the process of knowledge creation and its application to advancing technologies.

Therefore, in addressing an explicit real estate strategy that supports the goals of these organisations, campus managers should be aware of the complementary relationship between (1) stimulating innovation, (2) increasing user's satisfaction and (3) supporting image as inseparable real estate strategies. These interdependence has been outlined in previous research and also in a form of a map supporting decisions in Dutch higher education institutions (De Vries, 2007). Accordingly, these three real estate strategies can be used to set real estate objectives and guiding real estate decisions. Therefore, this tool sketches the interdependency among these three aspects of organisational performance at the level of real estate strategy.

Third, *stimulating innovation is an intermediary strategic level to guide real estate operational decisions and interventions*. Indeed, having clear the combined effect of innovation, users' satisfaction and image on organisational performance facilitates focusing the campus strategy and making campus decisions. For instance, with a clear focus managers can pinpoint objectives of real estate interventions and make choices that best support their objectives. In this context, attracting and retaining knowledge workers or high-skilled individuals becomes an essential real estate objective in technology campuses. This implies intervening the built environment in ways that call the attention and satisfy the needs, demands and preferences of specific target groups (e.g. engineers, creative workers, managers, scientist, among others). For instance, building new, redeveloping areas, renovating facilities, adjusting the functionality of a space, among others transforming the built environment are examples of real estate interventions that can be directed to attract and retain knowledge workers. However, these interventions are the implemented choices of specific real estate decisions.

This research has demonstrated that location is a crucial decision in attracting and retaining knowledge workers and organisations. It does so because location decisions define the access to amenities that are important for high-skilled workers in deciding where to live and work (e.g. housing, leisure, culture, etc.). Cities and densely populated areas are abundant in amenities. Therefore, it is obvious that campuses located in cities or close to cities have a natural advantage over those who are in isolated locations. However, location decisions imply the selection of a site that not always involves making a choice from different alternatives. When organisations decide to relocate or expand their activities somewhere else, the site is often given because of availability of (cheap) land. In such case, the provision of sufficient and diverse amenities in campus becomes an important real estate decision regardless the location characteristics from an urban perspective (e.g. inner-city or peripheral).

This is important for both campus models suggested in this research. On the one hand, Tech-parks need sufficient and varied amenities to attracting high-skilled workers and satisfying their basic demands, because the lack of functions in their surroundings and their dependence on efficient connectivity to inner city areas. On the other hand, Tech-districts need a balanced provision and distribution of amenities between the campus and the city specially to retain high-skilled workers. It does so because Tech-districts face different challenges related to their optimal functional and physical integration with the city, which can have a negative effect in their vicinities regarding social inclusion, affordability and traffic congestion, among others. In both cases, the provision of amenities together with the involvement of external parties at either regional or municipal level is crucial in solving these issues in each campus model.

This tool outlines location and the provision of amenities per campus model as crucial real estate decisions stimulating innovation. Similarly, this tool lists a number of possible interventions –at area and object levels- transforming the built environment of technology campuses, that can be seen as choices to implement these real estate decisions.

§ 8.4 Conclusions

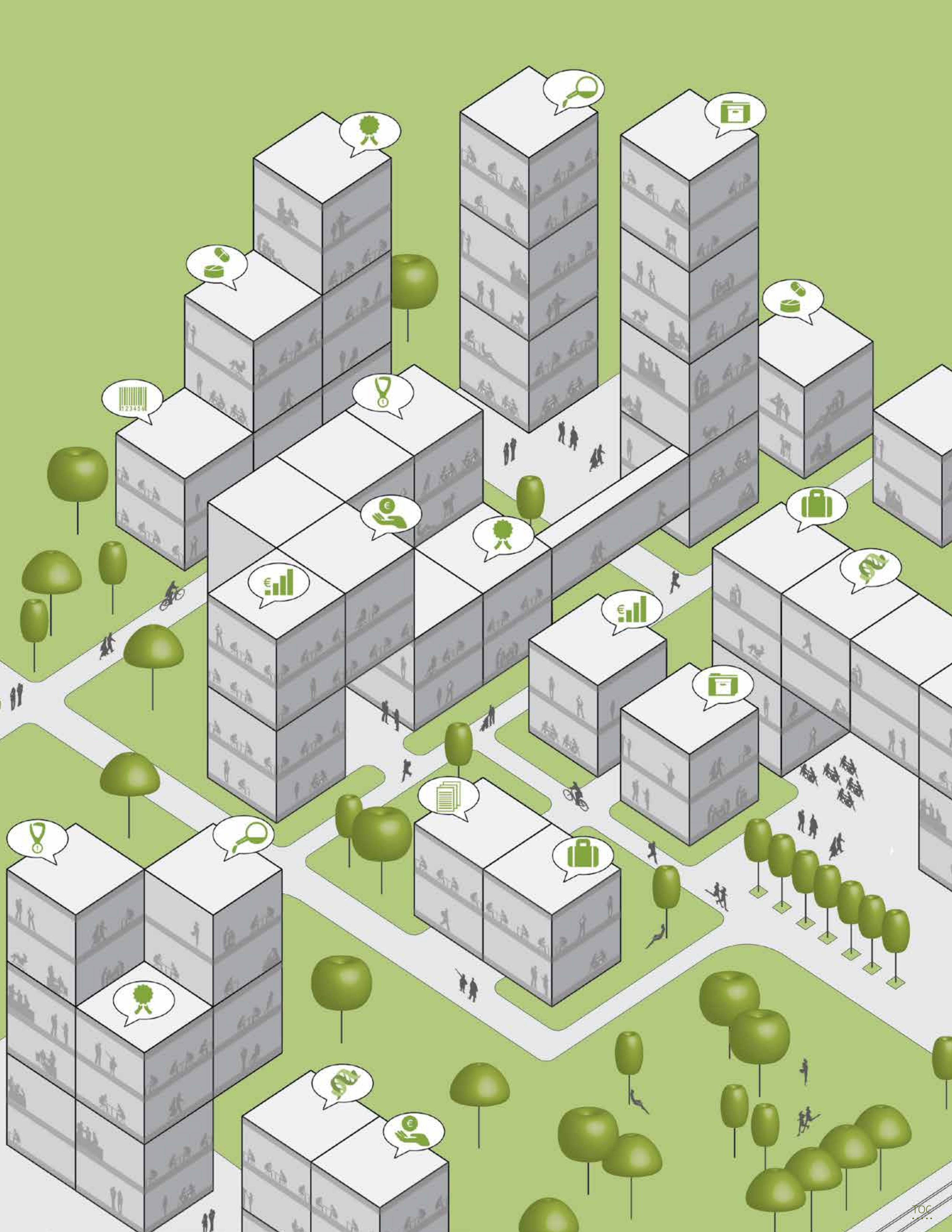
What can be concluded on the built environment as catalyst for innovation from the observed patterns in the two case studies?

This chapter summarised the knowledge and understanding emerging from the empirical research in a conceptual model [See § 8.2]. Accordingly, the built environment is one of the six mutually dependent conditions for innovation as seen in this research. These are (1) Long-term concentration of innovative organisations, (2) Climate for adaptation along changing technological trajectories over time, (3) Synergy among organisational spheres, (4) Scale, Connectivity and Identity of the innovation area; (5) Diversity of people & density of social interaction and (6) the built environment as catalyst for innovation. Each of them has a different function in the process of knowledge creation and its application leading to innovation. This research concludes that the role of the built environment as catalyst for innovation cannot be isolated from the other five conditions. This is demonstrated through real estate interventions in the practice of campus development that facilitated the other five input-conditions for innovation over time.

Furthermore, this model outlines the importance of the local contexts shaping these six conditions. For instance, these conditions are seen as the results of specific demand- or supply characteristics, which are unique to the contexts in which innovation takes place. Indeed, technology campuses are the result of both demand and supply characteristics (i.e. they have emerged and developed due to deliberated organisational goals supporting primary processes and the singular geographic settings in which these organisations locate). From a real estate management perspective, the built environment as catalyst for innovation depends upon the capacity to steer the built environment as a resource to matching specific organisational demands with the unique supply conditions of their local contexts.

How can we use this knowledge to improve future outcomes and challenges in the practice of developing technology campuses and similar built environments?

This chapter provided insights for decision makers involved in the different stages of campus development [See § 8.3]. These insights are given in the form of tools containing information relevant to planners, designers and managers of technology campuses and their hosting cities/regions. This research outlines the need for specific information as relevant in the complex practice of campus development because it involves the objectives and accommodation processes of multiple and different organisations, in unique places and changing contexts. Thus, the knowledge developed in this research is integrated in a so-called campus decision-maker toolbox. It contains information that helps decision-makers to dealing with situations of uncertainty, uniqueness, instability and value conflict, when aiming at stimulating innovation through the built environment. Overall, the information presented in this tool can be used as reference to improving existing and future built environments and to dealing with challenges in similar contexts – i.e. shaped by similar demand and supply characteristics.



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PART IV Conclusions

9 Conclusions and recommendations

§ 9.1 Introduction

This PhD research has developed knowledge about the relationship between innovation and the built environment at area level. This knowledge is provided in the form of a conceptual model containing the hypothesis that 'the built environment is a catalyst for innovation' understood as the process of knowledge creation and its application to develop new and improved technologies. This 'catalyst' function is demonstrated through decisions and interventions in the built environment facilitating conditions required for innovation in the context of the knowledge economy. This research acknowledges the facilitating role of the built environment stimulating innovation by strengthening five conditions for innovation outlined in the model.

The statements above can be considered the main insight of this PhD research, which will be discussed in this chapter. This knowledge developed by examining the development of technology campuses as built environments and their facilitating role in stimulating innovation. This research assumed technology campuses as resources supporting the goal of stimulating innovation in multiple organisations (e.g. universities, firms, municipalities and regional government agencies).

Technology campuses were central for this research because there is increasing societal demand for promoting their development based on the assumption that the concentration of research activities in one location stimulates innovation. However, the capacity of these built environments to support processes related to innovation is not well understood and the existing knowledge that can explain this capacity is limited. This research acknowledged the existence of concepts in different research fields that can clarify the relationship between innovation and the built environment. This thesis addressed the need to integrate the existing concepts and to develop more knowledge at the scale level of the area.

In practice, this knowledge gap may lead to inefficient use of the many resources employed by multiple organisations to develop technology campuses. The lack of understanding addressed above can frustrate attaining innovation. These built environments can easily become a threat in attracting and retaining knowledge workers, because of issues related to poor connectivity, high vacancy, affordability, lack of amenities and poor spatial quality.

This research provide understanding of the role of the built environment in stimulating innovation by asking '*how does the built environment stimulate innovation in technology campuses?* The answer to this question is discussed in this chapter. This knowledge builds upon and connects existing theories in the fields of corporate real estate management, economic geography and urban studies in the knowledge economy. It adds to the existing information available to decision makers, who can influence the development of technology campuses and similar built environments.

This chapter provides first a synthesis of the key research findings supporting the thesis described above. Later, it elaborates on the scientific and practical impact of these findings by outlining their contributions to theory and practice. Consequently, it reflects on the validity of the results and its limitations in relation to the methods used. Last, it draws on the potential of the findings suggesting avenues for further research.

§ 9.2 Research findings

This research has developed knowledge about the role of the built environment stimulating innovation through two core studies: exploratory research and explanatory research. The answer to the main research question is the emergent theory developed from the evidence accumulated in these core studies. The key findings of this research are discussed according to each core study. Their relationship is summarised in Table 1 below. Altogether, these findings and the evidence gathered through the exploratory and explanatory researches contributed to reaffirm the thesis that 'the built environment is a catalyst for innovation in technology campuses demonstrated by location decisions and particular interventions'.

	I. Background	II. Exploratory research	III. Explanatory research	IV. Conclusions
Main question	**How does the built environment stimulate innovation in technology campuses?**			
Guiding questions		How can we study the development of technology campuses and simultaneously provide understanding about the role of the built environment in innovation? By using which concepts from theory and cases from practice?	What can be concluded on the built environment as catalyst for innovation from the observed patterns in the two case studies? How can we use this knowledge to improve future outcomes and challenges in the practice of developing technology campuses and similar built environments?	
Answers		Establishing relationships between existing concepts and testing them in the empirical world. A **conceptual framework** is suggested to guide two cases studies (Chapter 4)	The empirical evidence helped to clarify some of the relationships established in the conceptual framework. This last is revised and developed into **conceptual model** with tools on how to use this knowledge in practice (Chapter 8)	
Evidence		Theoretical concepts (Chapter 2) and the Compendium of technology campuses (Chapter 3)	Two in-depth case studies (Chapter 5 and 6) and its comparison (Chapter 7)	
Status theory development	***Assumption >>*** Technology campuses are resources supporting the goal of stimulating innovation in multiple organisations	***Main proposition >>*** The development of technology campuses is a catalyst for innovation depending on the goals and activities of organisations involved in their developments, their location characteristics, and the historical events shaping their emergence and development.	***<< Hypothesis & 5 propositions >>*** The built environment is a catalyst for innovation understood as the process of knowledge creation and its application to develop new and improved technologies. This 'catalyst' function is demonstrated through decisions and interventions on the built environment facilitating other conditions required for innovation in the context of the knowledge economy.	***Thesis*** The built environment is a catalyst for innovation in technology campuses demonstrated by location decisions and interventions responding to particular settings.

TABLE 9.1 Summary of findings in each of the two core studies adding to the main thesis of this research

§ 9.2.1 Exploratory research: A conceptual framework

A conceptual framework illustrated is the main result of the exploratory research (Chapters 2 to 4). This framework contains the proposition that 'the development of technology campuses is a catalyst for innovation depending on (1) the goals and activities of organisations involved in their developments, (2) their location characteristics and (3) the historical events shaping their emergence and development'. This proposition has been developed from the following observations and patterns that emerged from theoretical and empirical evidence.

The role of the built environment in innovation has received little explicit attention in theory. This research outlines and connects existing concepts that indicate location is a key aspect to explore the relationship between innovation and the built environment.

The exploratory research gathered theoretical constructs that uncovered and positioned the relationship between innovation and the built environment in a scientific context (Chapter 2). There are different concepts in the fields of corporate real estate management (e.g. added value of real estate), urban studies in the knowledge economy (e.g. knowledge clusters) and economic geography (e.g. proximity), whose interrelations are suitable to investigate the role of the built environment stimulating innovation at area level. This research builds upon these interrelations because most of the existing studies in each of these fields do not address an explicit relationship between innovation and the built environment. For instance, the built environment remains a hidden aspect at the intersection of these three fields when explaining the concentration of innovative activities at area level as a demand of multiple organisations to remain competitive in today's developed economies.

This research is based on the theoretical assumption of CREM to manage the built environment as a resource to stimulate innovation, which is seen as an organisational goal. The existing empirical research investigating the particular added value called 'stimulating innovation' has mostly focused on measuring the impact of real estate on organisational performance and has encountered difficulties outlining such impact. Besides, most of these researches have focused on the workplace level.

There is an increasing body of knowledge in urban studies investigating the role of knowledge in the economic development of cities and regions. The 'area' is recognised as an adequate scale level to explore the role of the built environment in stimulating innovation involving multiple organisations because there is knowledge available and it is gaining societal relevance.

This research moved the relationship between innovation and the built environment to a broader perspective, which is being discussed in economic geography through the concept of knowledge spillovers explaining the concentration of innovative activities in particular places. There is an on-going debate in this field because the mechanism explaining innovation and the environments favouring knowledge spillovers are ambiguous. For instance, specialised and diverse environments (i.e. regional clusters and cities respectively) are both related to innovation and growth in different aspects. More recently, the evolutionary perspective of economic geography can offer explanations linked to context-specific aspects including time and place. These insights give a prominent role to the location when exploring the relationship between innovation and the built environment.

Overall, the identification of concepts in the different fields mentioned above provided a theoretical context to develop the thesis of this research and narrow down the object of study.

Technology campuses have remained roughly unexplored from its physical dimension. This research outlines that built environments with similar characteristics (in terms of demand and supply) have shaped the concentration of research activities in different locations around the world.

This exploratory research gathered empirical evidence that describes and compares patterns of the development of technology campuses as built environments in different regions of developed economies (Chapter 3).

On the one hand, the demand for technology campuses is characterised by the explicit intention to concentrate research activities in a single location in a deliberate manner. Universities, R&D firms, research institutes and governments are the main stakeholders involved in the development of technology campuses as founders, managers and promoters of these built environments. These stakeholders share the demand for developing real estate with the aim to stimulate innovation and to encourage economic development. This demand emerged and developed during critical periods of technological advancements during the 20th century. Nowadays, most of these built environments accommodate multiple organisations that perform research activities in a broad range of technology fields to support different core businesses.

On the other hand, the supply of technology campuses is more heterogeneous because it is described through various characteristics. Empirical evidence supported the existence of differences but also marked similarities describing the supply of technology campuses regarding location, layout, size, density, and block pattern. This research indicates that some of these characteristics are the result of explicit intentions of planners and designers. For instance, in some cases, the layout, size and block pattern characteristics suggest the influence of modern and contemporary urban planning principles, which became popular by the time these built environments have been developed (e.g. self-standing buildings on the green, large and open spaces outside cities to be accessed by car). These findings emphasise the character of these built environments as preconceived or ideal models envisioned as part of comprehensive plans influenced by multiple stakeholders. Their intentions to concentrate research activities in one place are translated into design and planning principles that gave shape to an archetype that has been replicated -with slight variations- in many places up today.

The most significant variation is revealed in the location. For instance, there are five types of relationships observed between the campuses and its hosting cities/regions. These relationships range from the inner city up to peripheral locations and are determined by the physical and functional integration of the campus with its hosting city/region. In turn, regardless the different location characteristics, there is a persistent isolation condition in most of the campuses surveyed. For instance, campuses are archetypes recognisable as distinct and sometimes independent built environments in their spatial contexts. These observations suggested that the intentions influencing location decisions are far more complex and context specific. These findings made location an even more interesting aspect to address the relationship between the built environment and innovation, especially in the dynamic context of the knowledge economy.

Overall, the description of technology campuses as built environments provided an empirical ground to develop further the thesis of this research and examine its subject of study from a development perspective.

The connections between the theoretical and empirical insights discussed above are integrated into the conceptual framework that positions the development of technology campuses as an alternative way to understand the relationship between innovation and the built environment [See Figure 9.1].

The relationship in this framework is indirect and dependent on local conditions including organisations, location characteristics and history.

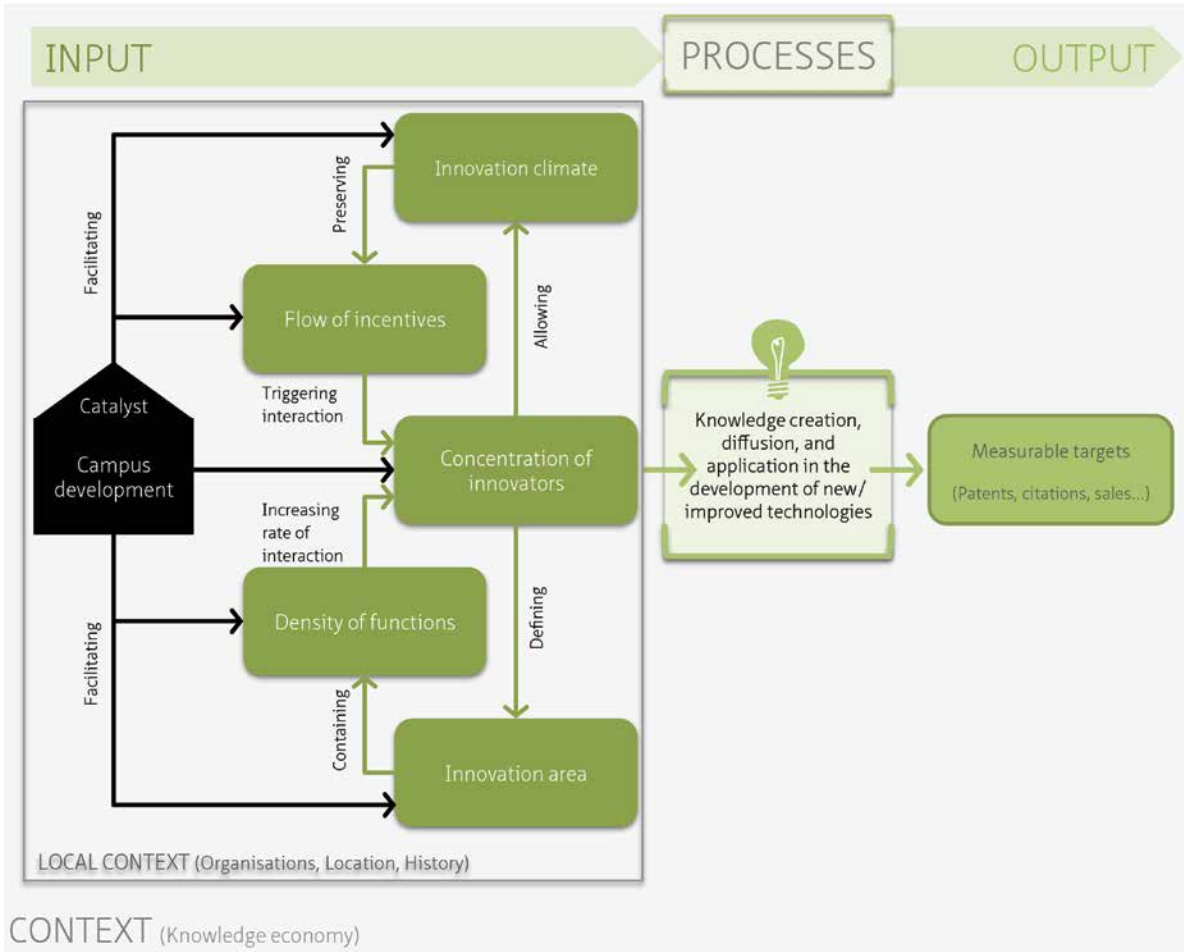

Figure 9.1 Conceptual framework

§ 9.2.2 Explanatory research: a conceptual model and tools to support campus decisions

A conceptual model is the main result of the explanatory research (Chapters 5 to 8). This model [See Figure 9.2] contains a hypothesis that has been developed throughout the application, verification, and revision of the conceptual framework above with empirical data from in-depth cases. Its central proposition developed into a hypothesis that 'the built environment is a catalyst for innovation demonstrated through decisions and interventions on the built environment facilitating conditions required for innovation in the context of the knowledge economy'. This hypothesis is sustained in five propositions that emerged from the empirical evidence of the cases, which has been discussed in Chapter 8 and listed as key findings s follows:

- Location decisions and area development facilitate the long-term concentration of innovative organisations in cities/regions.
- Interventions enabling the transformation of the built environment at area and building levels facilitate the climate for innovation over time.
- Large-scale real estate interventions facilitate the synergy among organisational spheres.
- Location decisions and interventions supporting image and accessibility define the innovation area by emphasizing its distinct identity, scale and connectivity features.
- Real estate interventions enabling the access to amenities increase the diversity of people & density of social interaction regardless the distinct geographical settings in which the concentration of innovative activities takes place.

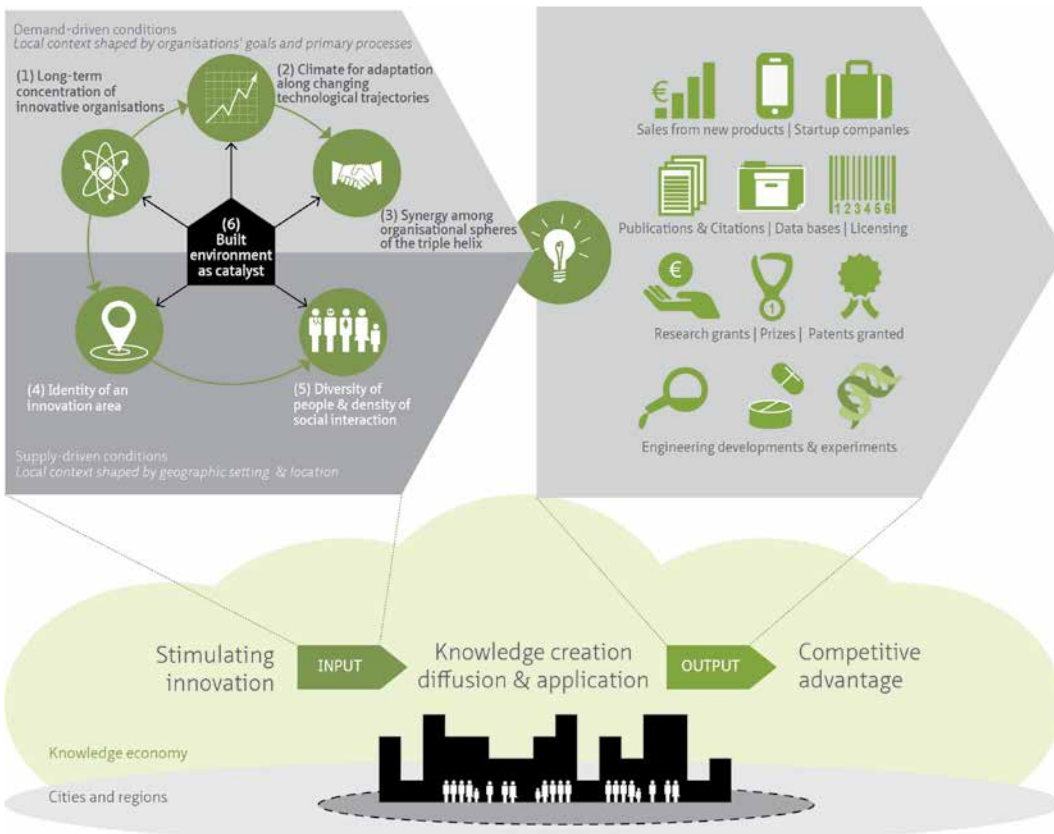

Figure 9.2 Conceptual model

Cases provided rich descriptions linking these findings to empirical evidence (Chapters 5 and 6). The five propositions described above explain how the built environment facilitates each of the five input conditions for innovation verified in this research. These conditions are:

- (1) Long-term concentration of innovative organisations,
- (2) Climate for adaptation along changing technological trajectories over time,
- (3) Synergy among organisational spheres,
- (4) Identity of the innovation area, and
- (5) Diversity of people & density of social interaction.

Each of them has a different function in the process of knowledge creation and its application inherent to innovation. This research concludes that the role of the built environment as a catalyst for innovation

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cannot be isolated from the other five conditions. This is demonstrated through real estate interventions in the practice of campus development over time. This thesis provides a number of performance indicators that universities, R&D firms and governments can use to measure the contribution of campus development to their competitive advantage as a main performance criteria. This performance indicators derived from the understanding of the relationship between innovation as an aspect of organisational performance and the built environment as a resource manage to support this aspect.

The rich empirical evidence supporting these propositions was structured and converted into information available to decision makers involved in the development of technology campuses. The 'campus decision maker toolbox' [See Figure 9.3] was developed as a structured way to make use of the understanding provided in the framework targeted to decision makers on the built environment (Chapter 8).

This research outlines the need for context-specific information relevant to the complex practice of campus development. The knowledge developed in this research is integrated in a so-called campus decision-maker toolbox. It contains information that helps decision-makers to deal with situations of uncertainty, uniqueness, instability and value conflict when aiming at stimulating innovation through the built environment. It contains a set of three tools supporting three tasks targeted to different professionals in the practice of developing technology campuses (planners, designers, and management).

The following lines summarise each tasks with their respective tools. Each of them is targeted to enhancing three important products in different stages of the campus development process (i.e. the campus vision, brief, and strategy during initiation, preparation and use stages respectively).

- The planning task is 'envisioning the desired campus considering the location options in the city/ region'. The tool for planners comprises models to frame the campus vision during the initiation stage of campus development.
- The design task is 'exploring accommodation alternatives based on functional demands or end-users'. The tool for designers consists of alternatives to enhance the campus brief during the preparation stage of intervention on campus.
- The management task is 'assessing and adapting the campus choices according to the changing demand over time'. The tool for managers contains an information map to steer the campus strategy during the use of the campus.

The information presented in this toolbox can be used as reference to improve existing and future built environments, and to deal with challenges in similar contexts – i.e. shaped by similar demand and supply characteristics.

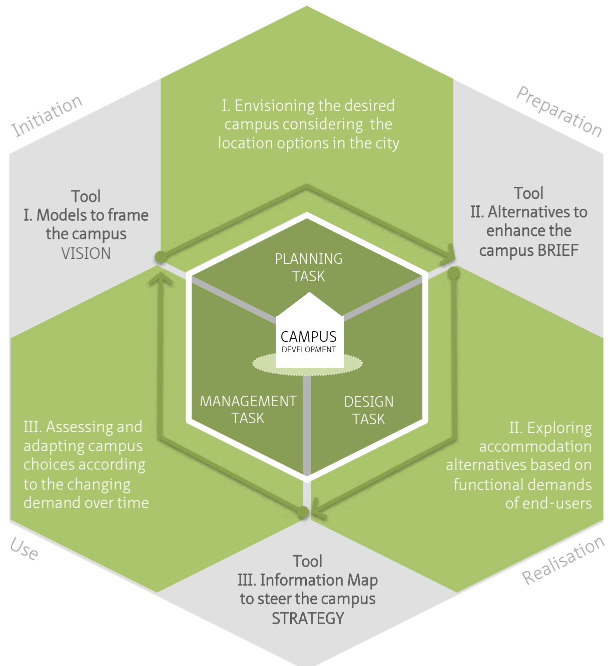

Figure 9.3 Campus decision-maker toolbox

§ 9.3 Impact of the findings

The knowledge developed in this research contributes to the existing understanding of the relationship between innovation and the built environment in theory and practice. The following paragraphs briefly argue how these findings could influence further understanding and application of this knowledge according to their respective theoretical and societal relevance.

§ 9.3.1 Theoretical insights

The theory developed in this research adds to existing theoretical concepts in three fields: corporate real estate management, urban studies in the knowledge economy and economic geography. The conceptual model proposed a new combination of existing theoretical concepts addressing a new way to look at the relationship between innovation and the built environment. The knowledge developed throughout the combination of different concepts may also encourage an existing academic debate related to some of these concepts. The main theoretical insights are addressed per field of study as follows.

Corporate real estate management (CREM)

The thesis of this research builds upon the existing knowledge investigating the contribution of real estate to organisational performance, which is understood as the fulfilment of organisational goals according to the judgement of various stakeholders and their perspectives on real estate (De Jonge, 1996; De Vries, 2007; De Vries et al., 2008; Den Heijer, 2011; Jensen et al., 2010; Krumm, 1999; Lindholm et al., 2006; Nourse & Roulac, 1993; Van Der Zwart, 2014). This research shared this field's position on the built environment as a resource steered to stimulate innovation, which is one of different organisational goals identified in previous research within this field. The knowledge developed in this research revealed an emergent perspective that strengthens the concept of 'added value' in the CREM field.

In a broad sense, this research adds an alternative way to look at the relationship between innovation and the built environment already established in theory in this field. The knowledge developed in this research provides understanding and clarification on this specific relationship rather than measuring its impact or proving causal links between these two aspects. This research emerged from the need to clarify such relationship because the existing research in this field provides both, a theoretical basis that is too broad and an empirical one that is too narrow to address this relationship in the current context in which its problem is situated (i.e. campus development in the knowledge economy).

There are different theoretical researches in this field addressing ways to stimulate innovation through a series of real estate decisions and interventions (e.g. workplace design, the design of facilities, location, the provision of- and access to amenities, among others). Overall, the existing theoretical knowledge is rather broad because it addresses the relationship between the built environment and innovation along with other aspects of organisational performance. Indeed, an important theoretical argument in this field is that the added value of real estate on performance resides in the combination of strategies. To date there are few empirical researches in this field supporting this theoretical assumption that have focused on the added value of real estate in innovation as aspect of organisational performance. These researches have focused on measuring the impact of the design of the workplaces and facilities on performance. Yet, these researches found difficult to measure and thus, to prove the actual impact of real estate on innovation when isolating this from other aspects.

The way in which this research builds upon its theoretical assumption (i.e. the contribution of real estate to organisational performance) differs in its approach because it sought for understanding the mechanisms behind this relationship already established in theory in a broad sense, rather than measuring the impact of real estate on innovation. In this way, it avoids the difficulty of testing an assumption that it is based on a presumed effect. Instead the detailed and isolated study of campus development and stimulating innovation as an organisational goal is an alternative way to outline the relationship between real estate and performance, which might be neither direct nor an assumed one. The following paragraphs elaborate on how this research supports existing theoretical assumptions of the CREM field by reassuring three attributes in the concept of added value of real estate that emerged from the in-depth study of the relationship between innovation and the built environment.

Added value is versatile

This research strengthens the existing position that the added value of real estate on organisational performance is understood as the contribution of real estate strategies in attaining different organisational goals The knowledge developed in this research supports this viewpoint by suggesting that stimulating innovation is a versatile real estate strategy. This attribute is demonstrated through the understanding of innovation as an aspect of organisational performance in multiple organisations involved in campus development (e.g. universities, R&D firms, governments). Accordingly, competitive advantage is a common performance criterion of these organisations because the creation and application of knowledge to advance technologies is their major driving force. However, depending on their respective core businesses innovation is an aspect of organisational performance that leads either to distinctiveness, profitability, and/or productivity. In the end, the contribution of real estate to innovation is determined by the different ways in which innovation is perceived and valued by the multiple stakeholders involved in campus development.

This perception might change over time along with the dynamics inherent to the core processes leading to innovation in specific organisations driven by technology. In R&D firms the focus of innovation as an aspect of organisational performance can be judged by means of different performance criteria (e.g. distinctiveness, profitability or productivity) depending on the dynamic business cycles changing the focus of their driving forces and the path of their business strategies. In this sense, this research suggests that this particular added value is not only versatile but also dynamic.

Added value is interdependent.

This research strengthens the existing position that the added value of real estate on organisational performance is understood as the combined effect of interdependent real estate strategies, The knowledge developed in this research supports this position by suggesting that stimulating innovation is an interdependent real estate strategy. This attribute is demonstrated through the understanding of innovation as an aspect of organisational performance in the context of the knowledge economy. Accordingly, innovation relates to other aspects of organisational performance such as 'user's satisfaction' and 'image' because of the demand for attracting and retaining high-skilled people that is essential to the process of knowledge creation and its application to develop new and improved technologies. In this sense, this research supports the already mentioned view that in demonstrating the impact of real estate on performance, one cannot isolate real estate strategies. The knowledge developed in this research supports that (1) stimulating innovation, (2) increasing user's satisfaction, and (3) supporting image are interdependent real estate strategies already outlined in previous studies.

Added value is intermediary.

This research strengthens the existing position that the added value of real estate on organisational performance is understood as strategic courses of actions guiding real estate decisions. The knowledge developed in this research supports this position by suggesting that stimulating innovation is an intermediary strategic level to guide real estate operational decisions and interventions. Accordingly, this research builds upon existing conceptual models that tried to simplify the relationship between real estate and organisational performance. The built environment is addressed as an input resource in a process that refers to organisational core businesses. Nonetheless, this research adds a level of detail to this relationship, which might seem less simple but closer to reality because of the in-depth study of a single added value – i.e. stimulating innovation. In the model developed in this research, the built environment is positioned as catalyst facilitating other input conditions for innovation, which are directly linked to the core business processes of technology driven organisations.

This thesis builds upon this theoretical assumption since it outlined the facilitating role of the built environment in innovation through some of the decisions and interventions already addressed in early theories (i.e. location decisions and the access to amenities). Besides, the study of campus development revealed other interventions suitable to explain this relationship at the scale level of the area (i.e. the re-development of urban areas, the development of shared facilities, flexible buildings allowing functional change, and physical infrastructure connecting functions). This knowledge and approach moves the relationship between innovation and the built environment to a larger scale (e.g. urban area), which was empirically unexplored in the CREM field until now and is gaining importance in other related fields such as urban studies and economic geography.

This insight is particularly relevant in the management of large-scale built environments (e.g. portfolios and urban areas) because their potential contribution on performance acknowledges the judgement of a broad range of stakeholders beyond a single organisation's boundary. It is not new that the management of large scale built environments is complex because it implies balancing the multiple -and some times conflicting- perspectives of these stakeholders on real estate. This research sees the management of these built environments as an opportunity to outline the relevance of the added value of real estate on performance supporting the goals of multiple stakeholders including the society as a whole.

This research has demonstrated the relevance of the built environment stimulating innovation, which is a goal shared by multiple organisations in the knowledge economy. This alternative way to look at the relationship the built environment and innovation could be applied to other aspects of organisational performance that are relevant for multiple organisations and their stakeholders and yet their contribution to performance is hard to demonstrate in the CREM field. The clarification of the indirect relationship between the built environment and performance for some added values (e.g. stimulating innovation) might facilitate the search for indicators to measure the actual impact of real estate on performance.

Urban studies in the knowledge economy

This thesis builds upon theoretical notions in urban studies that strengthen the existing view of the built environment as an infrastructure resource supporting knowledge-based development. In its outset, this research outlines the need to address the concentration of innovative activities inherent to technology campuses not only from its economic and social dimension but also from its physical-functional one embedded in broad contexts – i.e. the city and the region. This research acknowledged some concepts in urban studies that help to clarify the relationship between innovation and the built environment. The theory that emerged from the cases contributes to the existing understanding of the following four concepts concerning innovation in urban studies.

The economic base and knowledge base are the essential foundations of cities in the knowledge economy (Van Den Berg et al., 2005)

This research acknowledges and supports the view that the long-term presence and concentration of different technology-driven organisations in a city/region is a fundamental condition for innovation as studies in this research (Proposition 1). This study confirms the presence of both, multinational corporations with a focus on R&D and prestigious universities of technologies and research institutes working in complementary fields over extended periods in regions, which are considered role models regarding growth and development in the context of the knowledge economy.

The organising capacity is essential to create and apply knowledge in cities in the knowledge economy (Van Den Berg et al., 2005)

This research recognises and supports the view that the synergy among different organisational spheres in cities and regions are essential to stimulate innovation and therefore, it is considered as a condition to activate the process of knowledge creation and its application carried by different parties (Proposition 3). This research ratifies the existence of a proactive allocation and appropriation of roles and activities among various stakeholders in the two cases studies in their contexts.

The triple helix region has no precise dimension but it is determined by geographic features (Etzkowitz & Klofsten, 2005)

This research shares and supports the view that the concentration of innovative activities defines areas with distinct identity, scale and connectivity (Proposition 4). This area not only allows face-to-face contacts among existing knowledge networks but also serves as brand and representation for these networks. This research adds that some loose geographic features in cities and regions (e.g. the valley, the corridor, the route, the axis) help to strengthen their distinct identity, scale and connectivity beyond administrative boundaries that are rather precise and strict.

Cities are engines of growth and creativity determined by the diversity of people and their opportunities for interaction (Jacobs, 1961)

This research acknowledges and supports the view that cities are environments facilitating the creativity and the generation of ideas required for innovation, because of the provision of different functions, and the access to different amenities enabling diversity of people and opportunities for social interaction (Proposition 5). Conversely, this research acknowledges that these key aspects, which are abundant in inner city locations, can also be provided in peripheral locations. This research suggests that the diversity cities offer can be replicated somewhere else in a different degree and scale (i.e. specific functions and distributions). However, this alternative environment for innovation depends on the efficiency of its connectivity with inner cities and (inter)national hubs allowing people to move and access complementary functions and amenities.

Economic geography

This thesis builds upon existing theories addressing knowledge spillovers as one of the varied sources of agglomeration economies and the on-going theoretical debate explaining the mechanism by which the presence and collective actions of firms positively affect innovation. There is a main theoretical assumption in this field that knowledge spillovers tend to be geographically bounded because they involve tacit knowledge and its transmission depends on distance. This assumption gives to the concept of geographical proximity a central role that has been challenged after many tried explaining the source of knowledge spillovers either via specialisation or diversity externalities. These two theoretical stands suggest different types of environments providing conditions that can enhance growth and innovation as confirmed by many empirical researches in this field. These environments are regional concentrations specialised in a particular industry or urban concentration in cities with a diversified structure across sectors. To date, there is no clarity yet whether one or the other environment is more beneficial to innovation.

A good number of researchers argue that diverse environments are more beneficial because they have lesser adverse impacts on innovation compared to specialised regions (Beaudry & Schiffauerova, 2009). Either way, it is generally accepted that the spatial concentration in a determined geographical setting has an effect on the creation and diffusion of knowledge. In clarifying the relationship between innovation and the built environment, this research acknowledged the relevance of both cities and specialised regions as environments providing favourable conditions for innovation, but concerning specific concepts from evolutionary economic geography that can serve to illustrate key aspects in this debate. The theory that emerged from the cases contributes to the existing understanding of two central concepts addressed as follows.

Proximity and its multiple dimensions

The multiple dimensions of proximity are a fundamental argument of the evolutionary and institutional school of thought in agglomeration economies when providing understanding of how innovation as a learning process operates between regions, industries and organisations (Boschma, 2005). The distinction of five types of proximity became relevant because of globalisation and the multiple geographical sources of new knowledge. Then, cognitive, organisational, social, institutional and geographical proximities have both advantages and associated problems for learning. This theory concludes that only cognitive proximity is a prerequisite for interactive learning and all the dimensions are mechanisms that bring together actors within and between organisations. Accordingly, geographical proximity is neither necessary nor a sufficient condition for learning. However, this theory recognises its facilitating role strengthening the other dimensions of proximity.

This thesis shares and supports this last view through the study of campus development in two contexts with different characteristics (e.g. city and region). Both cases confirmed the existence of these dimensions of proximity in various degrees. For instance, this research acknowledges the long-term concentration of innovative organisations as a condition for innovation (Proposition 1). Indeed, the organisations in each context shared complementary capabilities in a common knowledge base supporting the relevance of cognitive proximity as a prerequisite for interactive learning. Similarly, this study shows that these organisations shared relations in an organisational arrangement (i.e. organisational proximity) since a good number of them are associated with one major institution or entity (e.g. spin-offs, start-ups, and collaboration initiative that takes the shape of departments or institutes). Correspondingly, this study also suggested that their relative physical proximity (i.e. organisation's locations defining an innovation area that is well connected and representative – Proposition 4) stimulate other forms of proximity, including cognitive, social (i.e. sharing relations based on trust and commitment) and institutional (i.e. collective values and norms in which organisations perform). Real estate interventions enabling (non) local actors in knowledge networks to meet and connect illustrate the facilitating role of geographical proximity.

The co-evolution of institutions and technological trajectories over time

This notion is at the contemporary definition of evolutionary economic geography in which innovation is seen primarily influenced by institutions and their co-evolution with technologies over time and differently in distinctive regions (Boschma & Frenken, 2006). Accordingly, the local context in which organisations decide to locate provides specific conditions allowing organisations to adapt according to specific trajectories over time. This thesis supports this view through the study of campus development from a long-term perspective referring to this notion of the 'climate for adaptation along changing technological trajectories over time', which is a condition for innovation (Proposition 2). This dynamic climate illustrated how organisations follow paths in time and space to deal with the uncertainties inherent in innovation. For instance, the organisations' location decisions to establish their research activities in particular places played a significant role in where innovation located in the two contexts studied in this research.

Furthermore, this study illustrated how in these two different environments the local context met the new and changed requirements for innovation in organisations that have been cognitively-, organisational-, social-, institutional-, and physically close. Each environment allowed these organisations to adapt the focus of their research activities according to open technological trajectories over time. These trajectories relate to specific periods of technological advancement influencing the direction of both, the primary activities in the technology-driven organisation and the local economies in particular environments. For instance, each local context provided the institutional frameworks to succeed in adapting the shifts to the technological paradigms in each period. This research also acknowledges the power of an economic crisis pushing the need for adaptation and to work collectively in targeting innovation for growth. This last observation recognises a theoretical assumption that proximity can be explained from collaboration when studying the different forms of proximity from a dynamic perspective – i.e. processes changing proximities over time. According to this view, knowledge networking can increase proximity levels in the long run (Balland, Boschma, & Frenken, 2015).

In this context, these findings also support the contemporary concept of 'related variety' as an alternative explanation linking innovation and growth in regions (Frenken, Van Oort, & Verburg, 2007). These are places where technological trajectories are open and heavily based on tacit knowledge via communication and understanding (i.e. cognitive, organisational, and institutional proximities) and facilitated by face-to-face interactions (i.e. geographic and social proximity). The two cases studies in this research are examples of places in which successful sectors have diversified in a good degree over time based on existing competences and specialisations, overcoming the risk of locking-in that results from path dependent technological trajectories.

Overall, the concepts from this field used in this research had the intention to explain a established relationship between innovation and the built environment from the CREM perspective. These insights do not have the intention to encourage a theoretical debate in this field. Rather, they provide a solid theoretical ground to explore innovation as an aspect of organisational performance through real estate decisions.

§ 9.3.2 Practical implications

The knowledge developed in this research is relevant for practitioners involved in the development of technology campuses including policy makers, controllers, planners and designers in governments, universities, and firms, which aim to stimulate innovation through campus development.

The main reason for developing and providing such knowledge is to encourage the efficient use of the many resources required to develop these built environments – including public and private capital, land, expertise and time. Furthermore, this understanding may also help to attain effectively the desired goal of stimulating innovation by targeting such resources on strategic decisions and interventions, which under certain conditions can have a positive effect on innovation as a learning process. This research provided both, the knowledge (i.e. the conceptual model) and the way to use that knowledge in practice (i.e. the campus decision-makers toolbox). The latter is targeted to stakeholders, who are directly involved in campus decisions during its planning, design and management processes. The tools containing information were designed to use them as a reference to improve existing and future built environments, and to deal with challenges in similar contexts – i.e. shaped by similar demand and supply characteristics. The following paragraphs discuss the main lessons for practice based on this knowledge.

Investments in campus development to stimulate innovation worth proportionally to the co-existence of five conditions for innovation

At first glance, this research seems to encourage the development of built environments to stimulate innovation in practice. Rather, this research provides information that can help to use the built environment as a resource to stimulate innovation –i.e. by making strategic decisions that lead to effective interventions under certain conditions. As outlined throughout this research, developing campuses and making interventions in the built environment is costly. Investing large amounts of capital and other resources is required in campus development. This research has outlined that universities, R&D companies and governments have spent hundreds hectares of land, millions of euros from public or private funds, and decades developing technology campuses because these areas are seen as engines of innovation (Chapter 1 and 3). Investing in the built environment is often criticised in practice because the return on these investments are hard to measure and justify. This research has shown that the built environment facilitates conditions for innovation in technology campuses. In this context, the knowledge developed in this research does not justify more investments in real estate, but resource-efficient investments instead.

Innovation alone is a difficult aspect to measure. In practice, organisations usually look at the relationship between investment on the built environment and output indicators such as high-skilled jobs, patent grants, start-ups, Nobel laureates, etc., depending on their core businesses. Instead, this research has shown that the way in which the built environment supports innovation is linked to five input conditions (see Section 9.2.2). These conditions do not happen in short-term periods, as the changing administrations in organisations would like to show the impact of their decisions. On the contrary, it takes time to create the right conditions for innovation, which seem to co-evolve in the long run and particular places. This research has outlined that these conditions are often the result of a combined effort of different organisations whose interest in innovation and ways to measure performance differ as well. These organisations are collectively capable of attaining the goal of stimulating innovation, and the built environment can facilitate its attainment. Location decisions and other particular interventions involving the collective action of multiple stakeholders in different roles demonstrate this. Examples of these interventions are (1) transforming areas through urban renewal or redevelopment, (2) building, adapting and re-using flexible facilities, (3) implementing the shared use of facilities accommodating different functions and users, (4) developing physical infrastructure that enable access to amenities and connect functions and (5) developing representative facilities and area concepts that support image and attract people.

This research provided a repertoire of information (i.e. exemplars of campus interventions based on campus models) that practitioners can bring to unique situations to optimise the allocation of resources on the built environment based on expectations about similar patterns and contexts. This information builds upon the stock of knowledge available, in which decisions makers rely according to the concept of bounded rationality. Last but not least, this research emphasises that the facilitating role of the built environment through concrete decisions and interventions depends on the co-existence of five conditions for innovation.

The location of technology campuses is a strategic decision that determines the way in which the built environment facilitates the conditions for innovation at area level.

There are several demand drivers influencing organisation's location decisions, which cannot be oversimplified to a single aspect nor generalised to all organisations. In economic geography, agglomeration economies are regarded as cost savings to the firm resulting from the concentration of production in a single location. This cost saving effect has different sources in the literature including infrastructure sharing, input sharing, knowledge spillovers, labour market pooling, consumption, political support, and natural advantages among others. In the context of this research, knowledge spillovers and (high-skilled) labour market pooling can be regarded as relevant sources of agglomeration economies in organisations driven by technology and whose primary goal is to stimulate innovation.

This research has shown that the organisations' location decisions to establish their research activities in particular places played a significant role in where innovation located. The location decisions of the two campuses studied resulted in the combined need for expansion of their end user's organisation and the convenience of inexpensive land that supposed a cost saving decision for these organisations in the short term. Unexpectedly, the different local contexts in which these campuses developed provided both the right conditions for innovation but as the result of a co-evolution of various aspects at the right time and place.

In today's knowledge economy, organisations compete to attract and retain the best talent (i.e. students and knowledge workers). The mobility patterns of people and the access to the different amenities they are attracted to, suppose changes in the way organisation's location decisions are made. In the competitive and global environment in which the new knowledge is created and applied, organisations are less likely to let innovation be an unforeseen outcome. Indeed, organisations whose core processes rely in the creation of knowledge cannot afford to lose highly educated people because they are their most valuable assets. Thus, the consideration and integration of the knowledge workers' preferences are essential for organisation's location decision-making.

The importance of location characteristics implying benefits and threats for organisations is already perceived in practice. For instance, campuses in peripheral locations have started to be perceived by many as vulnerable environments in this competitive context. Inner city locations are increasingly regarded as the right environment for innovation and creativity. Policy makers in universities -which are organisations historically linked to a place- are considering to open new brand campuses in what are considered 'more attractive' locations because their isolated locations represent a threat in connecting with their knowledge networks and attracting students. In firms, the same threat is also perceived by a location's capability of attracting and retaining high-skilled workers, who might prefer working in places that match better their living preferences.

This research provides insights that different types of locations provide conditions for innovation. Each of them supposes costs and gains in attracting and retaining high-skilled people. Inner city locations that have abundant amenities and are considered attractive now, can also bring challenges for organisations in achieving their goal of stimulating innovation due to congestion, affordability and social exclusion driving away the interest of knowledge workers and organisations. Similarly, peripheral locations can recreate some of the diversity cities offer but depend on time-proximity and the efficiency of transportation allowing contacts among actors in knowledge networks and the access to a variety of amenities preferred by knowledge workers. Improving the connectivity and accessibility to networks and amenities in locations play an equal and perhaps more important role than being in the inner city itself. In this context, the location might become a strategic decision, which benefits for innovation are indeed, difficult to measure in the short term because places are continuously changing over time. As it happens in the past with the cases studied in this research, the local contexts that suggest the right conditions for innovation today might change in the future. When deciding on new locations for technology campuses or similar environment, the trade-off for decision makers is to pay the high cost of easily-accessed and connected locations, in return for an increased capacity to attract and retain high-skilled people in the long term, which is still hard to measure but problematic to risk.

This research provides a repertoire of interventions on the built environment that facilitated conditions for innovation in different contexts and according to particular location characteristics. The information that emerged from empirical evidence is generalizable based on expectations about similar patterns of reasoning when developing campuses in similar contexts.

The dimensions of proximities call for a revision of the campus' notion going beyond physical clustering

This research supports the relevance of five types of proximity dimensions relevant for innovation as an interactive learning process, from which only cognitive proximity is a prerequisite for this process. Indeed, the other four dimensions are facilitating mechanisms for learning (e.g. organisational, institutional, social and geographical proximities). This research has shown that geographical proximity of technology-driven organisations in a city or region has indeed strengthened the other five dimensions of proximity in two different contexts. The facilitating function of geographical proximity becomes more evident at the scale of the campus because these built environments are archetypes that physically concentrate the research (and other related) activities of these organisations.

Campuses decrease the physical distance among organisations that are cognitively, organisational and institutional close, providing the opportunities for them to be socially close as well. This research praises the ability of campus development strengthening dimensions of proximity relevant for innovation as a learning process. However, in many cases, these opportunities provided by the built environment are misrepresented or not well understood. This lack of understanding lies in the geographical proximity paradox because knowledge networks do not have clear physical boundaries. In other words, providing a model that concentrates organisations and people in a single location makes no sense if they are not efficiently connected to the different geographical sources of knowledge networks, and to the amenities and functions people need and prefer.

This research provided campus decision makers with two models to improve the existing stock of technology campuses (i.e. there are 700+ built environments worldwide that can be recognised either as Tech-parks or Tech-districts). These two models reject the isolation characteristic of many campuses planned and designed to respond to the dynamics of the mid 20th century. In new developments, the campus idea needs to be redefined. The campus should be a geographical node in a network of interconnected organisations that are cognitively close and complementary. This geographical node could be inner city or peripheral locations as long as they are efficiently connected to other nodes, transport hubs, and amenities. These geographical nodes do not have to be necessarily a group of buildings in a clearly delimited area. They could be a network of existing buildings in cities and regions. There is abundant opportunity in cities to adapt and reuse existing space and infrastructure that can accommodate knowledge networks in efficient and effective ways. This kind of strategy also needs the collective effort and commitment of different actors, who share the goal to stimulate innovation in their local context but must assume distinct roles in attaining such goal. In this context, the planning, design and management of the revised campus as a geographical node in knowledge network requires coordination.

§ 9.4 Reflections on the quality of the results

This study provides understanding of the relationship between innovation and the built environment at the scale level of the urban area. This understanding is delivered through a conceptual model, which is the resultant theory emerging from the combination of two core studies using mixed methods. As a direct consequence of the approach and methods used, this research encountered some limitations, which need to be considered. These limitations are presented per core study and according to standards of research quality used for systems of enquiry – i.e. truth value, applicability, consistency and neutrality (Groat & Wang, 2002). Accordingly, this can be considered a naturalistic enquiry because it acknowledges the existence of multiple realities shaped by social constructions, which is inherent to the reality of technology campuses[183]. This research has made explicit the researcher's theoretical position on the topic investigated as well as the role of interpretation and creativity in reporting its findings because of the research process is predominantly inductive. Thus, the quality standards through which this research is assessed are referred to as credibility, transferability, dependability, and confirmability (Guba, 1981). Main issues are addressed in each of them and per core study as follows.

183 It can also be referred to as qualitative and interpretative/constructivist enquiry.

§ 9.4.1 Exploratory research

This core study used literature review and a qualitative survey as main methods of data collection and analysis. The literature review lies at the intersection of the three disciplines of corporate real estate management, economic geography and urban studies. In our knowledge, this approach has rarely been attempted before. While the last two fields have been associated earlier, a closely linked model comprising concepts of economic geography, urban studies and CREM theories is unusual. The qualitative survey is rather an unfamiliar method in social research methods compared with the well-known statistical survey (Jansen, 2010). It studies the diversity (not the distribution) of a population with the purpose of description. Since campuses are the subjects under examination, this qualitative survey uses documentation analysis rather than questionnaires for data collection.

This unconventional way to explore methods supposed methodological challenges causing research limitations. Regarding credibility, this exploratory research is documented through multiple sources of data collection (e.g. mostly academic but also non-academic sources). The broad range of disciplines covered in the literature review and the rather unfamiliar topic investigated made difficult to narrow down the focus of the research, especially in the first stage because the volume of literature reviewed became overwhelming. A similar challenge was experienced with the qualitative survey as being simultaneously informed by the literature. The vast amount of data collected from different sources and in different contexts supposed limitations for comparison in a reduced time. The consistency of this data was audited through the design of a protocol that developed and expanded iteratively with the simultaneous insights from theory and empiric. This flexibility in the protocol strengthened the richness of the data collected while at the same time supposed limitations concerning complexity experienced during its analysis. Overall, revisiting and redefining the guiding questions helped to prioritise and select the relevant sources and data analysed in this research.

The empirical data collected in this research is presented in a compendium that describes technology campuses in a systematic way that allows comparison. This information can be applied to other settings for comparison. Overall, the applicability of the main result of this exploratory research (i.e. the conceptual framework) is discussed in the next section because it is an interim finding, which built upon the overall conclusions of this research. Therefore, assessing the applicability of these research findings is not exclusive to one or the other core study but the combination of both, exploratory and explanatory researches.

§ 9.4.2 Explanatory research

This core study used theory building from case studies as a main research strategy. A preliminary arrangement of concepts (resulted from the theoretical and empirical insights from the exploratory research) was applied and verified with two exemplar cases in different contexts. Accordingly, this research combines both, deductive and inductive approaches through a continuous iterative process that concludes with a conceptual model supporting this research thesis. This conceptual model represents 'good theory-building' because it is parsimonious, testable and logically coherent developed throughout- and emerging at the end of the study (Eisenhardt, 1989). This also supposed a broad and open-ended focus in case study research, which was challenging because the outcome was not explicit at the beginning of the research. The quality of the findings is assessed as follows by outlining the limitations encountered in this research in each standard.

Credibility (Truth value)

This research used a variety of data sources for triangulation (e.g. in-depth interviews, documentation, direct observations, and mapping). Next to cross-check data from different sources, some interviewees confirmed via email the data collected through the interviews. A limitation in this regard was encountered because not all the interviews transcripts were confirmed by the experts or key respondents interviewed due to lack of response and time constraints. Nevertheless, the credibility of this research lies in the use of multiple data sources and the combination of data collection techniques, which provided sufficient empirical evidence required in theory building from cases. Indeed, the case studies collected a significant amount of qualitative data (e.g. descriptions, maps and figures), whose analysis provided a good understanding of the mechanism underlying the relationship between innovation and the built environment (i.e. decisions and interventions documented in the cases studies).

Transferability (Applicability)

The conceptual model provides an understanding of the relationship between innovation and the built environment. The insights from the model can be applied to other situations because the relationships in the model are context-dependent. For instance, the knowledge economy is the broad contemporary context, in which stimulating innovation is assumed as a goal pursued by technology-driven organisations to remain competitive. Furthermore, the mechanisms explaining the facilitating role of the built environment in innovation is demonstrated by demand and supply conditions inherent to organisations' processes and location characteristics in local contexts.

This conceptual model is likely to be testable since it emerged from empirical evidence and the constructs have been already measured in the theory building process. For instance, the model developed from two paradigmatic cases in different settings but sharing relative similarities in both, the broad and local contexts addressed above. Although this research did not intend to generalise, it is safe to assume that the findings that emerged from the two cases are not unique and can be found in other campus development processes intended to stimulate innovation.

Accordingly, the conclusions of this research can be transferred but it is limited to cases in relatively similar circumstances and expectations – i.e. contexts where stimulating innovation is a goal and there are sufficient conditions to attain this objective. The close link between the model and the reality makes its result empirically valid but at the same time supposed a limitation because the relationship addressed is not likely to hold in cases lacking the required conditions for innovation specified in the model.

Overall, the conceptual model explains a theory about a particular phenomenon and its logic is suitable to strengthen the theory developed in this research with similar cases. All in all, the logic of the model and its level of abstraction could be used to clarify the relationship between the built environment and other aspects of organisational performance in a comprehensive way and at different scale levels.

Dependability (Consistency)

In case studies, the challenge to integrate many data sources in a coherent way is considered a weakness of this method (Groat & Wang, 2002). The (mainly) inductive approach of this study increased the challenging task of integration. In overcoming this potential limitation, this research followed a carefully analytical procedure. A case study protocol guided the data collection and analysis processes. Besides, the analysis and interpretation of data followed as much as possible the explicit process of 'theory building from case study research' (Eisenhardt, 1989; Eisenhardt & Graebner, 2007). For instance, the use of rich and extensive descriptions, tables, maps, and figures was central to the generation of insights and helped to cope with the analysis process and the enormous amount of data collected. Data saturation became a burden during the analysis and interpretation phases. The systematic use of notes, drawings and diagrams organised trough codes and categories in both, personal diaries, Excel sheets, and online applications helped to solve this issue.

The use of replication logic in case study research contributed to compare two cases that confirmed the emergent relationships enhancing confidence in the validity of the relationships. This approach presented an opportunity to refine and extend the theoretical constructs in the conceptual framework that developed into a model. Therefore, using similar displays and unifying story-telling across the two core studies (i.e. exploratory and explanatory) provided a deep familiarity with the empirical information accelerating the comparison and the generation of observations of identified patterns in the data. Undoubtedly, this iterative analytical procedure helped to sharpen the constructs by displaying enough evidence for each of them with examples, anecdotal reports and descriptions. Though, there is no perfect fit with qualitative data in the end because its analysis relied on human capabilities.

In the end, the amount of data systematically analysed supposed limitations in the process of theory building from case study research. The close link to reality produced a model that is rich in details trying to capture everything, which made difficult to keep the simplicity of the whole. Indeed balancing between simplicity and complexity became a challenge. At first, the conceptual model and the underlying propositions emphasise the most important relationships to look at raising the level of abstraction of the thesis. Because of reaching this level of conceptualisation, the model was unable to display other relationships. The research approach for validating its proposition resulted in a model that exhibits only the facilitating role of the built environment on innovation. Once the relationship between the built environment and innovation has been clarified, a hindering function of the built environment on innovation can be also displayed in the framework. Some aspects of this hindering function are mentioned in the process of theory development, but left out when visualising the emergent theory in the model.

Confirmability (Neutrality)

The potential interference of the researcher in the research process is implicit in theory building from cases. Although case study research is often seen as less rigorous than other research methods, the expectation of subjective and arbitrary judgement does not lie in the lack of rigour, but the degree of strictness compared to other methods (Flyvbjerg, 2006). Instead, the data and interpretations of this research are confirmed by using triangulation and practising reflexivity (Guba, 1981). This research validates a proposition that explicitly states the researcher's position on the subject investigated. This position not only expresses the researcher's theoretical grounds, but is also shaped by the researcher's background as designer, researcher and end-user of campuses. Although there is an influence of the researcher in framing the research questions, the open-ended process in theory building from cases allowed the juxtaposition of unexpected evidence from real life situations, which helped to revise the conceptual framework into a model.

This process was supported by exposure of the theoretical constructs in different phases of the theory development process (i.e. interim presentations with external reviewers and colleagues, brainstorming sessions with the supervisory team and in-person discussions with various peers). This exposure provided several insights (both conflicting perceptions and converging observations) avoiding premature conclusions and influencing changes in the preliminary constructs that emerged throughout the research. In this sense, the open-ended approach of this research strengthened its neutrality because none of the constructs had a guaranteed place in the resultant hypothesis. Last but not least, tying the emergent theory in the model to the existing concepts from the literature and prior knowledge in the research field also enhanced the confirmability of this thesis.

§ 9.5 Further research

This research clarified the relationship between innovation and the built environment at a large and multifaceted scale by studying the development of campuses. To date, the study of campus development has been at the intersection of various disciplines including regional studies, science & technology studies, urban planning, corporate real estate management and architecture. Individually, these disciplines offer various perspectives that address the potential role of campuses in the economic, social and spatial development of organisations, cities and regions. Although these disciplines have shared assumptions, when combined they are overlapping and sometimes redundant, which separately do not offer a coherent whole to explore the campuses' potential in the performance of organisations and cities. This PhD dissertation took a step towards solving this issue by connecting insights from various disciplines including real estate management, knowledge-based urban development and economic geography into a conceptual model. Although the model was empirically validated because its theoretical constructs emerged from cases, its insights can be further explored empirically and in different domains not covered in this study. Exploring the following as future research areas might strengthen the combination of disciplines to scale up the study of campuses as geographical nodes in collaborative knowledge networks.

The impact of organisations' location decisions on organisational- and cities performance

The knowledge developed in this research extended the empirical scope of the concept of added value in corporate real estate management, both at physical and organisational levels. This capacity is outlined through the study of campuses as large-scale built environments, whose developments involve multiple organisations with their goals and interest in innovation. Seeing campus management from this multifaceted perspective allowed this research to provide theoretical grounds for more empirical research investigating the relationship between innovation and the built environment. Although this research had no intention to measure the impact of real estate on organisational performance, the way in which this research established such relationship suggests a pathway for future research seeking to measure performance through real estate.

When focusing on innovation as an aspect of organisational performance, this research suggests that location decisions and related interventions can facilitate five input conditions for innovation in multiple organisations driven by technology. Further research might define performance indicators for these organisations based on these input conditions rather than focusing on outputs as it has been mainly studied. In this way, future research can facilitate to outline the costs and the benefits implicit in organisations' location decisions in innovation. As shown in this model, this requires understanding 'stimulating innovation' as a long-term goal that can be measured after decisions and interventions are implemented. Empirical research developing more indicators and measuring the long-term impact of organisation's location decisions on organisational performance might strengthen the theory emerged in this research.

The role of campus development in urban transformation

The logic of the conceptual model could be extended to the full potential of innovation as a learning process to envision future cities. This extension requires broadening the perspective from which innovation is seen now towards what innovation will mean for cities in the future. In the current model, innovation is a learning process leading to the competitive advantage in different organisational spheres (governments, corporations, and universities). Then, what do innovation and competitiveness mean for these organisations now and in the future? These organisations often look at innovation through different lenses, but they also share mutual goals. Their areas of alignment (and also conflict) need to be identified to address collaboratively societal challenges. Stimulating innovation is already identified as one of these areas.

An extended version of the model sees innovation as a window opportunity to explore competitiveness as a means for collaboration bringing stakeholders together. A competitive city is an attractive, inclusive, networking, and open city. Attaining these attributes requires the collective action of these organisations, which collide during different stages of campus development. Campuses are living laboratories to explore potential solutions to the urbanisation challenge society is facing. They can be seen as both, smaller prototypes of cities and 'the city'. Campus development is an exemplar case of new practices of urban governance. For instance, attracting students and retaining them as future knowledge workers and entrepreneurs in cities has become a shared goal of universities, firms and local governments. They are organising their capacities to attain this goal, which benefits them in different ways because attracting and retaining talented people can lead to positive economic, social, and spatial effects in cities.

The contemporary view of knowledge as the driver of the current economies might lead the shift to the next economies, in which skilled people will strengthen their current position as the most valuable assets of the future cities. There are already exemplar practices of the collective action of organisations using the political 'innovation discourse' that lies at competitiveness when adapting to the dynamic urban transformation of areas towards more attractive, inclusive, sustainable and well-connected cities. Different local actors are collectively working on adapting and re-using the heritage and industrial infrastructure in abandoned or vacant urban areas to accommodate offices and housing tailored to the flexible demands of students and young entrepreneurs. Implementing this has required political, planning and design interventions. Simultaneously, these areas can function as laboratories for testing new green technologies both, at building and area level using citizens' feedback. The role of the public space gains momentum by adding to the urban biodiversity, creating civic places around public amenities, and strengthening walk-ability and transit-oriented development.

Many university- and corporate campuses around the world have already started these types of interventions reaching a level of organisational and spatial integration required to address the urbanisation challenges of future cities. Most campuses have this potential but also pose issues that can be tackled by learning from context-specific experiences. Cities can be envisioned by using campuses as test beds to involve, engage and empower citizens through the urban transformation. This thesis anticipates the future campuses and cities as the co-evolution of not only institutions and technology but also people.

To begin this work, this research recommends testing the tools developed to apply the knowledge embedded in the conceptual model empirically. The already developed 'campus decision-maker toolbox' is a structured way to make use of the understanding provided in the framework targeted to decision makers on the built environment. It contains a set of three tools for three tasks targeted to different professionals in the practice of developing technology campuses (planners, designers, and management). These three tasks can bring together different actors to work collectively on shared goals and learn from context-specific practices. The tools are expected to enhance the campus vision, brief and strategy during the initiation, design and use stages of campus development respectively. The tools can be applied to campuses and related areas targeted to stimulate innovation in relatively similar contexts to those studied, both in the inner city and peripheral locations.

This research provided understanding of the capacity of built environments to support different conditions for innovation, because of the societal demand to promote the development of campuses based on the assumption that the concentration of research activities in one location stimulates innovation. The insights of this thesis may lead to a more efficient use of the many resources employed to develop technology campuses including public and private capital, land, expertise, and time among others. This understanding suggested interventions in the built environment that can have a positive effect in attracting and retaining talent to organisations and cities, which is crucial to stimulate innovation.

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Appendix A Qualitative survey protocol

OVERVIEW QUALITATIVE SURVEY	
Starting point	Knowledge gap about technology campuses from their built environment perspective.
Objective	Uncovering and describing the general patterns in the demand for- and the supply of technology campuses in an international context.
Subject or unit of analysis	Technology campuses in their hosting city/region
Object or analytical frame	The built environment as resources enabling the activities of- and supporting the goals of organisations.
Guiding question	What are the distinct characteristics of technology campuses from the built environment perspective?
Sub-questions	What are technology campuses? When and where did technology campuses emerge and develop? Are there evident patterns in their emergence and development? Who are the stakeholders involved in the development of technology campuses? What are their goals? Are there common patterns in the supply of technology campuses? What characteristics define the supply of technology campuses?
Relevant readings about the subject investigated	Castells, M, & Hall, P. (1994). Technopoles of the World. London Routledge. Carvalho, Luis. (2013). Knowledge Locations in Cities. Emergence and development dynamics. (Doctor), Erasmus University Rotterdam, Rotterdam. Hoeger, Kerstin, & Christiaanse, Kees. (2007). Campus and the City - Urban Design for the Knowledge Society (K. Hoeger & K. Christiaanse Eds.). Zürich: gta Verlag. Link, Albert N., & Scott, John T. (2003). U.S. science parks: the diffusion of an innovation and its effects on the academic missions of universities. International Journal of Industrial Organization, 21. Link, Albert N., & Scott, John T. (2006). U.S. university research parks. Journal of Productivity Analysis, 25(1-2), 13.

Data collection procedures

Sample

This survey describes and compares a sample of 39 technology campuses from 50+ subjects listed through the review of the literature and other non-academic sources (e.g. newspapers, magazine articles, etc.). This selection is based on the consistency and availability of information documented about the subjects, both in existing research and in public documents from primary sources. The amount of subjects in this sample is aimed to be representative of the diversity of built environments matching the preliminary definition of technology campuses. These are built environments that have been deliberately to accommodate technology-based research as core activity of specific organisations. The existing number of built environments matching this definition is unknown. An estimation of 700+ is made based on the amount of science parks registered with International Association of Science parks (IASP); research parks registered with the Association of University Research Parks (AURP); and campuses of universities and colleges of technology included in university rankings. The sample of 39 technology campuses is built based on a scan of subjects meeting the criteria in the following table. The selected subjects are further listed.

CRITERIA	DESCRIPTION
1. Geography	Campuses in different regions of the world that allows an international comparison
2. Time	Campuses that emerged and/or have experienced significant physical changes during and after the post-WWII period, recognised in this research, as the historic periods of major technological developments up today.
3. Data availability	Campuses already built and documented in previous empirical researches and/or in official primary sources (e.g. institutional documents and websites), which are able to be located in open source maps.
4. Subject (option 1)	Campuses of universities of technology meeting the two previous criteria.
5. Subject (option 2)	Campuses that accommodate technology-driven research activities carried out by more than one organisation (e.g. more than one company and/or institute), considering the relevance of 'tech-based research' as an activity that increasingly involves the interaction of government, industry and universities.

NR.	CODE	NAME SUBJECT	NAME CITY - REGION
1	SRP	Stanford Research Park	Palo Alto, California, USA
2	CBTP	Cornell Business & Technology park	Ithaca, New York, USA
3	TUESP	TU/e Sicence Park	Eindhoven, North Bravant, NL
4	AAT	Akademgorodok Academic Town	Novosibirsk, Siberia, RU
5	RCG-TUM	Research Campus Garching - Technical University of Munich	Garching, Munich Metro Region, DE
6	RTP	Research Triangle Park	The 'Triangle region' between Durham, Raleigh, and Chapel Hill, North Carolina, USA
7	ETHSC	ETH Hönggerberg Science City	Zurich, Zurich, CH
8	MIT - UP	MIT Campus & University Park at MIT	Cambridge, Massachusetts, USA
9	DCUT	Drienerlo Campus University of Twente & The Innovation Campus Kennispark Twente	Enschede, Overijssel, NL
10	TUDTIC	TU Delft District & Technopolis and Innovation Campus Delft	Delft, South Holland, NL
11	TSC	Tsukuba Science City	Tsukuba, Ibaraki, JP
12	CSP	Cambridge Science Park	Cambridge, Cambridgeshire, UK
13	SAP	Sophia-Antipolis Park	Côte d'Azur Region, FR
14	TST	Taedok Science Town & Daedeok Innopolis	Daejeon, Hoseo, KR
15	HSP	Hsinchu Science and Industrial Park	Hsinchu City, Northwestern Taiwan, TW
16	SSP	Singapore Science Park	Singapore City-State, SG
17	LBSP	Leiden Bio Science Park	Leiden, South Holland, NL
18	SYRP	Surrey Research Park	Guildford, Surrey, UK
19	WATP	Western Australia Technology Park	Perth, Western Australia, AU
20	OSP	Otaniemi Science Park & Otaniemi Technology Hub	Espoo, Greater Helsinki, FI
21	ST-IPT	Sendai Technopolis & Izumi Park Town Industrial Park	Sendai city, Miyagi prefecture, JP
22	KSC	Kansai Science City	Kansai [unincorporated city], JP
23	ZGCSP	Zhong Guan Cun Science Park	Beijing, CN
24	TPUB	Technology Park Bremen & University of Bremen	Bremen, Bremen, DE
25	BTUC	Brandenburg Technical University Campus	Cottbus, Brandenburg, DE
26	ZJHTP	Zhangjiang Hi-Tech Park	Shanghai, CN
27	TP	Taguspark	Lisbon, PT
28	BAHU	Berlin Adlershof Humboldt University	Berlin, Brandenburg, DE
29	SHIP	Shenzhen Hi-Tech Industrial Park	Shenzhen, CN
30	TSP	Tainan Science Park	Tainan City, TW
31	HTCE	High-Tech Campus Eindhoven	Eindhoven, North Bravant, NL
32	SPA	Science Park Amsterdam	Amsterdam, North Holland, NL
33	BPS	Biopolis	Singapore City-State, SG
34	TCSP	Taichung Science Park	Taichung,Central Taiwan, TW
35	BP	Biocant Park	Cantanhede, Coimbra, PT
36	CRDP	Chemelot Campus	Sittard-Geleen, Limburg, NL
37	BCK	Barcelona City of Knowledge	Barcelona, Catalonia, ES
38	GIANT	GIANT Innovation Campus (Grenoble Innovation for Advanced New Technologies)	Grenoble, Isère, Rhône-Alpes, FR
39	RWTH-RCM	RWTH Aachen University -Research Campus Metalen [expansion]	Aachen, North Rhine-Westphalia, DE

Sources

	DATA COLLECTION PLAN	
	SOURCES	EVIDENCE COLLECTED
Type 1: Document analysis	Academic (e.g. journal papers, books, empirical studies, and other scholar reports)	Broad-coverage information of the subject of study, with facts, details of events, and references of the subject of study.
	Non-academic (e.g. journalism, institutional, governmental, educational, and other public records)	Exact information containing facts, names, references, and details of the subjects of study.
Type 2: Web-based analysis from open access mapping applications	Google Maps	Specific information containing spatial data regarding the accessibility and connectivity of the subjects of study
	Google Earth	Exact information containing details of the physical developments of the campus in different time periods– imagery over time
	Arc Map	Base maps used to confirm data collected
	iTouchMap	Geographic coordinates of the subjects of study

Data overview

In order to have an integral description of technology campuses as built environments, this study uses an approach from CREM/PREM theories (De Jonge, 1997; Den Heijer, 2006), by which campuses are seen as real estate objects from four different perspectives: strategic, financial, functional, and physical. Similarly, the city is seen as the strategic, economic, functional, and physical context of campuses.

CREM perspectives	Strategic	Functional	Financial	Physical
CREM domains	*General management*	*Facility management*	*Asset Management*	*Project management*
Stakeholders	*Policy makers*	*Users*	*Controllers*	*Technical managers*

Based on these perspectives, the data is classified in four sets (strategic, financial, functional, and physical data) next to an additional set of general data. This classification was used to store the data in a computer database (with spread sheet applications), which formed an inventory of built environment information about technology campuses. In order to make this data uniform, categories are distinguished in the inventory due to the diverse ways in which public data is presented by different institutions, scholars, or organisations. An overview of the data collected, inventoried, and controlled is summarised in the following tables. Information about each technology campus is found in Appendix B.

GENERAL DATA This refers to the data used to identify both the objects and their contexts	
Code	Based on the campus name and listing position according to the year
Year	Year of emergence (opening) and/or year in which significant physical changes has taken place (e.g. implementation of Master Plan; start of redevelopment)
Name campus	Official designation as appear in documented sources
Name city	Specific location addressing city, state/region, and country
Description	Brief introduction outlining where the campus are located, their profile or way they are regarded (known-for); the way they have been established if available.

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TOC

GENERAL DATA This refers to the data used to identify both the objects and their contexts	
Official designation of the campus	Three categories are distinguished: (1) Permanent: campuses that have kept the same name since their foundation, (2) Changed: campuses that accommodate changing end-users in relation with transitions in their profiles, and (3) In transition: campuses that are part of current or recent project which has a different name and are referred interchangeable as both denominations.
Geographic coordinates	The official address of the campuses available in their websites is converted into Latitude (X) and Longitude (Y) points by using an open access online application (iTouchMap.com. Mobile and desktop maps). Information displayed on the application is based on content provided by Google, the U.S. Geological Survey and National Geospatial-Intelligence Agency.
Cluster base campus	The industries represented in the campuses differ according the type of research clusters. Three categories of research are addressed: (1) Scientific or fundamental research, (2) Research and development, and (3) Research and development in combination with production.
Economic base of cities	The industries represented in the economic profile of the city. Three categories of data are identified: (1) Consolidated sectors/industries: descriptive data with facts of most representative industries in the economy, (2) Emergent sectors: descriptive data with facts of growing sectors, and (3) Key sectors: descriptive data without facts on priority areas for focus. This category emerged since in many cases, cities outline what they want to become rather than what they actually are.

STRATEGIC DATA **This refers to the qualitative information focusing on institutional strategy (i.e. information through which campuses and cities identify and promote themselves, through institutional and/or official documents over time)**	
Vision campus and Vision City	Based on the diversity of the data collected, the following four categories are identified and organised by their degree of specificity outlining a strategy: (V1) Policy, Strategy or Plan: the name of the specific instrument were the vision of the cities and institutions are contained if available, (V2) Ambition and/or Goals: the general aim and/or specific aims containing in a vision if available, (V3) Concepts and/or Pillars: the core elements throughout the vision is implemented, and (V4) Motto or Slogan: the official words used to identify the core of the vision on their documents or websites.

FINANCIAL DATA **This refers to qualitative data about the stakeholders investing and steering capital resources in the development of the campus (e.g. key development actors, and/or development partners).**	
Campus Funding	Three types of funding are distinguished to identify the ownership and governing structures of technology campuses: (1) Public, (2) Private, and (3) PPP-PublicPrivate Partnership. Nevertheless, when the objects have both public and private funding but a partnership is not officially established, it is outlined as (3a) PP. In cases that have changed their funding structures, the original type of funding is addressed by adding 'Changed' to their classification.
Campus Controllers	These are the advisory and management structures understood as a 'Stewardship that embodies the responsible planning and management of property resources'. This entity is distinguished as the campus manager.
City promoters	These are partners in campus development. Two types of promoters are distinguished: (Prom1) Official Promoter - the external stakeholders who are actively and formally marketing the campus. In some cases, these stakeholders are involved in campus decisions related to the provision of physical infrastructure in the vicinities of the campus. (Prom 2) Unofficial Promoters - the external stakeholders who informally market the campus as a positive brand for the economic development of the city.

FUNCTIONAL DATA

This refers to quantitative and qualitative data about the users of the campus in the context of the knowledge economy. It distinguishes several fields to identify different types and sizes of users and functions accommodated on the campus and its hosting city

Population campus	The size of the population on the campus. Two main categories of population groups are identified: (P1) Employees: workers and/or staff including academic staff, and (P2) Student: in Bachelor, Master and PhD levels. In the case this data is not found, it is replaced by the data available and categorised as 'Other'.
Population City	The size of the population in the city hosting the campus. The data is collected in most of the cases using the last census or the estimates published by the official statistics bureau of each city.
Organisations campus	The number and diversity of end-users' organisations accommodated in campus. There is a distinction on the type of end-users of the campus in three main categories: (E1) Companies: firms or multinational corporations (E2) Academic institutes: faculties, research institutes, and/or offices linked to a university and/or a higher education institution, and (E3) Other Institutes: research centres and institutes. In some cases, universities are part of these research institutes. The total number of organisations is an approximated number estimated on the amount of firms, the amount of the universities or HEI -without considering their institutes, departments or faculties separately; and the amount of other institutes.
Employment City	The size of the population employed in the city. The data focuses on the number of jobs and employed people. If available, the data includes the main employers by staff or by sectors. In the case this data is not found, it is replaced by the data available and indicated as '*' (e.g. percentage of employed population; unemployment rate; active staff, etc.). The data also varies from each region and their ways of measurement.
Tertiary Education City	Quantitative data on the academic knowledge base existing in the city where campuses are located. This field distinguishes two categories: (U) Universities and (HEI) Higher education institutions (e.g. colleges and other institutes that are not regarded as universities). The education systems vary from each region and so the different layers of tertiary education. A distinction in some universities is made outlining their respective rank number as 'R' by crossing data from a previous analysis that used the Top 200 universities (The Higher Education University Rankings 2011-2012).
Campus Amenities	Overview of the variety in the complementary functional space available on the campus besides those accommodating research as core activity (e.g. offices, labs or academic space). Three main categories are distinguished: (F1) Shared facilities: mixed uses in one single facility (F2) Green & Sport facilities: sport halls and courts, landscape features, etc., and (F3) Residential & Care facilities: housing, hotels, day-care, supermarkets, etc. When these functions are planned and not realised yet, the data is categorised as 'F-Plan'. Other facilities that do not fall in these categories are addressed as ' F-Other'
City Amenities	Overview of the size of the available amenities that potentially improve the quality of living in the city, enhancing its international attractiveness as a place to live and work. This field distinguishes four functional categories related to the built environment: (A1) Cultural amenities: theatres and stages, music and concert halls, libraries, museums, art galleries, etc., (A2) Leisure amenities: Shopping centres and malls, retails districts, markets; restaurants, bars and pubs, etc.; (A3) Green & Sport amenities: parks, beaches, lakes, natural reserves, forests, sport halls, and centres.

PHYSICAL DATA

This refers to the physical aspects of the campuses and their surroundings that might help to describe the spatial qualities of technology campuses. It distinguishes several fields outlining different scales, sizes and location characteristics of the objects in relation to relevant structures of their hosting cities according to knowledge-based urban development.

Campus scale	A distinction on the scale of the campus in relation to its urban context in three categories according to their perceived physical boundary: (S) Small - Portfolio in an Area: the campus is perceived as a group of buildings in a defined area (M) Medium - Area in a District: the campus is perceived as an area that is part of the city (L) Large - District or Town: the campus is perceived as a large part of the city and in some cases, as the city itself.
Land use area	Numeric data in hectares of the area occupied by the objects.
City density	Contextual information to place the size of the campus in relation to the size of the city in number of inhabitants per squared kilometre
Transportation city	Contextual information to positioning the campus in relation to the spatial structure of its hosting city. For instance, outlining the main transportation systems in the city provides with an overview of the possible ways to access the object in term of transportation.
Distance	Data exploring the concept of proximity in knowledge based development. For instance, the data collected situates the accessibility of the campus in relation to three important elements of the urban structure for knowledge-based development: (1) Campus's distance from University Campus: Considering the university campus, as a relevant concentration of talent (knowledge workers and students) that accommodates the knowledge base of the city (2) Campus's distance from Core City Centre: This core is mainly associated with the concentration of attractive places for talent. In this research this core centre has been positioned where the functional centre of the city is –e.g. downtowns or CBDs- and/or where the main accessible points are –e.g. central train stations (3) Campus's distance from Airport: this place is associated with the access point for international talent to the campus, considering the relevance of mobility patterns in KBDAccordingly, the campus's distance from these three places is measured in both space and time by using Google Maps as main resource for data collection. For instance, searching directions from the coordinates points where the campuses are located to the destinations described above*.

* The spatial distance is measure in kilometres and the temporal distance in minutes. Both are calculated according to the transportation means (by car, by public transport, walking) used in the analysis. In most of the cases, public transportation is preferred measuring the distance, since it might cover a larger group including young international talent and/or students who commute by other means rather than car. Nevertheless, Google data on public transport is limited to their coverage area, containing data on participating public transit agencies. In cases where this data is not available, car is used to measure the distance.

technopoles creative factories science parks
urban campuses technology parks science cities
knowledge university campuses greenfield campus
locations
tech hightech open innovation university research park
knowledge corporate campuses
hubs campus campuses campuses quarters

technology campuses & cities

A description of built environments accommodating technology-based research

39 research sites 69.600 hectares 37 cities
16 countries 4 global regions 5 built form qualities
5 design/planning concepts 63 years of development 5 topological relationships
6 spatial/functional layouts 21 mixed sources of funding 2 block patterns
5 main ambitions 3 main stakeholders
5 context aspects 11 partnerships 1,3 million users
1 accommodation solution 3 stakeholders' roles

Appendix B Compendium of technology campuses

This description has been undertaken with the objective to build up a definition of 'technology campuses' suitable for the purpose of this PhD research. It provides descriptive data of 39 built environments accommodating technology-driven research activities, as well as the contexts in which they have emerged and evolved. Details about data collection procedures are described in Appendix A. The data of this compendium is presented in two consecutive parts that can be read independently.

In Part I, the data is presented in single pages for each of the campuses and their hosting cities. The data is organised into general, strategic, functional, and physical data. The general data is highlighted in a single column on the outside margin of each page. Symbols are used to identify the last four perspectives in line with Corporate Real Estate management theories as follows.

CREM perspectives	Strategic	Functional	Financial	Physical
CREM domains	*General management*	*Facility management*	*Asset Management*	*Project management*

Similarly, an additional reference is used to categorise the campuses according to their location characteristics as resulted from the analysis of the physical data. The following five topological relations were identified between the campuses and their hosting cities and summarised below. In Part II, these four relationships are used to group the campuses accordingly. This part describes the patterns observed in each group per type of perspective (Strategic, Financial, Functional and Physical)

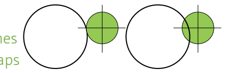
RELATIONSHIP	*DESCRIPTION*	*SUBJECTS*
Equals	City is the same as Campus. It includes those areas that were newly built as towns and/or cities. These were built and planned from scratch to accommodate clusters of technology. They are located only in Asia.	4/39
Contains	City contains Campus. It includes those areas that are inside the urban fabric but they are perceived as distinct campus with borders.	12/39
Overlaps	City and Campuses have multiple points in common. It includes those areas that integrate with the urban fabric and in many cases the borders between the sites and the city are not clearly defined or perceived.	6/39
Touches	City touches Campus. It includes those areas which are located in a border condition in relation with the city. In most of the cases, they are located at the edge of the city. In some cases, they are in the city but their locations hold a border condition e.g. separated by a river, or a highway.	17/39
Disjoints	City shares nothing with the Campus. It includes those areas located in areas outside the city borders but are not a distinguished as independent cities itself.	8/39

NUMBER	CODE	NAME SUBJECT	NAME CITY - REGION
1	SRP	Stanford Research Park	Palo Alto, California, USA
2	CBTP	Cornell Business & Technology park	Ithaca, New York, USA
3	TUESP	TU/e Sicence Park	Eindhoven, North Bravant, NL
4	AAT	Akademgorodok Academic Town	Novosibirsk, Siberia, RU
5	RCG-TUM	Research Campus Garching - Technical University of Munich	Garching, Munich Metro Region, DE
6	RTP	Research Triangle Park	The 'Triangle region' between Durham, Raleigh, and Chapel Hill, North Carolina, USA
7	ETHSC	ETH Hönggerberg Science City	Zurich, Zurich, CH
8	MIT - UP	MIT Campus & University Park at MIT	Cambridge, Massachusetts, USA
9	DCUT	Drienerlo Campus University of Twente & The Innovation Campus Kennispark Twente	Enschede, Overijssel, NL
10	TUDTIC	TU Delft District & Technopolis and Innovation Campus Delft	Delft, South Holland, NL
11	TSC	Tsukuba Science City	Tsukuba, Ibaraki, JP
12	CSP	Cambridge Science Park	Cambridge, Cambridgeshire, UK
13	SAP	Sophia-Antipolis Park	Côte d'Azur Region, FR
14	TST	Taedok Science Town & Daedeok Innopolis	Daejeon, Hoseo, KR
15	HSP	Hsinchu Science and Industrial Park	Hsinchu City, Northwestern Taiwan, TW
16	SSP	Singapore Science Park	Singapore City-State, SG
17	LBSP	Leiden Bio Science Park	Leiden, South Holland, NL
18	SYRP	Surrey Research Park	Guildford, Surrey, UK
19	WATP	Western Australia Technology Park	Perth, Western Australia, AU
20	OSP	Otaniemi Science Park & Otaniemi Technology Hub	Espoo, Greater Helsinki, FI
21	ST-IPT	Sendai Technopolis & Izumi Park Town Industrial Park	Sendai city, Miyagi prefecture, JP
22	KSC	Kansai Science City	Kansai [unincorporated city], JP
23	ZGCSP	Zhong Guan Cun Science Park	Beijing, CN
24	TPUB	Technology Park Bremen & University of Bremen	Bremen, Bremen, DE
25	BTUC	Brandenburg Technical University Campus	Cottbus, Brandenburg, DE
26	ZJHTP	Zhangjiang Hi-Tech Park	Shanghai, CN
27	TP	Taguspark	Lisbon, PT
28	BAHU	Berlin Adlershof Humboldt University	Berlin, Brandenburg, DE
29	SHIP	Shenzhen Hi-Tech Industrial Park	Shenzhen, CN
30	TSP	Tainan Science Park	Tainan City, TW
31	HTCE	High-Tech Campus Eindhoven	Eindhoven, North Bravant, NL
32	SPA	Science Park Amsterdam	Amsterdam, North Holland, NL
33	BPS	Biopolis	Singapore City-State, SG
34	TCSP	Taichung Science Park	Taichung,Central Taiwan, TW
35	BP	Biocant Park	Cantanhede, Coimbra, PT
36	CRDP	Chemelot Campus	Sittard-Geleen, Limburg, NL
37	BCK	Barcelona City of Knowledge	Barcelona, Catalonia, ES
38	GIANT	GIANT Innovation Campus (Grenoble Innovation for Advanced New Technologies)	Grenoble, Isère, Rhône-Alpes, FR
39	RWTH-RCM	RWTH Aachen University -Research Campus Metalen [expansion]	Aachen, North Rhine-Westphalia, DE

Stanford Research Park

Palo Alto, California, USA

Touches
Overlaps



Code: 1-SRP

Year: 1951

Ext. promoters: Prom2: City of Palo Alto play a role as promoter in branding and marketing for business location.

Vision city: V2-Goals: Encourage innovation and technology; Make the inner city attractive and vibrant; Encourage diversification of the economic base./ V4-Motto: "Birthplace of the Silicon Valley"

Funding campus **Private**: Stanford University

Vision campus: V4-Motto: Great ideas growth here.

Controllers campus **Defined**: Stanford Real Estate

By Jrissman (Own work) [CC-BY 3.0] via Wikimedia Commons

financial | strategic

physical | functional

Population campus: **23.000**
[P1-Employees: 23.000] *1990s

Orgs. in campus: **151**
O1:150 companies
O2: 2 offices, 1 School; 1 Library; a Medical Centre and Hospital of Stanford University.

Facilities in campus:
F1: Restaurants, Cafes
F2: University Club; Sport facilities
F3: Hospital, Medical Centre

F1
F2
F3

Official denomination:
Changed: from Industrial Park [origins] to Research Park [today]

Named initially Stanford Industrial Park, was the first of its kind and became the cornerstone of what would eventually be known as Silicon Valley. Nowadays, called Stanford Research Park, is still home to the main headquarters of Hewlett-Packard and recently Facebook's headquarters. Since the early 1990s, many large American law firms have established Silicon Valley branch offices in or near the park.

Scale campus: **M** [Area in a District]

Land use area: **283 ha**

Density city: **1.041** inh./sq km [*USCB, 2010] *converted

Transportation City: Bus, Caltrain and Bike

Population city: **66.363** [USCB, 2012, est.]

Employment city: **98.000**
Main employers-staff: Stanford University

Tertiary education city: **1** university [Stanford University, R-2]

Cluster base campus:
R&D: Mostly scientific, technical and research oriented in the fields of electronics, space, biotechnology, computer hardware and software.

Distance campus from:

Airport	City centre	University
32 km 60'	4,9 km 30'	4,1 km 10'
San Jose Airport	Palo Alto Caltrain Station	Stanford University

Amenities city:
A1: 5 branch libraries, 4 museums
A2: 3 shopping centers; downtown shopping district; >100 restaurants in downtown; 1 amusement park
A3: Several parks; 3 Golf Courses;

A1
A2
A3

Economic base city:
Consolidated: High tech businesses.

Cornell Business & Technology park

Ithaca, New York, USA

Touches

Code: 2-CBTP

Year: 1952

Official denomination:

Permanent: Business & Technology Park

The Cornell Business & Technology Park is a suburban office and lab park, regarded as a place that provides a first class environment for local, national and international office and research firms. The park provides an interface between Cornell University and the business community. A majority of the companies within the park are technology-based, many of which conduct research associated with or derived from Cornell University. (Based: Cornell Real Estate)

Cluster base campus:

R&D: 62% of the companies are technology-based, many of which conduct research associated with or derived from Cornell University.

Economic base city:

Consolidated: shipping port, agriculture, dairy farming, and business machine manufacturing
Emergent: High-technology firms, biotechnology, and electronics. The research activity at Cornell University is largely responsible for this expansion of "clean" industries. Education and Tourism also contribute to the economy.

Vision city: V3-Concepts: "Diversity & Sustainability"
V4-Motto: Ithaca a Model Community: A great place to create, dream, live, learn, work and play.

Ext. Promoters: Prom2: the City of Ithaca play a role as promoter in branding and marketing for business location.

Vision campus: V1-Ambition: Keeping Ithaca a great place to live, by helping companies provide quality jobs, tax revenues, and strengthen the community's economic base.

Funding campus: **Private**: Cornell University and the General Electric Company. When GE announces it is leaving Research Park, Cornell appropriates capital to further the development of the Park, contingent on matching funds from the community. Tompkins County Area Development (TCAD) Corporation assumes primary role of development of the Park.

Google Earth, 2016

Controllers campus: **Defined**: Cornell University Real Estate Department.

strategic | financial

functional | physical

Population campus: 2.000
P1-Employees: 2.000

Orgs. in campus: 81 est.
O1: 80 companies
O2: 4 offices of Cornell University.

Facilities in campus: F1:Cafes & Restaurants
F2: exercise facility, picnic area, waterway
F3: Marriott Courtyard Hotel, child-care center, medical clinics
F-Other: Airport, Post Office.

F1
F2
F3

Population city: 30.331 [USCB, 2012, est.]

Employement city: 14.863 employed
Main employers-sector: Educational services, and health care and social assistance industry

3rd education city: 1 university [Cornell University, R- 20]
HEI: 1 [Ithaca College]

Amenities city: A1: 7 theatres; 8 museums and science centres
A2: Downtown Ithaca Commons pedestrian mall, several restaurants, Farmers market
A3: Several waterfalls and State Parks

A1
A2
A3

Scale campus: M [Area in a District]

Land use area: 121 ha

Density city: 2.151 inh./sq km [*USCB, 2010] *converted

Transportation City: Bus TCAT system [Tompkins Consolidated Area Transit bus trasport system]; Bike

Distance campus from:

Airport	City centre	University
0,8 km <5'	9,6 km 15'	7,5 km 10'
Ithaca Tompkins Regional Airport	Downtown Ithaca	Cornell University

TU/e Sicence Park

Eindhoven, North Bravant, NL

Contains

Code: 3-TUESP

Year: 1957

Official denomination: **Changed**: from University Campus to Science Park

Located at the hearth of the city, TU/e has consulted closely with the municipality of Eindhoven to draw up a development vision for the campus and ascribe it with a more appropriate name: TU/e Science Park. TU/e Science Park will be an attractive place for students, researchers and entrepreneurs to meet, with excellent facilities and amenities. (Source: presentation TU/e Website)

Cluster base campus: **SciResearch+R&D**: Energy, Health and Smart Mobility.

Economic base city: Consolidated: high-tech industrial clusters include mechatronics, the automotive industry and electronics. Emergent: industrial distribution, environmental technology, medical technology and information technology.

Ext. promoters: Prom1: The Municipality of Eindhoven helps to draw the development vision together with the university; Brabant Development Agency (BOM); The City Region Eindhoven (SRE).
Prom2: Brainport Foundation and Brainport Development. The latter is a agency of the Brainport foundation represented by members of the triple-helix, including the university, which task is to drive the region forward and make the economy of the region 'future proof'.

Funding campus: **Private changed from Public**: Eindhoven University of Technology, originally public funded until 1995 when ownership of the campuses was ransferred from the Dutch government to the institutions.

Vision city: V1-Strategy: Brainport 2020
V2-Ambition: to develop the Eindhoven region as an internationally recognised technology region; to position the Southeast Netherlands as a leader in the international knowledge economy.
V3-Concept/Pillars: People; Technology; Business; Basics; Governance ; and international cooperation.
V4-Motto: Top Economy, Smart Society / V4-Slogan City: "Leading in Technology" [Eindhoven City Region].

Vision campus: V1-Plan: From university Campus to Science Park, Masterplan TU/e Science park 2010 - 2020
V3-Concept:The campus will become a 'Living Lab': a laboratory in which researchers and students cooperate with industry to put tomorrow's solutions into practice today
V4-Motto: "Where innovation starts"

Controllers campus: **Defined**: Eindhoven University of Technology Real Estate Management


By Stephane Gaudry from Best, Netherlands [CC BY 2.0] via Wikimedia Commons

financial | strategic

physical | functional

Population campus: **12.361**
P1-Employees: 3.131 including 1.900 academic staff
P2-Students: 9.230 including 4.740 BSc students; 3,070 MSc students; 260 PDEng; 1.160 PhD

Orgs. in campus: **37** aprox.
O1:30 start-up companies aprox.
O2: 9 departments of TU/e;1 HEI-Fontys University of Applied Sciences
O3: 5 research institutes.

Facilities in campus:
F1: conference centres; shops
F2: sport facilities; cultural centre; park and water corps
F3: Student housing

Scale campus: **S** [Portfolio in an Area]

Land use area: **70,4 ha** [75 ha including 2 plots around]

Density city: **2.499** inh./sq km [2011]

Transportation City: Interlocal Bus lines, National railway network,bike infrastructure, the 'Phileas'; a regional bus rapid transit; served by Eindhoven Airport

Population city: **219.173** [CBS, 2013]

Employment city: **>145.000** [2009]
Main employer-sector: Consultancy, Research and Specialised services

Tertiary education city: **1** university [Technology University of Eindhoven,R-115]
HEI:2 [Fontys Fontys University of Applied Sciences and the Design Academy]

Distance campus from:

Airport	City centre	University
9 km 30'	1 km 10'	≤1 km ≤15'
Eindhoven Airport	Eindhoven Central Station	Eindhoven University of Technology

Amenities city:
A1: 4 large museums and serveral smaller museums; 1 international school; big public library
A2: shopping centre 'De Heuvel Galerie', amusement park "Efteling"
A3: Genneper Parks, Stadswandelpark, Dommeldal and the wood at Strijp

Akademgorodok Academic Town

Novosibirsk, Siberia, RU

Equals

Code: 4-AAT

Year: 1957

Official denomination:

Permanent: Academic Town

Akademgorodok, ("Academic Town" in Russian) is a scientific research city located near Novosibirsk at the northeast corner of the Novosibirsk Reservoir, south-central Russia. Akademgorodok is home to numerous research institutes and is the seat of the Siberian Branch of the Russian Academy of Sciences. It is, with Moscow and St. Petersburg, an important research and educational centre in Russia. Nowadays Akademgorodok houses Academpark; an integrated technology park with unique business and technological infrastructure providing ideal conditions for the generation and the development of innovative companies as well as the development of existing innovative productions; it is regarded as a place where research turns into industrial technologies.

Cluster base campus:

R&D: technologic development in microelectronics and nanoelectronics, ray and laser technologies, catalysis technologies, advanced materials, information technologies, and biotechnologies.

Economic base city:

Consolidated: Novosibirsk's economy is based on industries [aircraft, nuclear, engineering, power, metal working, and pharmaceutics], trade, services, transport, construction, science, and scientific services.

Vision city: V2-Ambition: Sustainable improvement in the quality of life of the general population of Novosibirsk; in the welfare of the inhabitants; in the economic growth potential.
V3-Concept: Strategic Sustainable Development [Translated Novosibirsk, 2004]

Ext. Promoters: Prom2:The Administration of Novosibirsk region addresses AAT as Novosibirsk Scientific Center (NSC) and promotes it as a pillar in the presentation of the region.

Vision campus: V2-Ambition:Conceived as a milieu of scientific innovation to serve the industrial development of Siberia and the Sovietic Union.

Funding campus: **PPP-Changed from Public** Akademgorodok started as scientists dream supported by the socialist government planning in the 60s.After the transition to a market economy in the 90s, the Administration of Novosibirsk region together with the management of the Siberian branches of the Russian Academies of Sciences carried out a range of works on the establishment of a Scientific and Technological Park (Technopark) "Novosibirsk" in this territory of the region.

By Elya [GFDL or CC-BY-SA-3.0] via Wikimedia Commons

Controllers campus: **Undefined**: Akademgorodok Academic Town is part of the Municipality of Novosibirsk. The Siberian branches of the Russian Academies of Sciences addresses Novosibirsk and AAT as the central location of the Siberian Branch. Nowadays, large projects in AAT that involve urban area development are beign presented by the Siberian Branch of the Russian Academies of Sciences.

functional | physical

Population campus: **70.000**
[Residents: 70.000] *1990s

Orgs. in campus: **256** aprox.
O1: 220 companies
O2: Novosibirsk State University
O3:>35 research organs of the Siberian Branch of Russian Academy of Sciences.

Facilities in campus: F1: Shopping centre, cinema, bars, supermarkets, billiard and night clubs
F2: saunas, sport grounds; Botanical garden
F3: residential areas

F1

F2

F3

Population city: **1.400.000** [Census 2010]

Employement city: **750.000** [in Novosibirsk]

3rd education city: **14** universities in Novosibirsk
HEI: 7 academies, and 15 institutes including 12 branches of higher education institutions based in other cities.

Amenities city: A1: 15 theatres
A2:the Novosibirsk Zoo,Planetarium Children's and Youth Centre

A1

A2

A3

strategic | financial

Map image: Esri 2013

Scale campus: **L** [District or Town]

Land use area: unknown

Density city: **2.833,4** inh./sq km

Transportation City: Trans-Siberian Railway, 4 railway stations, buses, trolleybuses, trams, taxicabs, shuttle taxicabs and a subway

Distance campus from:

Airport	City centre	University
44 km 120'	28 km 70'	≤1 km ≤15'
Tolmachevo Airport	Novosibirsk-Glavny Station	Novosibirsk State University

Research Campus Garching - Technical University of Munich

Garching, Munich Metropolitan Region [EMM], DE

Disjoints

Code: 5-RCG-TUM

Year: 1957

Ext. promoters: Prom1:Municipality of Garching promotes higher education and research at TUM as a pilar for the economic development of the region as a business location. Also, developing and planning infrastructure [e.g.The design of the B11 in 2012, the construction of office buildings and research that should be available at the TU Munich]

Vision city: V2-Ambition Region: to increase the attractiveness of the entire economic space in the greater Munich. It focuses on four areas of action: knowledge; economy; mobility; and Environment & Health. [Munich Metropolitan Region Inititative (EMM)]
V2-Concept Garching: Science and research as a business location is a key driver and evolving the brand of Garching./
V4-Slogan Garching: "City will be city, town remain!"

Funding campus: **Public & Private**: The state has invested around 1,3 billion euros in the TUM's Garching infrastructure since 1995. The Budget of the university comes from these sources: study fees; state subsidies; Third Party Funding; and own income (e.g. research, medical care, materials testing). In 2007-2008 a pan-European investor competition was conducted and the grouping of several medium-sized Bavarian company won - the first PPP project at Bavarian universities.

Vision campus: V2-Ambition: new ways toward a competitive university of international standing [2006 Excellence Initiative]
V4-Motto:"TUM. The Entrepreneurial University" [Institutional Strategy]

Controllers campus: **Defined**: Real Estate Management Department at TUM Central Administration

By Graf-flugplatz (Own work) [CC BY-SA 3.0] via Wikimedia Commons

Official denomination: **Permanent**: Campus

financial | strategic

physical | functional

Population campus: 15.000
P1- Employees: 5.000
P2- Students: 10.000

Orgs. in campus: 15 aprox.
O1: 7 companies
O2: 4 departments and 1 faculty of TUM
O3: 7 research institutes

Facilities in campus: F1 F2 F3
F1: restaurants, cafes
F3: kindergarden
F-Plan: Recreational facilities, an integrated shopping mall and various restaurants [* 2007]

The Garching Campus has developed in the north of Munich from the Neutron Research Facility (1957) as a science and engineering campus. The concentration of scientific and technical research institutions and companies work in areas ranging from basic research to the development of high-tech applications.

Scale campus: S [Portfolio in an Area]

Land use area: 170 ha

Density city: 4.440 inh./sq km [Munich EMM]
576 inh./sq km [Garching]

Transportation City: European Railway network - ICE high-speed trains; Underground railways and suburban trains; Tramway ~ Regional buses, Underground railways; Taxi [Munich EMM ~ Garching]

Population city: 5.500.500 [Munich EMM]
16.901* [Garching, 2012]

Employment city: 2.100.000 [*Munich EMM, 2010]
Main employers-sector: Education and teaching 22,2%; Business services 18,6%; Information Technologies 16,4%.

Tertiary education city: 15 universities in Munich [2 in Garching including Technical University of Munich, R-88; and a research site of the Ludwig-Maximilians-University of Munich, R-45]

Cluster base campus: **SciResearch+R&D**: fields of TUM faculties are chemistry, mechanical engineering, computer science, mathematics and physics. Research institutes specialise in areas such as Medical Technology, Semiconductor Physics and Catalysis.

Distance campus from:

Airport	City centre	University
17 km 15'	23 km 55'	≤1 km ≤15'
Munich Airport	Munich Hauptbahnhof	Technical University of Munich

Amenities city: A1 A2 A3
A1: 452 museums, 165 theaters, 15 monuments ~ City library, 1 theatre
A3: 4 national parks; 7 winter sport areas; 89 pools ~ Garden park and lake; sport area
[Munich EMM ~ Garching]

Economic base city: Consolidated: Innovative and future-oriented high-tech industries [aerospace and electronics, vehicle and machine construction], service sector [media, banking and insurance trades] ~office location and service production
Emergent: information and communication sector ~ research and development.
[Munich Metropolitan Region ~ Garching]

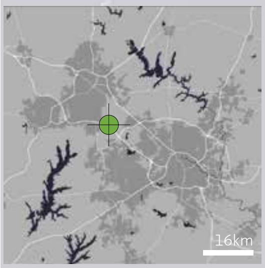
Disjoints

Research Triangle Park

The “Triangle region” between Durham, Raleigh, and Chapel Hill, North Carolina, USA

Code: 6-RTP

Year: 1959



Official denomination:

Permanent: Park

Leaders in business, government and academia together framed an ambitious plan to transform thousands of acres of woods and farmland into one of the world’s first science parks. The fruit of this vision, the Research Triangle Park (RTP), has been a resounding success, leading the way in creating a more diverse, knowledgebased economy and generating considerable prosperity in the region and in the State of North Carolina as a whole. [Source: RTP Master Plam, Research Triangle Foundation of North Carolina, 2011]

Cluster base campus:

R&D: Biotechnology & life sciences, clean & green energy, advanced gaming & e-learning, information technology.

Economic base city:

Key industries: Technology, Life Sciences; and Cleantech.

Vision city: V1-Strategy: Regional economic-development strategy 2009-2014
V4-Motto region:The Shape of Things To Come
V4-Slogan region: “Work in the Triangle, smarter from any angle”

Ext. Promoters: Prom1:The Research Triangle Region actively promotes RTP as main place to work under the flagships “Work in the Triangle, smarter from any angle” Research Triangle Regional Partnership (RTRP) is a business-driven, public-private partnership dedicated to keeping the 13-county Research Triangle Region economically competitive through business, government and educational collaboration.

Vision campus: V1-Plan: The Research Triangle Park Masterplan, November 2011
V3-Concepts/Pillars: Employment, Innovation and Sustainability
V4-Motto: the future of great ideas.

Funding campus: **PPP**:The Research Triangle Foundation of North Carolina. State and local governments teamed up with the universities and local business to construct RTP. The existing land use is 16% RTP Foundation [For sale sites, headquarters, and Natural Area Preserve]; 13% roadways; 71% leaseholders and research companies

By RTI International [CC BY-SA 3.0] via Wikimedia Commons

Controllers campus: **Defined**: The Research Triangle Foundation of North Carolina manages the sites and expansion services in campus.

strategic | financial

Map image: Esri 2013

functional | physical

Population campus: **38.000**
P1-Employees: 38.000

Orgs. in campus: **173** est.
O1:170 companies
O2:TUCASI campus -Triangle Universities Center for Advanced Studies Inc. is the home of the three Founding Universities [Duke University, NC State University, and UNC-Chapel Hill]

Facilities in campus: F1 F2 F3
F2: Park and natural area
F3: Hotel
F-Plan: Cafes and other retail uses, active open space, shared business support services and shared conference facilities.

Population city: **761.244** [UCSB 2012, est]
*Data combined Durham, Raleigh, and Chapel Hill

Employement city: **362.578** [*Data combined Durham, Raleigh, and Chapel Hill, 2011]
Main employers-sector: technology industry accounts for nearly 50,000 jobs

3rd education city: **5** universities [including Duke University, R-22, North Carolina State University, University of North Carolina at Chapel Hill, R-43]

Amenities city: A1 A2 A3
A1:>20 museums
A2: >15 shopping malls
A3:several parks
[in the Triangle region]

Scale campus: **L** [District or Town]

Land use area: **2830 ha**

Density city: **833** inh./sq km aprox. [*Data combined Durham, Raleigh, and Chapel Hill, USCB, 2010]

Transportation City: Triangle Transit [City Bus Service, Regional Bus Service]; Nationwide Bus Service; Taxi; Ridesharing Services; Raleigh–Durham International Airport]

Distance campus from:

Airport	City centre	University
11 km 40’	13,5 km 30’	3 km 5’
Raleigh Durham International Airport	Durham Station	TUCASI campus [3 universities in campus]

ETH Hönggerberg Science City

Zürich, Zürich CH

Touches

Code: 7-ETHSC

Year: 1959

Ext. promoters: Prom2:The current vision of the City of Zurich "2000-Watt Society" was developed at the Swiss Federal Institute of Technology (ETH). In the Education and Knowledge portrait of the city, ETH is presented as the flagship of Swiss college. In the history of the City, the universitoes -including ETH- and cultural bodies areaddressed as a pillars in Zürich as an economic, scientific and cultural centre.

Vision city: V1-Policy: "2000-Watt Society" developed at ETH is a model for energy policy which demonstrates how it is possible to consume only as much energy as worldwide energy reserves permit and which is justifiable in terms of the impact on the environment.

Funding campus: Private & Public: ETH operates with 75% Government funds and 25% Third-party funds (2012). "Realizing the Vision Together": The numerous architectural projects on site could only be realized with the help of generous sponsors. Also in the future ETH Zurich will rely on strong partners from the economy as well as private donors, in order to provide an optimal environment and to maintain its international reputation as a leading technical school.

Vision campus: V1-Strategy: ETH strategic orientation 2012-2016 and Real Estate Strategy 2008-2011/2015 approved by the Board of ETH Zurich.
V2-Ambition: Achieving Sustainability: by 2025, the campus can be largely CO2-free.
V3-Concept: Culture of empowerment, making space for creativity and supporting innovative ideas. A dominant theme is the idea of networking on all levels. ETH strategy for 2012-2016: sustainable growth as the guiding theme
V4-Motto Institution: "Where the Future begins"
V4-Motto campus: 'City district for thinking culture'

Controllers campus: Defined: the Vice President of Human Resources and Infrastructure is responsible for the management of construction projects including the corresponding relations to the public and political authorities as well as the management of the real estate portfolio. ETH Zurich Property develops and implement a real estate strategy.

By GurkanSengun [Public domain] via Wikimedia Commons

financial | strategic

Scale campus: S [Portfolio in an Area]

Land use area: 32 ha

Density city: 4.289 inh./sq km [2011]

Transportation City: Trams, buses, ferries, suburb trains and funiculars; international rail links including high-speed trains; Zürich airport

Distance campus from:

Airport	City centre	University
14 km 15'	6 km 26'	≤1 km ≤15'
Zürich Airport, Kloten	Zürich Hauptbahnhof	ETH Zürich

physical | functional

Population campus: 8.800
P1-Employees: 3500
P2-Students :5300 [*2007]

Orgs. in campus: 11 aprox.
O1:10 companies planned [*2007]
O2:7 ETH departments

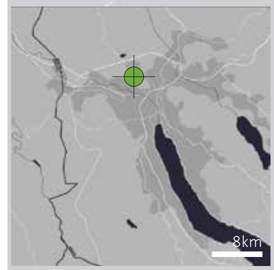
Facilities in campus: F1 F2 F3
F1: Mobile cafes and food, market, central auditorium
F2: sports, 365.000 m2 of green space, 4 gardens
F-Plan: The university intends to build a total of 900 rooms for students on the campus by 2015.

Population city: 376.990 [2011]

Employment city: 362.012 [2008]
Main employers-sector: 90% of employed are in the service sector.

Tertiary education city: 2 universities [ETH Zürich, R-15; the University of Zürich, R-61]
HEI:3 [The Pedagogical College, the Zürich University of Applied Sciences and the Zürich University of the Arts]

Amenities city: A1 A2 A3
A1:>50 museums, >100 galleries, Opera House, several architecture attractions and heritage sites
A2: >135 stores in city, shop district street; several international restaurants
A3: natural park , public gardens, mountain, lake and rivers for hiking activities, adventure parks and zoo.



Official denomination:
Changed: from Campus to Science City [today]

Hönggerberg campus is located on the outskirts of the city of Zurich. It is presented by the university as "a perfect example of the links between science, industry and the general public". The ETH intends in the coming years for its location on the Hoenggerberg to develop its education and research facilities as well as continue to create a dynamic city quarter with an attractive environment in which people live and interact.[Source Science City website]

Cluster base campus:
SciResearch: main areas are Sustainable worlds; Technology and knowledge for health; Complex systems; Materials, Technologies and industrial processes; Scientific foundations of the future.

Economic base city:
Consolidated: The finance sector generates around a third of the wealth and a quarter of the jobs in the city. Various innovative businesses and industries.
Emergent: Biotechnology, life sciences [currently enriching the medical tech sector] the automotive supplier industry, aerospace and the creative economy.

Overlaps

MIT Campus & University Park at MIT

Cambridge, Massachusetts, USA

Code: **8-MIT - UP**

Year: **1960** [*Masterplan]

Official denomination:

Permanent: Campus. [New developed areas have distinct names]

Located in Cambridge since 1916, this campus accommodates a private university: MIT. this campus had a period of expansion and change after WWII. In 1949 a review of MIT's organization and misson called for the development of a new campus plan. In 1960, a Campus Master Plan established the ground rules for the campus future development. This plan has been reviewed, amended and improved every five years, but its basic goals have served as the standards for physical decisions regarding the evolution of MIT's campus [Simha, R.O. 2001] In 1983 MIT developed in partnership with Forest City, University Park at MIT: a 11 ha development located directly adjacent to the MIT Campus. The project successfully integrates scientific research facilities with more than 670 residential units, a hotel and conference center, retail amenities, and more.

Cluster base campus:

SciResearch: Fields of study at MIT include architecture; engineering; management; science; humanities, arts, and social sciences **+ R&D**: Biotechnology companies settled at UP.

Economic base city:

Consolidated: life-sciences and technology business.

Vision city: V2-Ambition: The City of Cambridge is dedicated to maintain its competitiveness and desirability as the place to live, work, and do business
V4-Slogan: Cambridge - the heart of innovation!

Vision campus: V1-Plan: MIT 2030 is a living framework that guides our planning activities, with a focus on fulfilling the MIT mission and keeping the innovation engine running well into the 21st century.
V3-Concepts: Innovation and collaboration; Renovation and renewal; Sustainability; Enhancement of life and learning
V4-Motto University: "Mind and Hand"
V4-Slogan MIT 2030 framework: Envisioning, Renewing and Building for the future.

Ext. Promoters: Prom2: The City of Cambridge, presents MIT as an institution with a large impact on the economy of the region. The Institute is Cambridge's second largest employer and largest taxpayer; and The Cambridge Community Development Department [CDD] is developing important areas [University Park inLower Cambridgeport and Kendall Square in east cambridge] that serve the MIT community.

Funding campus: **Private**: MIT Corporation [board of trustees]. MIT is a coeducational, privately endowed research university. With a campus located between Central and Kendall Squares, and across the Charles River from Boston, the Institute has an optimal position to engage in collaborative endeavors with its neighbors and give back to the community.

By DrKenneth (Own work) [CC BY 3.0] via Wikimedia Commons

Controllers campus: **Defined**: MIT Investment Management Company (MITIMCo) in two teams: The Investment team supports MITIMCo's mission by sourcing, executing and managing investments in accordance with their Investment Principles [incl. Rea Estate team]; The Operations team supports MITIMCo's mission by managing MIT's financial resources. MIT Department of Facilities [Campus Planning, Engineering, and Construction (CPEC)] works with the Office of the Vice President for Finance, MITIMCo and other stakeholders to identify the Institute's current academic priorities and development goals. When a top priority emerges, a working group of key stakeholders charged by the Committee for the Review of Space Planning (CRSP)

functional | physical

Population campus: **26.489** aprox.
P1-Employees: 11.000 MIT staff including Faculty (1.753)
P2-Students: 11.189
Others-University Park: 3500 employees and 800 residents

Orgs. in campus: **16**
O1:No companies in campus property due to MIT's tax-exemption status ~ 15 companies in University park
O2: 5 schools; 56 Interdisciplinary Centers, Labs, & Programs of MIT.

Facilities in campus:
F1: museum and art centre, cafes, library ~ retail
F2: 10,5 ha of playing fields ~ parks and open space with public art
F3: 19 students residences ~ residential area, 668 rental apartments and MIT graduate students dormitories
[MIT campus ~ University Park]

Population city: **106.471** [USCB, 2012, est.]

Employement city: **59.018** [USCB, 2011]
Main employers-sector: biotechnology companies with 8.000 workers;
Main employers-staff: Harvard University and MIT

3rd education city: **2** universities [Harvard University, R-2; Massachusetts Institute of Technology, R-7]
HEI: 2 [Lesley College and Cambridge College]

Amenities city:
A1: Main Library and 6 branches; 6 museums
A2: 7 commercial districts [retails, hotels, restaurants and shops]
A3: 1 Golf Course; 80 Parks, Playgrounds and Reservations;

strategic | financial

Scale campus: **M** [Area in a District]

Land use area: **67,9 ha**

Density city: **6.361** inh./sq km [*USCB, 2010]

Transportation City: Two subway lines with 6 stations and one commuter rail station; 29 bus routes through Cambridge that connect to Boston MA; EZ Ride Shuttle; network of pedestrian walkways and bikeways. Served by Logan International Airport in Boston

Distance campus from:

Airport	City centre	University
8 km 40'	1,4 km 15'	≤1 km ≤15'
Logan International Airport	Cambridge Central Square	MIT

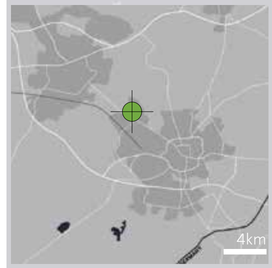
Drienerlo Campus University of Twente & Kennispark Twente

Enschede, Overijssel, N

Touches

Code: 9-DCUT

Year: 1961



Official denomination:

In transition: from Campus to Park

Drienerlo Campus is the campus of the University of Twente located between the cities of Hengelo and Enschede. The innovation Campus Kennispark Twente integrates in an area the Campus of the University of Twente and the Business and Science Park.

Ext. promoters: Prom1:The Foundation Kennispark Twente is a joint initiative of the University of Twente, the City of Enschede, the Region of Twente, the Province of Overijssel and the Saxion University of Applied Sciences.

Vision city: V1-Strategy: Development Vision Network City Twente 2040, June 2013
V3-Concept/ Pillars: the urban quality; collaboration and respect for complementary diversity.
V4-Slogan: Enschede, where the sky's the limit.

Funding campus: **PPP** in transition from Private [Originally Public]: Foundation Kennispark Twente is a joint initiative of the University of Twente, the City of Enschede, the Region of Twente, the Province of Overijssel and the Saxion University of Applied Sciences. The University of Twente and the city of Enschede have partnered up to make sure the area becomes and stays a state of the art innovation campus and have initiated several projects. The University of Twente and its campus was originally public-funded until 1995 when ownership of the campuses was ransferred from the Dutch government to the institutions.

Vision campus: V1-Plan: Kennispark Area Development Masterplan
V2-Ambition: to create an attractive business climate. Through Kennispark Twente the Foundation Kennispark Twente share the economic development goal of creating 10.000 new jobs for the region.
V4-Motto campus: Empowering Innovation & Entrepreneurship
V4-Motto Institution: High Tech, Human Touch

Controllers campus: **Defined** [in transition]: Since 1995 the university became owner of Drienerlo campus. Today, the university has a campus management section called The Eenheid Campus which consist of the Booking office, Event office, Vrijhof Culturecentre and the Sports centre. The University of Twente and the city of Enschede have partnered up to make sure the area becomes and stays a state of the art innovation campus.

By Daiancita (Own work) [CC BY-SA 3.0] via Wikimedia Commons

financial | strategic

physical | functional

Population campus: **19.690** est.
P1-Employees: 6.300 commercial jobs, 3.000 scientific positions and 2.630 staff from University of Twente
P2-Students: 7.760

Orgs. in campus: **381**
O1: 380 companies
O2: 6 faculties of the University of Twente

Facilities in campus: F1:conference centres; film and music studios; stages
F2:sport facilities
F3: Student housing and hotels

F1
F2
F3

Scale campus: **M** [Area in a District]

Land use area: **180 ha** aprox.

Density city: **1.122** inh./sq km

Transportation City: National railway network, Interlocal Bus lines; served by Enschede Airport Twente; Bike infrastructure

Population city: **158.194** [CBS, 2013, est.]

Employment city: **80.742** [active staff, 2011]
Main employers-sector: 19% in Health care & Welfare; 16% Business

Tertiary education city: **1** university [University of Twente, R- 200]
HEI: 1 [Saxion Hogeschool]

Cluster base campus:

R&D: ICT, biotechnology and nanotechnology

Distance campus from:

Airport	City centre	University
92 km, 2h30'	4,1 km, 20'	≤1 km, ≤15'
Münster Osnabrück International Airport	Enschede Central Station	University of Twente

Amenities city: A1:2 Museums, >5 Theatres and concert halls, several restaurants and pubs.
A2: 1 shopping centre and 350 shops
A3: 1 football stadium; several parks.

A1
A2
A3

Economic base city:

Key industries: Twente is specialist in High Tech Systems [nanotechnology; mechatronics; sensing, monitoring and imaging; semiconductors; industrial printing; hightech engineering] and Materials.

TU Delft District & Technopolis and Innovation Campus Delft

Delft, South Holland, NL

Overlaps
Touches

Code: 10-TUDTIC

Year: 1961-65

Official denomination:

In transition: from TU-District [TU-Wijk in Dutch] to Innovation Campus [in TIC Masterplan]

Firstly established in the inner city, TU Delft gradually moved to the Wippolder, a district in the South of Delft. In the period of 1961 to 1965 a large number of buildings were located in the Wippolder [Baudet, H, p430] Currently, the campus has three main areas: North, Centre and South with different characteristics and strategies. The south will become Science Port Holland, developed between the municipalities of Delft and Rotterdam, adding large related business and stimulating university-industry interaction. [Den Heijer, 2011] The Technopolis and Innovation Campus Delft [TIC-Delft]currently on planning phase, cover the area where TU-Delft District is located

Cluster base campus:

SciResearch: Health & Lifesciences; Cleantech; Infrastructures & Water; High Tech Systems & Materials Creative Industry

R&D: Ambition for TIC is focused on Water and Delta technology; ICT, industrial biotechnology, and health and life sciences; and smaller concentrations of organisations active in nanotechnology, aerospace, industrial design and architecture.

Economic base city:

Key sectors: The region South-Holland focuses on two themes: medical technologies and clean technology aligned with both the Dutch agenda on science and innovation policy, the 'top sectors' initiative, and the European research agenda Horizon 2020.

Vision city: V1- Strategy Region: Zuid-Holland Structural Vision 2020 ~V1-Strategy City: **Delft City of Knowledge Strategy** since early 90s
V2-Goals: strengthening of specific sectors and promoting entrepreneurship. ~V2-Goal Region: Rotterdam, Delft and Leiden have the ambition to be in the top 3 of knowledge and innovation regions of Europe by the year 2025.
V4- Brand City: "Delft, City of Innovation"

Vision campus: V1-Plan: Campus vision 2030
V2-Goals:to make the campus an integrated part of the city of Delft by increasing density – of floor area and people – and allowing other and related functions on the large campus ~V2-Ambition TIC-Delft: Linked to the expertise of TU Delft, the area will be developed into an engine for R&D activities and High Tech production.
V4-Motto University: "Challenge the future" ~ Slogan TIC-Delft: 'Driving force of the Randstad knowledge Economy"

Ext. Promoters: Prom1:The Municipality of Delft, is actively involved with the university in the development of a masterplan for the TIC-Delft. / The Province of Ziud Holland outline TUDelft Campus and TIC-delft as a cluster of knowledge intensive activity of a so-called knowledge axis in the region. The province authorities aim to develop this axis since they are of economic importance for the region.

Funding campus: **Private changed from public**: TU Delft was publicly funded by the Dutch government until 1995 when the ownership of the campus was transferred to the institution. Nowadays, TU Delft owns and manages its building complexes and land. Large-scale projects often require the involvement of external parties. Real Estate Development maintains contacts with e.g. the municipality of Delft, 'Stadsgewest Haaglanden' (Haaglanden Regional Authority), DUWO, TNO, private developers, The Hague University of Professional Education, INHOLLAND University and other university real estate organisations.

By M8scho (Own work) [CC BY-SA 4.0] via Wikimedia Commons

Controllers campus: **Defined**: TU Delft Real Estate Development is responsible for the development and realisation of the TU-wide real estate strategy. The activities of Real Estate Development include the initiation, definition and coordination of real estate investment projects, controlling and directing the internal and external use of space in the buildings, the preparation of real estate transactions (purchase, sale and leasehold) and the strategic developments that reach beyond the campus.

functional | physical

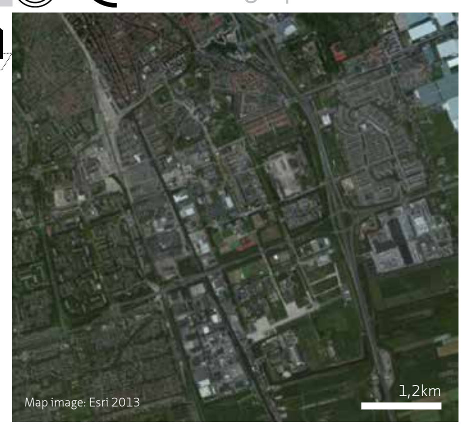
Population campus: **22.860**
P1-Employees: 5.330 TUD staff including 3.070 academic [* 2011 in den Heijer]
P2-Students: 17.530

Orgs. in campus: **39** aprox.
O1: 19 TU Delft Enterprises; >15 star-ups
O2: 8 Faculties and 26 research institutes of Delft University of Technology; 2 HEIs
O3: 2 independent Research Insitutes [Deltares & TNO]

Facilities in campus: F1: cultural centres; restaurants; library; central auditorium
F2: sport centre and sport fields; central park
F3:Student housing
F-Plan: shops and commerce

F1
F2
F3

strategic | financial



Population city: **98.727** [CBS, 2013]

Employement city: **45.685** [2008]
16.531 employed are knowledge workers (36,1%) [Gemeente Delft, 2010]

3rd education city: **1** university [Delft University of Technology, R-104]
HEI:2 [InHolland and De Haagse Hogeschool]

Amenities city: A1: 13 Museums, 23 art galleries and ateliers; souvenirs shops; historic monuments and architecture; several event and festivals; 1 library; 2 cinemas, 1 theater
A2: 65 cafes and pubs; 121 restaurants and bars serving meals
A3: 2 sport halls; 2 swimming pools; lake and woods.

A1
A2
A3

Scale campus: **M** [Area in a District]

Land use area: **162 ha** [500 ha TIC-Delft Masterplan]

Density city: **4.326** inh./sq km [2011]

Transportation City: National railway network, Interlocal bus and tram lines; Delft is served by Rotterdam-The Hague Airport and Schiphol Airport; bycicle infrastructure.

Distance campus from:

Airport	City centre	University
48 km 60'	2,5 km 10-15'	≤1 km ≤15'
Schiphol Airport	Delft Station	Delft University of Technology

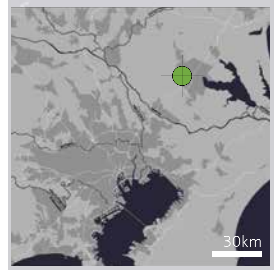
Tsukuba Science City

Tsukuba, Ibaraki, JP

Equals

Code: **11-TSC**

Year: **1968**



Official denomination:

Changed from Town [Tsukuba Creation Act] to International Strategic Zone including 9 industrial parks and 4 development areas [Today].

Surrounded by farmland and located about 60 km Northeast of Tokyo, Tsukuba is an early science city designed as a new satellite town and it was conceived totally as a government promoted scheme. Tsukuba Science City was built in order to ease congestion of Tokyo and to conduct high-level research and education by transferring national research and development, and educational institutions systematically. The city is now the largest science technology accumulation site among the country, where more than 300 public and private institutions and enterprises are located. [based on city website]. TSC is segmented into the Research and Education District and the Suburban District.

Cluster base campus:

SciResearch + R&D: Technologies with a focus on Life Innovations and Green innovations.

Economic base city:

Key sectors: Life innovation and Green innovation.

Ext. promoters: Prom1:"Tsukuba Global Innovation Promotion Agency" has been established as a central unit of academic-industrial cooperative system which mainly promotes business in International Strategic Zone. Tsukuba Science City Network (TSCN) with 103 members, works on research exchange and other common issues, to keep the vision of the city as stated in the Third Science & Technology Basic Plan.

Funding campus: **PPP in transition from Public**

TSC was a national research centre, funded totally by government. Nowadays, a new industry-government-academia collaboration system is to be constructed to change Tsukuba by using a preferential legal and tax measures that are available in the zone. The government bought land only for public facilities. A Land Readjustment Program witholds land for public insfrastructure such as parks and roads, and redistributes the land in proportion to the original land holding.Tsukuba involved 10 coperative groups with over 3000 land owners [Nishimaki, 2001]

Controllers campus: **Defined**: As International Strategic Zone Tsukuba is managed by the Planning Department, Science and Technology Promotion Division.

Vision city: V1-Policy:Tsukuba is designated as International Strategic Zone in Japan. The ISZs commit to industrial promotion given advantage on regulatory standard requirements and financial help from governmental body and local autonomy.

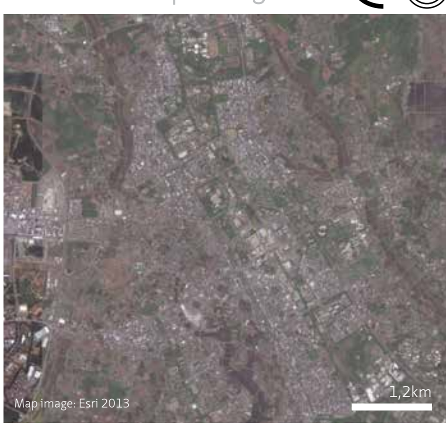
V4-Motto City: "Innovate today to create the future"

Vision campus: V1-Policy: "Comprehensive Special Zone for International Competitiveness Development" is a system aiming to form an integrated base for industry and function which can be an engine of Japan's economic development. It comprehensively enforces the special regulatory measures and tax, fiscal and financial support measures regarding regional comprehensive and strategic effort.

V4-Motto Campus: "Innovate today to create the future"

By On-chan (Own work) [CC BY-SA 3.0] via Wikimedia Commons

financial | strategic



Scale campus: **L** [District or Town]

Land use area: **28.500 ha**

Density city: **757,5** inh./sq km

Transportation City: Express railway [Tsukuba express is a rapid connection to Tokyo]; intracity bus lines; express tollway [Joban expressway]; served by Narita International Airport and Haneda Airport.

Distance campus from:

Airport	City centre	University
55 km 100'	62 km 60'	≤1 km ≤15'
Narita International Airport	Tokyo	Tsukuba University

physical | functional

Population campus: **214.000** [Residents:214.000 including 20.000 public and private researchers]

Orgs. in campus: **583** aprox.

O1: >550 companies
O2: 2 universities
O3: 31 research institutes and centres

Facilities in campus:

F1: >100 restaurants and bars; 4 cultural facilities including a museum; 5 libraries
F2:146 parks; sport facilities; 48 km of "pedestrian-only paths"
F3: Residential areas

Population city: **214.590** [Japan Statistics Bureau, 2010]

Employment city: **1.420.000** [in Ibaraki, JSP 2010]
Main employers-sector: 292.000 in Manufacture in Ibaraki ~ 20.000 public and private research jobs in Tsukuba

Tertiary education city: **2** universities inTSC [University of Tsukuba and Tsukuba University of Technology]

Amenities city:

A1-A2: >100 restaurants and bars; 4 cultural facilities including a museum; 5 libraries
A3:146 parks; sport facilities; 48 km of "pedestrian-only paths"

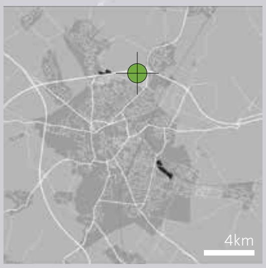
Touches

Cambridge Science Park

Cambridge, Cambridgeshire, UK

Code: 12-CSP

Year: 1970



Official denomination:

Permanent: as Science Park

Located at the north-east outskirt of the city, Cambridge Science Park was established by Trinity College in 1970 and is regarded as the UK's oldest and most prestigious science park, attracting new businesses, from small start-ups and spin-outs to subsidiaries of multinational corporations. The development of the park was a response to a report by the Mott Committee [a special Cambridge University Committee] published in 1969 that recommended an expansion of 'science-based industry' close to Cambridge to take maximum advantage of the concentration of scientific expertise, equipment and libraries and to increase feedback from industry into the Cambridge scientific community.

Cluster base campus:

R&D: Biomedical; Computer/ Telecoms; Consulting (Technical); Energy; Environmental; Financial, Business and other Non-Technical; Industrial Technologies; Materials.

Economic base city:

Consolidated: research and development, higher education, software consultancy, high value engineering and manufacturing, creative industries, pharmaceuticals, agriculture, processing and tourism.
Emergent: The hi-tech sector is generating national strengths in creative industries and clean technologies; important growth sectors.

Vision city: V4-Slogans: "Cambridge: where people matter - Cambridge: a good place to live, learn and work - Cambridge: caring for the planet"

Vision campus: V4-Motto: 40 years of Innovation

Ext. Promoters: Unknow: In official economic reports, the University of Cambridge is addressed as one of the innovation strengths of the region and also as a major attraction for tourists. Nevertheless, the campus is not promoted by any mean in city/regional council websites.

Funding campus: **Private**: The campus is property of Trinity College, which started the development and retains the majority ownership and control of the Park, and Trinity Hall since 2000. A joint venture between Trinity College and Trinity Hall (which owns the adjacent land) completes the remaining area of brown field development land adjacent to the Park.

Google Earth, 2016

Controllers campus: **Defined**: CSP's Management is organised in five sections: Property Manager; Press and Media; Site Manager; Conference Centre Trinity Centre; Innovation Centre.

strategic | financial

functional | physical

Population campus: **5.000** aprox.
P1-Employees: 5.000 aprox.

Orgs. in campus: **100** aprox.
O1:>100 companies

Facilities in campus:
F1: conference facilities; restaurant and bar
F2: health and fitness centre; recreational walks and jogging paths in 20 acres of landscaped grounds; squash courts
F3: child care nursery;

Population city: **123.867** [Census, 2011]

Employement city: **89.700** [employed, 2010]
Main employers-sector: 41% public sector; 26% Knowledge intensive jobs (teaching, research and health professions); 15% hi-tech sector

3rd education city: **2** universities [University of Cambridge, R-6 and the local campus of Anglia Ruskin University]

Amenities city:
A1: 10 museums, 2 theatres; cinemas; architecture and heritage buildings, community centres, events and festivals
A2: bars and clubs; traditional pubs; markets
A3: swimming pools, parks and playgrounds, sports centres

Scale campus: **S** [Portfolio in an Area]

Land use area: **61,5 ha**

Density city: **3.040** inh./sq km [Census 2011* converted]

Transportation City: Local Bus routes linking Park and Ride sites; Cambridgeshire Guided Busway bike infrastructure; railway network direct connection with London; served by own airport Cambridge Airport used mainly for business.

Distance campus from:

Airport	City centre	University
6 km 40'	6 km 30'	5 km 30'
Cambridge Airport	Cambridge Railway Station	University of Cambridge

TOC

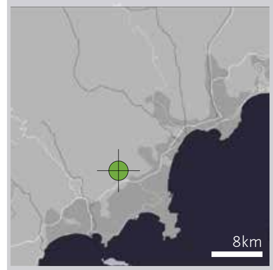
Sophia-Antipolis Park

Côte d'Azur Region [CDAz], FR

Disjoints

Code: 13-SAP

Year: 1972



Official denomination:

Permanent: as Park

Ext. promoters: Prom1: Invest in Côte d'Azur Team is the promotion and economic development agency of the Côte d'Azur Nice Sophia Antipolis region. They actively present the park as an important place for the economy of the region. Team Côte d'Azur is the entry point for investors and entrepreneurs who want access to economic, technological and institutional networks of the Alpes-Maritimes in general and especially Sophia Antipolis.

Funding campus: **PPP** originated Private: SYMISA is a Sophia Antipolis based public-private partnership formed by public authorities and local companies responsible for the future of the technology park. The State is land owner of almost one hundred hectares with urban development potential in this region. The first impulse for the creation of the technopole started from a private initiative of Pierre Laffitte, who conceived the project and was able to involve other key actors in its making. The organisation of Sophia Antipolis became wider, varied and made up of authoritative political and economically active players who contributed to legitimize Pierre Lafitte's project.

Controllers campus: **Defined**: SYMISA is a Sophia Antipolis based public-private partnership that brings together public authorities and local companies responsible for the future of the technology park.

Vision city: V1-Strategy:Economic development strategy Region PACA [Provence-Alpes-Côte d'Azur]
V4-Motto: "Innovating for better life"

Vision campus: V1-Plan: Sophia Antipolis 2030 planning and sustainable development
V2-Ambition: to give rise to a green area, in which "knowledge workers" of various cultures and profiles could meet and exchange their knowledge.
V3-Concept: "cross-fertilisation" between training, research and production, focusing on human values.
V4-Motto: "Le Site intelligent d'Europe" [The European Smart Site]; "a City of Science, Culture and Wisdom"

By Ouuups (Own work) [CC BY-SA 4.0] via Wikimedia Commons

financial | strategic

Map image: Esri 2013

Scale campus: **L** [District or Town]

Land use area: **2.320 ha** [60 ha occupied]

Density city: **155,7** inh./sq km [Provence Alpes CDAz]

Transportation City: CDAz offers vary railway networks served by national or regional companies; and Regional Bus networks. The bus lines connect to Nice Airport. Envibus network connects 24 municipalities in the Urban community of Sophia Antipolis.

Distance campus from:

Airport	City centre	University
21 km 25' (car)	14 km 20' (car)	≤1 km ≤15' (walk)
Nice Côte d'Azur Airport	Gare d'Antibes	Sophia Antipolis University Campus STIC

physical | functional

Population campus: **30.000** est.
P1-Employees: 25.000 workers of whom 4.000 are public sector workers
P2-Students: 5.000 [2008]

Orgs. in campus: **1.415** est.
O1: 1.414 enterprises
O2: University of Nice-Sophia Antipolis

Facilities in campus: F1 F2 F3
F2:open-air mall with a post office, bakery, restaurants, hairdresser, farmacy, Internet cafe, two supermarkets
F3:Residential area two hotels and a church [In the mixed area of Garbejaire]

Population city: **4.889.053** Provence Alpes CDAz region [2009]

Employment city: **1.877.500** [CDAz region 2009]
Main employers-sector: IT accounts for 46% of all new jobs generated; The services sector 25% of total jobs.

Tertiary education city: **1** university [University of Nice-Sophia Antipolis]
HEI: 7 [Polytech' Nice-Sophia, the Eurecom Institute; ICTS grad. program, the Ecole Nationale Supérieure des Mines de Paris, CERAM Sophia Antipolis, EDHEC and IAE]

Amenities city: A1 A2 A3
A1: 84 museums, >500 cultural events a year including Cannes Festival; 150 art galleries; 2 opera houses; several theatres; dozen international schools
A2: 3,000 restaurants; many hotels and resorts
A3:40 kms of beach; 14 ski resorts; 9 natural parks

Sophia-Antipolis Park is located in Côte d'Azur region between the cities of Nice and Antibes. It is regarded as a multicultural, multidisciplinary community focused on innovation, which has served as the model for competitiveness clusters in France. [Based on Presentation Region Cote d'Azur]

Cluster base campus:

R&D: computer science, electronics and telecommunications [reresentative]; life sciences and health [growing]; natural sciences and the environment [small share].

Economic base city:

Key sectors: Information Technology; Aeronautics & Space; Life Sciences; Fragrances; Services and Corporate Functions; Call Centers; Tourism; Clean Technologies; Environmental Sciences.
High attraction site for R&D and Services industry.

Taedok Science Town & Daedeok Innopolis

Daejeon, Hoseo, KR

Equals

Code: 14-TST

Year: 1974-78

Official denomination:

Changed: from Town [originally] to Special Research and Development Zone [today]

Located 160 km south of Seoul, Taedok was entirely conceived, built and for many years managed by the Central Government and its subordinate local agencies, through the Ministry of science and technology [Based on Castells]. The Science Town is regarded as an important milestone for science and technology in Korea. Today, the INNOPOLIS Daedeok [a cluster of interconnected organizations in industry, academia and public and private research] brings these efforts to fruition. In 2000 the Daedeok Valley was announced with the first entry of hi-tech companies. In 2004 the region has been publicly designated and set aside by the government in accordance with the Special Act on the Support of Daedeok Special Research and Development Zone. [Based on Innopolis website]

Cluster base campus:

R&D: Information technologies IT; Biotechnology; nanotechnology; Space technology; Energy and environmental technology.

Economic base city:

Consolidated: Research and Development, logistics, service and convention business.
Key sectors: The region has been publicly designated as Daedeok Special Research and Development Zone.

Vision city: V1-Policy= Daedeok Special Research and Development Zone.
V4-Slogan= It's Daejeon!

Ext. Promoters: Prom2: Daejeon City promotes Innopolis as an important economic asset of the region within the Economy and Industry Bureau.

Vision campus: V2-Ambition=To power Korea beyond the $40,000 per capita GNP level while building an innovative economy.
V3-Concept/Pillars= through a dynamic ecosystem of knowledge creation, technology expansion and entrepreneurship.

Funding campus: **Originally Public:** Starting with establishment of the Daedeok Science Town, many government-sponsored research institutes were located there. Nowadays, the INNOPOLIS Daedeok is presented as cluster of interconnected organizations in industry, academia and public and private research and designated as a special Research and Development Zone.

By Yoo Chung (Own work) [CC BY-SA 3.0] via Wikimedia Commons

Controllers campus: **Defined**: The Innopolis is managed and controlled by INNOPOLIS Foundation [a non-profit organization, Legal basis for establishment: Article 46 of the Special Act on the Support of Daedeok Special Research and Development Zone] Its main role is the Commercialization of research achievements by creating a technology commercialization base, transferring technology and commercializing research results. The foundation is organised in two divisions: Planing & Management Division and Strategy Development division.

functional | physical

Population campus: **62.689**
P1-Employees= 62.689
[including 26.493 researchers and engineers, 2011]

Orgs. in campus: **275** aprox.
O1: 133 companies
O2: 5 HEIs including 4 universities
O3: 49 research institutes, 30 government agencies; 11 public institutions; 14 national agencies; 33 non-profit organizations.

Facilities in campus: F3: Housing

F1

F2

F3

strategic | financial

Population city: **1.500.000** [Daejeon, 2012]

Employement city: **726.000**
[Economically Active Population*]

3rd education city: **4** universities [KAIST, R-94; Chungnam National University; Hannam University; Korean University of Science and Technology]

Amenities city: A1: dozens Museums and art galleries; Daejeon observatory; archeological sites; 5 art & cultural centres; 10 cinemas; several festivals
A2: shopping malls; traditional markets
A3: several Parks and Eco-recreational Forests, Theme parks; Natural Spa; 2 large Sport facilities

A1

A2

A3

Scale campus: **L** [District or Town]

Land use area: **2.800 ha**

Density city: **2.780** inh./sq km

Transportation City: Railway [2 lines]; Express Bus network; Airport limousine and taxi; intercity bus; expressway and subway lines;

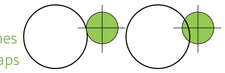
Distance campus from:

Airport	City centre	University
150 km 2-3hrs	28 km 45'	≤1 km ≤15'
Incheon Airport	Daejeon Station	KAIST and 3 other universities

Hsinchu Science and Industrial Park

Hsinchu City, Northwestern Taiwan, TW

Touches
Overlaps



Code: **15-HSP**

Year: **1980**

Ext. promoters: Prom1:Hsinchu City Government promotes itself as a Taiwan high-tech community and HSP is the flagship of the Business promotion; The Industrial Development Bureau, Ministry of Economic Affairs also promotes HSP as "Science-based industrial parks" in their network of Industrial parks.

Funding campus: **Public**: HSP is set up by The National Science Council and funded by the government driven by central government's policy initiative.

Controllers campus: **Defined**: Under the jurisdiction of the National Science Council, the Science Park Administration (SPA) is given the responsibility of developing, operating and managing the park. The SPA is composed of six divisions--Planning, Investment Services, Labor Relations, Business, Construction Management and Land Development.

Vision city: V1-Policy: Regional spatial planning initiatives [HSP Special District,1981; Hsinchu Science City Development Plan , 1990; Taiwan Knowledge-based Flagship Park development project 2000s] V2-Goals: Capitalize on technological advantages, and upgrade city administration and service; Showcase cultural creativity, and implement LOHAS city; Improve educational environment, and increase competitiveness; Take care of the disadvantaged, and actively protect the homeland.

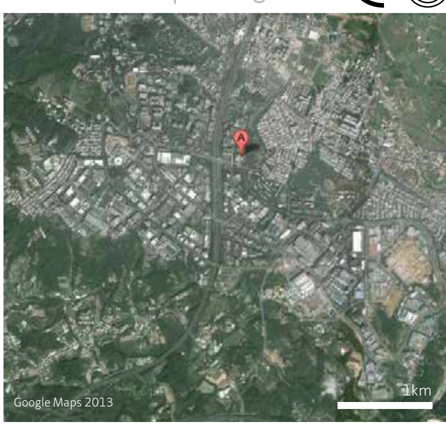
Vision campus: V2-Ambition: Nurture a quality investment environment conductive to the national economy. V2-Goals: Improve the park as an investment environment; Promote across-the-board technology upgrade to enhance the competitiveness of park tenants; Build a low-carbon park running on green energy; create an environment conducive to sustainable development; Strengthen cooperation across industry, government, academia and research institutions to boost the park's R&D capacity V3-Pillars: efficiency, honestly, competence and loyalty

Google Earth, 2016

Official denomination: **Permanent**:Science and Industrial Park [sometimes regarded as High-tech Industrial park]

Located in northwestern Taiwan, the HSP was established as an environment for R&D, production, work, everyday life and even recreation in Hsinchu city and the county. In addition to its home base in Hsinchu, the HSP currently has five satellite parks. The HSC Development Plan project in the 1990s, and the Taiwan Knowledge-based Flagship Park development project in the 2000s were the two most important spatial planning and development projects in Hsinchu city-region that had been brought into national economic development plan. [Based on Wei-Ju Huang, 2013]

financial | strategic



Google Maps 2013

Scale campus: **M** [Area in a District]

Land use area: **653 ha**

Density city: **3,952** inh./sq km

Transportation City: Express way and railway network.

Distance campus from:

Airport	City centre	University
50 km 2h 40'	5,5 km 45'	2 km 5'
Taiwan Taoyuan International Airport	Hsinchu train station	National Chiao Tung University

physical | functional

Population campus: **131.168**
P1-Employees: 131.168 [2012]

Orgs. in campus: **422**
O1: 422 companies

Facilities in campus: F1 F2 F3
F2: parks, leisure areas, with basketball courts, tennis courts, swimming pools and golf driving ranges.
F3: residential areas with dormitories for singles and married couples; schools.

Population city: **393.557** [2006]

Employment city: **176.000** [2006]

Tertiary education city: **6** universities [National Tsing Hua University, National Chiao Tung University, National Hsinchu University of Education, Chung Hua University, Hsuan Chuang University, Yuanpei University]

Amenities city: A1 A2 A3
A1:cultural heritage buildings and monuments; art museum
A3:17 km of coastline with several parks and fishing ports; the 18 peaks mountain as leisure site; 19ha green infrastructure in Grassland natural park and lake.

Cluster base campus: **R&D+Production**: semiconductor manufacturing, computer, telecommunication, and optoelectronics industries. Increasingly complete industry chain in LCD, LED and solar panel.

Economic base city: Consolidated: semiconductor, optoelectronics industry, computer and peripherals, telecommunication, precision instrument and biotechnology.
Key sectors: The strategic priority industry Investment focuses on Commercial Technology; Fashion Boutique; Health Care and International Tourism.

TOC

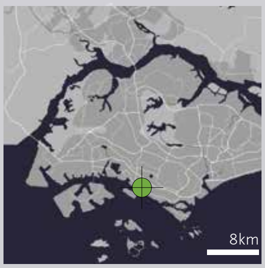
Singapore Science Park

Singapore City-State, SG

Contains

Code: 16-SSP

Year: 1982



Official denomination:

Permanent: as Science Park

Strategically located along the so-called Singapore's "Technology Corridor", the park is in close proximity to research and tertiary institutions such as the National University of Singapore (NUS), National University Hospital (NUH) and one-north, Singapore's biomedical R&D hub. The SSP has been an integral part of the technology policy that underpins Singapore's economic growth strategy. Like many Asian science parks, one of the initial motivations of the SSP was to provide and upgrade local infrastructure to house Multi National Corporations as well as new industries that require proximity to higher education institutions [based on Koh et.al., 2005]

Cluster base campus:

R&D: Biomedical sciences; Information technology; Software development; Telecommunications; Electronics; Food technology; Flavours and fragrances; Materials and chemical.

Economic base city:

Key sectors: biomedical sciences, engineering, logistics, healthcare, maritime, info-communications and digital media.
Consolidated: 48% Electronics industry; 26% Manufacturing; 26% Financial business.
Emergent: centralised or "shared services" such as IT, finance, and logistics.

Vision city:

V1-Plan: The Strategic Economic Plan [1991]
V2-Ambition: to attain the status and characteristics of a first league developed country within the next 30 to 40 years;
V3-Concepts: economic dynamism, a high quality of life, a strong national identity and the configuration of a global city.
V4-Motto: "A Developed country in the first league"

Ext. Promoters: Unknown

Vision campus:

V2-Ambition: to be a focal point for R&D and innovation in Singapore and the region.
V2-Goal: to outline Singapore's willingness to develop high-tech industries.

Funding campus:

Public: SSP is developed with government funding. The provision of infrastructure went beyond just physical facilities, and included the creation—with government encouragement in the form of tax breaks and other incentives—of a supporting infrastructure for the MNCs. Singapore's science park strategy has until recently been driven largely by the government. Private sector participation was limited

Google Earth, 2016

Controllers campus:

Defined: In 1990, Jurong Town Corporation [today JTC Corporation, Singapore's principal developer and manager of industrial estates] established a subsidiary company Technology Parks Pte Ltd to manage the Singapore Science Park on a commercial basis.

Nowadays, Ascendas develops, manages and markets SSP. In 2002, Ascendas launched Ascendas Real Estate Investment Trust (A-REIT). The group has two divisions controlling the case; Development & Project Management; Property & Estate Management.

strategic | financial

functional | physical

Population campus: **9.000** aprox.
P-Other-Community: 9,000 researchers, engineers and support staff

Orgs. in campus: **350** aprox.
O1/O3: >350 MNCs, local companies and national institutions

Facilities in campus:

F1:Foodcourts, restaurants and cafeterias; Auditorium and conference facilties
F2: fitness centre with gym, swimming pool, tennis courts, aerobics and weights studios; Intra-park
F-Other: inner university bus shuttles

F1

F2

F3

Population city: **5.353.494** [2012]

Employement city: **3.290.000** [*national labour force 2012]

3rd education city: **4** universities [the National University of Singapore, R-40; the Nanyang Technological University, R-169; the Singapore Management University; and the Singapore University of Technology and Design]

Amenities city:

A1:>50 Museums, several multi-cultural festivals
A2:>140 major shopping centres; several restaurants and bars that open 24/7; thematic attractions and parks [Universal studios; and the oceanarium]
A3:>300 parks and 4 natural reserves, 2800 trees/ sq km

A1

A2

A3

Scale campus: **S** [Portfolio in an Area]

Land use area: **65 ha**

Density city: **7.497,9** inh./sq km

Transportation City: Network of 4 Mass Rapid Transit - MRT train lines, Light rapid transit [LRT] or shorter trains. 387 bus services and 8 taxi companies; Changi International Airport

Distance campus from:

Airport	City centre	University
30 km 1h 40'	12 km 60'	3 km 30'
Changi International Airport	Downtown Core Singapore	National University of Singapore

Leiden Bio Science Park

Leiden, South Holland, NL

Contains
Overlaps

Code: 17-LBSP

Year: 1984

Ext. promoters: Prom1:The Province of Ziud Holland outline Leiden Bioscience park as a cluster of knowledge intensive activity of a so-called knowledge axis in the region. The province authorities aim to develop this axis since they are of economic importance for the region.
Prom2: The Dutch Ministry of Economic Affairs addresses the park as one of the only six campuses of national importance in the Netherlands.

Funding campus: **PPP**: Leiden Bio Science Park foundation was set up in 2006. The current stakeholders of the foundations are: City of Leiden; City of Oegstgeest; Leiden University; Leiden University Medical Center (LUMC); OV BSP, the entrepreneurial society of the park, representing the companies at the science park; Hogeschool Leiden (University of Applied Sciences); ROC Leiden (school for vocational training); Chamber of Commerce, The Hague area; Province of South-Holland; TNO, the Dutch Institute of Applied Technology; Naturalis Biodiversity Centre, the national museum of natural history.

Controllers campus: **Defined**: The development of Leiden Bio Science Park is managed the Leiden Bio Science Park foundation. The foundation aims to attract new life sciences related companies and institutes, promote the park and strengthen its life science cluster by managing projects and stimulating the network. The park management of Leiden Bio Science Park is run by the entrepreneurial society OV BSP. The OV BSP aims to represent the interests of companies and institutes at Leiden Bio Science Park, promotes communication and anticipates current economic and social developments. The OV BSP is an intermediary for all the relevant authorities, either directly or through industry associations.

Vision city: V1-Strategy: Leiden Knowledge City [2012/13] International knowledge as a pillar
V2- Ambition: develop a permanent place at the top of European knowledge regions whith life sciences and health as priorities.
V3-Concepts/pillars: Knowledge transfer, business environment and acquisition; Attractive student housing and living environments; Knowledge and culture; Care, health and social innovation; International branding and marketing; Excellent education and to the labor market.
V4-Motto: Leiden, Key to Discovery.

Vision campus: V2-Ambition: to develop further into a more complete cluster in terms of size and quality, with companies and institutions in all phases of development, from research companies to production companies and suppliers.
V4-Motto: key to discovery.

Google Earth, 2016

Official denomination:

Permanent: as Science Park

financial | strategic

Scale campus: **M** [Area in a District]

Land use area: **110 ha** [75 ha including 2 plots around]

Density city: **5.471** inh./sq km

Transportation City: Interlocal Bus lines, National railway network,bike infrastructure, served by Amsterdam Schiphol Airport

Distance campus from:

Airport	City centre	University
30 km 30'	1 km 15'	≤1 km ≤15'
Amsterdam Schiphol airport	Leiden Central Station	Leiden University

physical | functional

Population campus: **15.500**
P1-Employees:15.500 [2011]

Orgs. in campus: **154** est.
O1: 117 companies
O2: 7 educational institutes
O3: 12 research institutes; 9 care related orgs and 9 other orgs.

Facilities in campus: unknown
F1
F2
F3

Population city: **120.088** [CBS, 2013]

Employment city: **59.985**
Main employer-sector: Human health and social: 15.613 and Education: 8.814
Main employers-staff: The LBSP, the Leiden University Medical Centre and Leiden University.

Tertiary education city: **1** university [Leiden University, R-79]
HEI: 1 [University of Applied Sciences Leiden]

Amenities city: A1:12 museums, theatre,monuments, cultural centres; ancient alleyways, canals and moats
A2:shopping centre, market; congress centres;
A1
A2
A3

Leiden Bio Science Park is located next to the access point of the city, in close proximity to the city centre. It is regarded as the leading life sciences cluster in the Netherlands. LBSP is fully dedicated to biomedical life sciences and offers opportunities for both start-ups and established companies. [Based on presentation in official website]

Cluster base campus:

R&D: Medical life sciences.

SciResearch: Leiden University and LUMC focuses on 11 multidisciplinary themes, 5 of which are in life science and health.

Economic base city:

Key sectors: knowledge-intensive cluster. The coming years will focuses on the bio-based economy and innovation in healthcare. Also strengthen the services of insurance and pension opportunities. These sectors have a relationship with the Life Science sector, but will also broaden the economy.

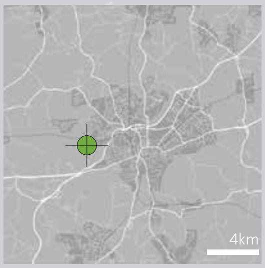
Surrey Research Park

Guildford, Surrey, UK

Touches

Code: 18-SYRP

Year: 1984



Official denomination:

Permanent: as Research Park

Surrey Research Park is located in the county town of Guildford, South East of England. The low density development is part of the University's campus in Guildford, and provides a working environment. [Based on official text from the website of the park]

Cluster base campus:

R&D: sciences, including social sciences, technologies and engineering activities.

Economic base city:

Key sectors: commercial, retail and leisure activities. The agricultural activities of the rural areas of Guildford make an important contribution to the economy.

Vision city: V1-Strategy: Guildford Borough Sustainable Community Strategy (SCS) (2009 – 2026) adopted in October 2009. This sets out the community's aspirations and establishes how partners intend to enhance the long-term economic, social and environmental wellbeing of the Borough.
V2-Ambition: An attractive, sustainable and prosperous Borough in which people fulfil their potential and the disadvantaged and vulnerable receive the support they need.

Vision campus: V2-Ambition: to support companies involved in the commercialisation of a wide range of sciences, including social science, technologies, health related activities and engineering.

Ext. Promoters: Unknown

Funding campus: **Private**: University of Surrey

Google Earth, 2016

Controllers campus: **Defined**: Research Park Management. Its work had concentrated both on routine activities (e.g. promoting and marketing the park and attracting new tenants; property management; providing business services and facilities for tenants; public relations; raising finance and grants from Government and/or other agencies) and on activities supporting tenants and the university (e.g. fostering links between the university and park tenants; fostering links between on-park firms; fostering links between on-park tenants and off-park firms; legal advice to tenants and the university concerning patents and licensing)

strategic | financial

functional | physical

Population campus: **Unknown**

Orgs. in campus: **110** aprox.
O1: 110 companies

Facilities in campus: F1: Café
F2:Landscaped areas and park

F1

F2

F3

Population city: **129.000** [Guildford Borough, 2003]

Employement city: **75.000** employed [2010]
Main employers-sector: Construction 38.5%; Agriculture, Manufacture and Utilities 34% and Leisure 36%.

3rd education city: **2** universities [the University of Surrey; The University of Law]
HEI: 2 [Battersea College of Technology; and Guildford School of Acting]

Amenities city: A1:>1,000 listed buildings and 38 Conservation Areas [cathedral; castles]; museums; concert hall; theatre.
A2: traditional high street shopping; 2 shopping centres;restaurants and pubs
A3: gardens and parks; sport complex

A1

A2

A3

Scale campus: **S** [Portfolio in an Area]

Land use area: **28,3 ha**

Density city: **2.151** inh./sq km [*USCB, 2010] *converted

Transportation City: Bus network [national, regional and local], railway with direct lines to London, Portsmouth, Reading and Gatwick. There are two trains each hour from Gatwick Airport to Guildford.

Distance campus from:

Airport	City centre	University
55 km 60'	5 km 30'	1,7 km 20'
Gatwick Airport	Guildford Station	University of Surrey

Western Australia Technology Park

Perth, Western Australia, AU

Contains

Code: 19-WATP

Year: 1985

Official denomination:

Permanent: as Technology Park

Located less than 6 kilometres from Perth; Western Australia's capital city, Technology Park is situated adjacent to the Curtin University of Technology. Technology Park is home to a number of organisations representing industry, R&D, academia, government and support services. Technology Park was opened in 1985 under provisions of the Technology and Industry Development Act. [Based on presentation in official website]

Cluster base campus:

R&D: Information technology and telecommunications, renewable energy and clean technologies and life sciences.

Economic base city:

Consolidated: Mining
Emergent: resource sector and non-residential construction activities.
Key sectors: Tourism and the creative industries are an important component within the City of Perth regional economy.

Ext. promoters: Prom1:The Department of Commerce within the Industry & innovation division, promotes WATP as Western Australia's premier location for technology driven and innovative organisations dedicated to information technology and telecommunications, renewable energy and clean technologies and life sciences.

Funding campus: **Public**: The Park is an initiative that supports the caseives of Government of Western Australia. The Minister for Industry and Innovation, under the Industry and Technology Development Act 1998, considers all lease applications, extensions and transfers of land in the Park.

Controllers campus: **Defined**: The Government of Western Australia, through the Department of Commerce, administers the Park, located in Bentley. New tenant applications are assessed by the Department and recommendations are made to the Minister for Commerce; Science and Innovation.

Vision city: V1-Strategy: Towards a Vision for Perth in 2029 [June, 2000]
V2-Ambition: connected and informed capital city with a unique identity and an economy that is diverse, resilient and adaptable
V3-Concept/Pillars: Unique Operating Environment; Advocacy & Engagement; Business Development will provide strong support and active encouragement for knowledge economy sectors, innovators and small businesses.

Vision campus: V2-Goals: Support emerging and small local companies interested in developing and exporting technology based products and services; Encourage interaction between private and public sectors; Attract international technology focused companies and research organisations to locate their operations to Western Australia; Promote commercialisation of research and development within universities and the public and private sector; Create and maintain international and national strategic linkages for possible future joint project opportunities.

Google Earth, 2016

financial | strategic

Scale campus: **S** [Portfolio in an Area]

Land use area: **32 ha**

Density city: **305** inh./sq km

Transportation City: Capital Area Transit buses and Train Services; network of cycle and dual-use paths. The Free Transit Zone (FTZ) allows travel on all trains and buses within the city boundaries, with a SmartRider card. Perth is served by Perth Airport.

Distance campus from:

Airport	City centre	University
13 km 60'	9 km 30'	2 km 20'
Perth Airport	Perth Station	Curtin University

physical | functional

Population campus: **14.000** aprox.
P1-Employees: 14.000 aprox.

Orgs. in campus: **100** aprox.
O1/O2/O3: >100 organisations [including technology based industry, research and development, academia and support organisations]

Facilities in campus: F1: Conference centre with meeting facilities; bar; Onsite bistro and catering service
F2: Landscaped gardens; Access to sports and recreational facilities including tennis, golf, yoga

F1

F2

F3

Population city: **1.644.849**
[Perth Statistical Division, 2013]

Employment city: **124.677**
Main employers-sector: Professional, Scientific and Technical Services accounts for 22.7% of total employmen [Australian Bureau of Statisitics (ABS) Census 2006 and 2011]

Tertiary education city: **5** universities [the University of Western Australia, R-189; Curtin University of Technology; Murdoch University; Edith Cowan University; and the University of Notre Dame]

Amenities city: A1: several cultural centres, theatres; art galleries; museums; concert halls
A2: CBD with several restaurants; coffees, bars and night clubs
A3: sporting venues including premier sporting grounds and for leisure; parks and gardens; zoo; rivers.

A1

A2

A3

TOC

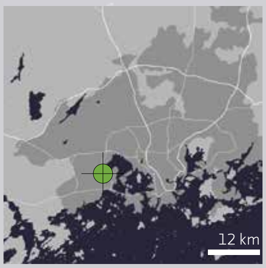
Otaniemi Science Park & Otaniemi Technology Hub

Espoo, Greater Helsinki, FI

Contains

Code: 20-OSP

Year: 1985-86



Official denomination:

In transition: from Science Park to Technology hub.

Otaniemi Science Park or Technology hub is located in Espoo, the second largest city in Finland and part of the capital region of Greater Helsinki. Otaniemi, which has grown up around TKK [Helsinki University of Technology] and VTT [Technical Research Centre of Finland], is the core of Finnish science and technology activities. The area is architecturally unique, boasting buildings designed by leading Finnish architects including Alvar Aalto. First to be built was the student campus of TKK. Starting in the 80s with the foundation of the Technology Park [today known as Technopolis Venture] and the Technology Centre Innopoli, a network of private office spaces have been built around TTK and VTT to support their activities.
Today the area is referred as Otaniemi Technology Hub. With the merging three top Finnish universities; the University of Art and Design Helsinki (TaiK), the Helsinki University of Technology (TKK) and the Helsinki School of Economics (HSE), to encompass new joint research and teaching programs, new jobs and new area of commercial space. are expected.

Cluster base campus:

R&D: ICT clusters include: mobility-based software and webware, as well as nanotechnology and microelectonics.

Economic base city:

Consolidated: commerce, ICT and science.

Vision city: V1-Strategy: City of Espoo 3T Strategy [T3 area: Tapiola-Otaniemi-Keilaniemi]
V2-Ambition: with the merging three top Finnish universities by 2030 there will be 15,000 new jobs and 300,000 new m2 of commercial space.
V3-concept: Energizing Urban Ecosystems (EUE) program will create an internationally recognized and multidisciplinary hub of excellence for urban development in Finland. It will offer a globally networked cooperation platform for various R&D projects of urban planning and development.

Vision campus: V2-Ambition: According to city of Espoo's T3 strategy plans Otaniemi will be integrated into the neighboring Keilaniemi and Tapiola districts creating a unique campus that combines research, art and business.
V4-Slogan: Bridging Innovation and Business. [Otaniemi Marketing, 2013]

Ext. Promoters: Prom1:Otaniemi Marketing; Aalto University; Technopolis; Otianiemi.Fi; City of Espoo Esbo; VTT Technical Research Centre of Finland; Aalto Entrepreneurship Society, Metropolia University of Apllied sciences; KCL laboratories; and RYM Oy- the Strategic centre for Science, Technology and Innovation of the built environment in Finland.

Funding campus: **Public & Private**: In 1949, the Government of Finland purchased the lands of Otaniemi manor for use as the campus of the Helsinki University of Technology [TKK], now a significant part of Aalto University and the VTT Technical Research Centre of Finland. Land ownership in Otaniemi is concentrated almost entirely between two main parties. In addition to Aalto University Properties Ltd, the other significant owner of real estate in Otaniemi is Senate Properties [an enterprise under the Ministry of Finance]

J-P Kärnä [GFDL or CC-BY-SA-3.0], via Wikimedia Commons

Controllers campus: **Defined**: University Campus is managed by Aalto University Properties Ltd. Besides, Otaniemi Marketing is a public-private partnership between key players in Otaniemi Technology Hub. It's key role is to assist foreign companies to find new opportunities, partnerships and open subsidiaries in Espoo [Aalto University; Technopolis; Otianiemi.Fi; City of Espoo Esbo; VTT Technical Research Centre of Finland; Aalto Entrepreneurship Society, Metropolia University of Apllied sciences;KCL laboratories]. Nevertheless, their managing the development of the area is unknown.

functional | physical

Population campus: **32.000** aprox.
Other-Technology professionals: 16.000
P2-Students: 16.000

Orgs. in campus: **816** est.
O1:800 companies
O2: 5 schools of Technology of Aalto University and 12 TTK institutions
O3: 15 institutions

Facilities in campus:
F1:Foodcourts, restaurants and cafeterias; Auditorium and conference facilties
F2: fitness centre with gym, swimming pool, tennis courts, aerobics and weights studios; Intra-park
F-Other: inner university bus shuttles

F1

F2

F3

Population city: **310.000** [2012]

Employement city: **123.000** [*labour force 2010]
Main employer-sector: Public administration and services 25% of labour force.
Main employeers-staff: City of Espoo, Nokia, Inex Partners, Tieto Finland Oy, Jorvi Hospital, Orion Oyj, Tapiola Insurance Group, Aalto University, VTT

3rd education city: **1** university [Merge of Aalto University and Helsinki University of Technology – TKK]
HEI: 2 [Laurea University of Applied Sciences and Metropolia; University of Applied Sciences]

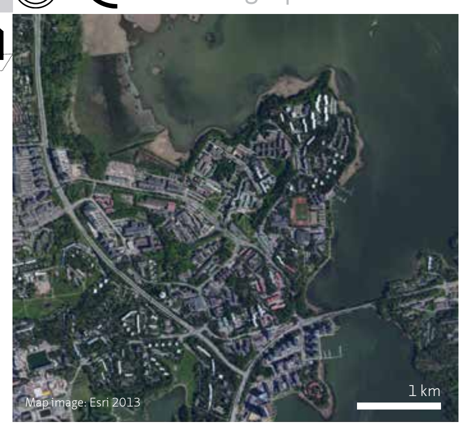
Amenities city:
A1: 14 libraries; 11 exhibitions in 4 museums; cultural centre with 648 public events
A2:concert hall; theatre; 19 club and youth premises
A3:14 activity parks; 144 municipal child day care centres; 7 sport locations and facilities including pools, football arenas, gyms, outdoor grounds; 10 harbours; 11 recreational islands; 21 beaches; 7 tennis courts; zoo.

A1

A2

A3

strategic | financial



Map image: Esri 2013

Scale campus: **M** [Area in a District]

Land use area: **100 ha* - 400 ha****
[*Science Park - **Technology hub]

Density city: **823** inh./sq km [on land]

Transportation City: Espoo is part of an integrated regional public transport area. Cycling and public transport [Bus, tram, Metro,Ferry and commuter train services] infrastructure. Espoo is served by Helsinki-Vantaa airport connected by bus.

Distance campus from:

Airport	City centre	University
23 km 60'	10 km 30'	≤1 km ≤15'
Helsinki Airport	Helsinki central railway station	Aalto University

TOC

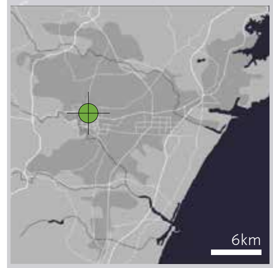
Sendai Technopolis & Izumi Park Town Industrial Park

Sendai city, Miyagi prefecture, JP

Equals

Code: 21- ST-IPT

Year: 1986



Official denomination:

Permanent as Technopolis and Park Town

Sendai Technopolis [ST] is one of the series of new science cities created within Japan's technology program, a national plan masterminded by the Ministry of International Trade and Industry [MITI]. ST includes Sendai City and Izumi City which together occupy 81.000 ha. The main focus is in two sites: the Sendai Hokobu Research and Industrial Park [200 ha located 20 km north of central Sendai] and Izumi Park Town Industrial Town [IPT] including the 21st century Plaza located 10 km north of sendai's city centre. The Park Town started in the early 70s designed for living and working as a selft-contained new twon on 1300 ha developed by the Mitsubishi Estate Company. The industrial park started in the early 80s and it was planned for an industrial park and central office complex; but when the technopolis was designated, the plan was changed to take advantages of the subsidies.

Cluster base campus:

R&D + Production: ST focuses on electronics and mechatronics; new material; biotechnology and urban information. Most of the companies in IPT focuses on electronic and new materials.

Economic base city:

Consolidated: tertiary industries focusing on service and commerce.

Ext. promoters: Prom1: Sendai City, the Miyagi prefectural government, the Tohoku Bureau of Economy, Trade and Industry, and Tohoku University participate in the "MEMS Park Consortium" (2004), located at IPT. The region makes concerted joint efforts to implement the transmission of information, human resource development, technical consultation, networking activities, etc. MEMS Park Consortium provides an open environment where researchers can share information and facilities.

Funding campus: **Public & Private** Sendai Technopolis is funded with public capital within the MITI Economic plan. A master plan determined in mid-1989 was developed cooperatively by the Prefecture, University and private enterprises to secure regional technological development. It aims to promote innovative scientific and technological R&D through the creation of systematic institutional structure and the creation of specialized R&D companies which are private but are largely funded by public capital. Izumi Park Town Industrial Park's main developer is Mitsubishi Estate Co. Ltd.

Controllers campus: **Defined**: Izumi Park Town Service Co. Ltd. manages the properties of the park. In order to embody the ideal of Mitsubishi Estate as "urban development and environmental development"

Vision city: V2-Ambition: attractive city for business [The city of Sendai Economic Affairs Bureau]
V3-Concept/Pillars: the "new industry creation plan" focuses on: Manufacturing products based on Micro Electro Mechanical Systems Technology; International Welfare; and the Creative industry encouragin design and printing, and media contents and IT .
V4-Motto: "Sendai, the best location for the future"

Vision campus: V1-Plan: ST is framed in the Ministry of International Trade and Industry Visions for the 80s
V2-Ambition: This concept aims at promoting regional development and creating a new regional culture under the lead of industrial and academic progress.
V3-Concept: Technopolis or technology-intensive city, is a city that effectively combines an industrial sector composed of electronics, machinery and other most advanced technologies with an academic and a residential secotr.
V-4: IPT's slogan: "Ideal Urban development for human" through thick and thin.

Google Earth, 2016

financial | strategic

physical | functional

Population campus: **53.431** [2012]
P1-Employees: 4.207 Faculty
P2-Students: 49.224
[50.000 was the population planned for ST]

Orgs. in campus: **60** est.
O1: 59 companies
O2: 1 University with 7 institutes.

Facilities in campus: F1: Stores; cafes; restaurants; libraries; convention and exhibition centre
F2: Golf court; tennis courts
F3: hotels

F1
F2
F3

Scale campus: **L** [District or Town]

Land use area: **1.070 ha**
[Izumi Industrial Park (155 ha), Soft park (16 ha)]

Density city: **1.335** inh./sq km [2011]

Transportation City: Connection to Tokyo by Railway Tohoku "Shinkansen" (Bullet Train); served by Sendai Airport. Public transportation system with interconnected subway lines, bus routes, and railways.

Distance campus from:

Airport	City centre	University
47 km 50'	12 km 30'	≤1 km ≤15'
Sendai Airport	Sendai Station	Miyagi University

Population city: **1.045.986**
[Japan Statistics Bureau, 2010]

Employment city: **546.366** [in Sendai, 2012]
Main employer-sector: Wholesales and retail trade with 143.135 jobs

Tertiary education city: **10** universities [including Tohoku University, R-120]

Amenities city: A1:heritage buildings; museums; 4 main festivals
A2: hot string resorts; 6 shopping malls; shops and restaurants
A3: natural attractions as the river and several tree-lined streets and parks; sport facilities including stadium; Many pedestrian walkways; golf court

A1
A2
A3

Kansai Science City

Kansai [unincorporated city between the prefectures of Nara, Kyoto and Osaka], JP

Disjoints

Code: 22-KSC

Year: 1987

Official denomination:

Changed: from Science City [origins] to Strategic General Special Zone [nowadays]

Known as "Keihanna Science City" it was designed as a network of technology parks with some added cultural facilities. Located between the prefectures of Nara, Kyoto and Osaka to the west of Tokyo, KSC includes five cities. Its core is the Cultural and Scientific Research District, which includes research, cultural and residential facilities among others, and organised in 12 different zones developed in a cluster-type and phased approach. The construction Act of KSC was enacted in 1987. In 2011 KSC is Designated as the kansai Innovation International Strategic General Special Zone aimed to develop high-tech medical and life innovation industries.

Cluster base campus:

SciResearch: Information and Communications; materials and light quantum science; biotechnology and the living environment.

Economic base city:

Key sectors: high-tech medical and life innovation industries.

Vision city: V1-Plan: In March 2006, the Ministry of Land, Infrastructure and Transportation formulated "Third Stage Plan" for 2015
V2-Goals: Construction of a creative future looking knowledge based city; "Science for a Sustainable Society" as a basis for international R&D; Creation of new industry through ties among industry, academia, and government; Positioning the city as a cultural base and offering new cultural & scientific research; developing social infrastructure to support the city's activities.
V4-Motto: "Challenging the Future...the New Cultural Capital, Keihanna".

Vision campus: V1-Plan: Construction Act. The "Culture and Scientific Research District", in KSC, define the boundaries and facilities to accommodate R&D, culture and scientific research, residential and other activities.
V2-Ambition-Goals: The construction of KSC was undertaken to create a base for activities focusing on: Creating a base for new development in culture, science, and research; Contributing to the development of culture, science, and research in Japan and throughout the world, and to the development of the nationak economy; Foundation of the intellectual and creative city that opens doors for the future.
V4-Motto:Challenging the Future...the New Cultural Capital, Keihanna.

Ext. Promoters: Prom1: Kansai Science City Construction Promotion Office from the Ministry of Land, Infrastructure and Transportation indicates the direction of activities for KSC. Kansai Economic Federation (Kankeiren) was established in October 1946 as a private, non-profit organization. It consists of 1400 members drawn from representative businesses and organizations which pursue economic activity mainly in the Kansai region.

Funding campus: **PPP**:The association to promote the area to outside industry was passed through an Act establishing KSC as a national project. Large companies have bought the land speculative resulted from the Japan's fiscal reevaluation in the 80s allowing incentives to the private sectors under special laws [such as lower land costs, property taxes and accelerated depreciation] as a solution for the government's fiscal problems.

Controllers campus: **Defined**: The organistation of KSC involves; the prefectures and local govenrments; the Kansai Research Institute [private]; Association of Kansai Culture, Academy and Research City. The institute was established in 1986 to plan and develop the city. It has 20 members; 10 from the prefectures, others from private companies, the national Housing corporation and others. Thier role is coordination and harmonization, since each prefecture's Ministry of Construction has power on its own. Today, Keihanna Interaction Plaza Inc. is a core organization of Kansai Science City, responsible for establishing and managing several central facilities located in Kansai Science City.

functional | physical

Population campus: **84.815*** [*Only in the Core District]
Other-Residents: 84.815 in its Core District [2010] [180.000 up to 210.000 residents was the population planned for KSC's Core District.]

Orgs. in campus: **133** est.
O1:> 110 companies and organizations
O2: 6 universities
O3:>17 main institutes and research facilities

Facilities in campus: F1 F2 F3
F1-F3: Keihanna Plaza operates as a core facility of the science city, providing hotel accommodations and a convention center with the capacity to handle up to a thousand participants; and other public welfare and residential facilities.

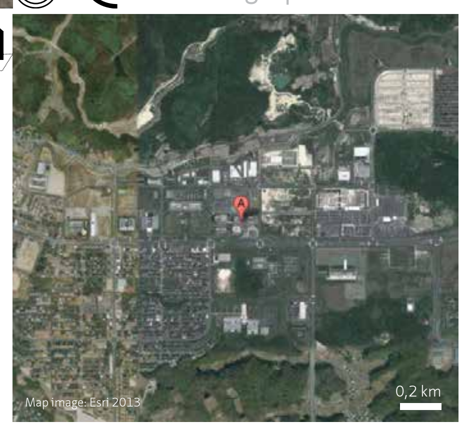
Population city: **238.341** [Kansai Science City, 2010]
[410.000 was the population planned for KCS]

Employement city: Unknown

3rd education city: **6** universities [including Osaka University, R-119]

Amenities city: A1 A2 A3
A2: Keihanna Plaza operates as a core facility of the science city, providing hotel accommodations and a convention center with the capacity to handle up to a thousand participants; and other public welfare and residential facilities.

strategic | financial



Scale campus: **L** [District or Town]

Land use area: **3.600 ha* - 15.00 ha****
[*Core District - **Kansai Science City]

Density city: **1.588** inh./sq km aprox. [Estimated by using from KSC area]

Transportation City: Expressway connecting to Kansai International Airport; JR Line and private railway network

Distance campus from:

85 km 120'	32 km 45'	12 km 20'
Kansai International Airport	Kyoto's and to Osaka's Central Stations	Kansai Gaidai University [taken from core district]
Airport	City centre	University

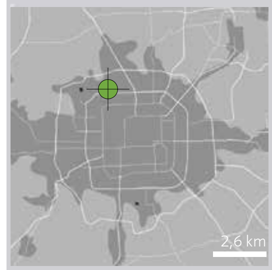
Zhong Guan Cun Science Park

Beijing, CN

Overlaps

Code: 23-ZGCSP

Year: 1988



Official denomination:

Permanent: as Science Park

Ext. promoters: Prom1: Vigorous promotion by the central state. Invest in Beijing actively promote the area as a Economic Development Zone to attract FDI.

Vision city: V1-Strategy: Beijing city master plan (2004-2010) V3-Concept/Pillars: capital city, metropolitan city, cultural city and livable city.

Funding campus: **Public and Private:** The ownership structure of ZGCSP has changed over time according to changes in the development state in China: "from state-owned enterprises to market-oriented enterprise; from domestic competition to international open competition". "The central government tentatively endorsed the ZGC trial by setting up an experimental zone in ZGC in 1988, and provided some tax relief for new enterprises. While granting unprecedented autonomy for these firms, the state made sure that it did not have to invest much capital or bear any responsibility for their failure" (Zhao, 1998) Because in the 1980s the users were largely universities, government ministries, and large state-owned enterprises, the academic backgrounds and research institution affiliation of the company founders were useful when negotiating contracts.

Controllers campus: **Defined**: Zhongguancun Haidian Science Park Management Committee. Beijing Experimental Zone for New Technology Industries (BEZ) is a regulatory and supportive institute for ZGCSP. The Management Commission of BEZ handles affairs such as licensing, taxation, international trade, finance and investment, employment, and intellectual property for new-tech firms, largely in accordance with the stipulations of national policy but with slight local modifications.

Vision campus: V1-Plan: The development of the ZGC Science Park underwent four major stages: (1) institutional innovation from the early 1980s to the late 1980s, (2) technological innovation from the late 1980s to the early 1990s, (3) market innovation from the early 1990s to the late 1990s, and (4) transition and reorientation from 1998 to the early 21st century. V2-Ambition: to develop a heightened innovative environment. / V3-Concept: Entrepreneurial culture in ZGC has been a driving force: Proximity, shared resource arrangements, and an emerging cluster identity.

By Charlie fong (Own work) [Public domain], via Wikimedia Commons

financial | strategic

Scale campus: L [District or Town]

Land use area: 7.500 ha* [ZGC Development Section at the core of 30,000 ha of Haidian Development Area]

Density city: 1.261 inh./sq km [2012]

Transportation City: Railway network [9 lines]; two high-speed rail lines; Beijing subway [17 lines]; public bus, trolleybus and bus rapid transit lines; served by Beijing Capital International Airport

Distance campus from:

Airport	City centre	University
30 km 120'	21,5 km 55'	7 km 60'
Beijing Airport	Beijing Railway Station	Tsinghua University [from central Haidian district]

physical | functional

Population campus: unknown*

[*Population Haidian District: 2,2 million]

Orgs. in campus: 2.298 aprox.
O1: 8.000 enterprises; 155 listed companies
O2: 68 universities
O3: >230 independent scientific research institutions at the national and municipal level

Facilities in campus: Unknown

F1

F2

F3

Population city: 19'612.368 [National Bureau of Statisitics China, 2011]

Employment city: Unknown*
[* 2.11% unemployement registered and 3,830,000 scientific and technical personnel in research insitutes, Beijing statistics Bureau, 2005]

Tertiary education city: 79 HEI [including Peking University, R-49; and Tsinghua University, R-71, Beijing Municipal Bureau of Statistics, 2005]

Amenities city: A1: 58 cinemas, 34 museums, 26 public libraries, 328 art galleries and Cultural Centers, 36 art performance troupes, 20 archives in Beijing
A3: 3.000 sport grounds

A1

A2

A3

Zhongguancun (ZGC) Science Park, has been seen as the largest cluster of semiconductor, computer, and telecommunication firms in China. It is located in the Beijing Haidian District geographically situated in the northwestern part of Beijing city, in a band between the northwestern Third Ring Road and the northwestern Fourth Ring Road. China officially established Beijing Experimental Zone for New Technology Industries, widely known as the ZGC Science Park in 1988. Today, the Zhongguancun Science Park, is composed of 5 different development areas [Haidian Development Area; Fengtai Development Area; Changping Development Area; Electronics Town Science and Technology Development Area; and Yizhuang Science and Technology Development Area] The Haidian Development Area is composed of seven sub-development areas.

Cluster base campus:

R&D+SciResearch: hi-tech business; Software R&D; Biotechnology; Science in the fields of electronic, information, biological pharmaceuticals, optics-machinery-electronics integration, new materials, new energy, and environmental science

R&D+Production: nano materials, information technology, bioengineering and new medicine, environmental protection and comprehensive utilization of resources, optics-machinery-electronics integration, space technology.

Economic base city:

Consolidated: tertiary industry [service sector] with 62.2% of the total GDP. Beijing has a fully integrated industrial structure covering fields of electronics, machinery, chemicals, light industry, textile and car manufacturing.
Key sectors: High tech and modern manufacturing industries.

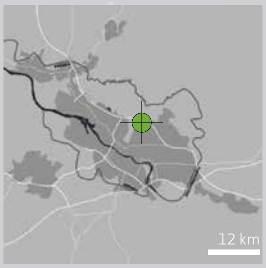
Touches

Technology Park Bremen & University of Bremen

Bremen, Bremen, DE

Code: 24-TPUB

Year: 1988



Official denomination:

Permanent: as Technology Park

Technology Park Bremen is a campus extension of the University of Bremen [established in 1971] which is built on in adjacent land. The technology park has attracted enterprises to locate there. These firms are linked to the University of Bremen via numerous cooperation agreements and joint projects. In 1988 the Bremen Senate made the decision of establishing a technology park. Today, the area around the University is regarded as a key high-tech district in Northern Germany.

Cluster base campus:

R&D: Information and communications; technology; Aerospace; Logistics; Materials, microsystem and production engineering; Sensor and nanotechnology.

Economic base city:

Key sectors: mix of global industries of technological competence and innovation: automotive engineering, aviation and space travel, food and beverages, mobile technologies, life sciences, biotechnology and logistics.

Vision city: V1-Plan: Industry Master Plan Bremen. A contribution to structural Concept 2015
V3-Concept-Pillars: profiling of Bremen as a location for industry; securing and strengthening the industrial cores; stabilize the industry by Diversification and SME development; development of innovation, technology and research; addressing skills shortages through the promotion of education and training; the development of environmental economics; Climate change and energy supply, providing need-based Commercial and industrial areas; providing efficient Transport infrastructure and the intensification of national borders cooperation
V4-Slogan: Bremen – a wonderful place to live! A modern city with a great maritime past.

Vision campus: V2-Ambition: to develop into a leading high-tech locations in Germany
V4-Motto: "Where science and business grow together in tamdem".

Ext. Promoters: Prom1:Bremen Invest promotes TPUB as one of Germany's leading centres of high technology: a site for innovation and growth.

Funding campus: **PPP**: involvement of the City of Bremen, Bremen Economic Development, the University of Bremen and the many companies who have chosen this site. More than 50 members – companies, research establishments, the University of Bremen and the Bremen Innovation and Technology Centre BITZ – give the Technology Park a profile and jointly work on qualitative development of the site to make it a specialised district for technology.

Google Earth, 2016

Controllers campus: **Defined**: Technology Park Uni Bremen e.V. is the network within the Technology Park. The association works, with its members, to achieve forward-looking management of the Technology Park and fosters cooperation between the enterprises as well as partnerships between the research and business communities. Technology Park Uni Bremen e.V. has played a leading role in designing and developing the site into an urban district in its own right. It operates close ties within the Technology Park, the state of Bremen and its business development system. As a registered association, Technologiepark Uni Bremen e.V. is nevertheless independent.

strategic | financial

functional | physical

Population campus: **29.500** aprox.
P1-Employees: 6.500 aproximately and 3.000 staff University of Bremen
P2-Students: 20,000 University of Bremen

Orgs. in campus: **421 - 521** est.
O1: 400 - 500 enterprises
O2: 1 university
O3: 20 research centres and institutes

Facilities in campus: F1:conference facilities; restaurants and catering establishements; The area known as Glass Hall have numerous shops and service facilities
F2: sport facilities
F3: child care facilities; hotels

F1

F2

F3

Population city: **548.319** [Bremen Statistical Office, 2011]

Employement city: **300.000** jobs [2011]
Main employers-sector: Manufacture with 46.245 jobs

3rd education city: **2** universities [The University of Bremen and Jacobs University Bremen]
HEI:2 [the University of Applied Sciences in Bremen and Bremerhaven, the University of Fine Arts Bremen]

Amenities city: A1:several exhibitions, trade fairs, concerts, musicals venues; several museums and art galleries; heritage buildings
A2: >1,000 cafés and bars, restaurants, bistros and pubs; several shops
A3: 2,800 hectares of the city is open green space; 17 historical parks; 9 lakes; >130 sport clubs; sports games

A1

A2

A3

Scale campus: **S** [Portfolio in an Area]

Land use area: **170 ha**

Density city: **1.668** inh./sq km [Census 2011]

Transportation City: Bremer Strassenbahn AG operates around 380 modern trams and buses; Bremen City Airport connected by tram. Region connected by railway network [InterCityExpress, InterCity/EuroCity and InterRegio trains].

Distance campus from:

Airport	City centre	University
15 km 15'	6 km 10'	≤1 km ≤15'
Bremen Airport	Bremen Central Station	University of Bremen

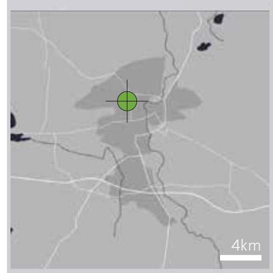
Brandenburg Technical University Campus

Cottbus, Brandenburg, DE

Contains

Code: 25-BTUC

Year: 1991



Official denomination:

Permanent: as Campus

The Brandenburg Technical University is located in the north of Cottbus, close to the city centre.The Brandenburg Technical University Cottbus was founded by the Federal State of Brandenburg in 1991 and today is regarded as an international innovation-oriented small technical university.

Cluster base campus:

SciResearch: Main topics are the environment, energy, materials, construction, and information and communication technology.

Economic base city:

Emergent: services, science and administration; technology and sciences. Research in the fields of "Energy", "Lightweight construction material" and "Information and communication technology".
Key sectors: Food; Media, Information and Communication Technology; Energy Industry and Technology; Automotive, Traffic Engineering; and Metal Production, Metal Machining and Processing, Mechatronics.

Ext. promoters: Prom1:the Economic Development board in the Federal state of Brandenburg; UNITEC GmbH - Society for Promotion of innovation and Technology transfer to the BTU Cottbus

Funding campus: Public: Brandenburg Technical University founded by the Federal State of Brandenburg in 1991.

Vision city: V1-Strategy:The "Joint Innovation Strategy of the States of Berlin and Brandenburg (innoBB)" was adopted by the Berlin Senate and the Brandenburg Cabinet on 21 June 2011.
V2-Goal: to develop the cutting-edge fields, identified as important to both states in 2007, into the following cross-border clusters:Life Sciences & Healthcare; Energy Technology; Mobility, Transport and Logistics; ICT, Media, Creative Industries; and Photonics
V2-Ambition: to qualify the existing industry competence clusters in accordance with the current cluster strategy of the Federal State of Brandenburg./ V4-Slogan: Economic, science and technology location Cottbus.

Vision campus: V4-Motto: We live science

Controllers campus: Defined: University Building Management Lausitz (Hochschul-Gebäude-Management-Lausitz or HGML) is the common management unit of the Brandenburg University of Technology Cottbus (BTU) and the Hochschule Lausitz (FH). The HGML is led by a board consisting of two equal members of the universities. The role of the HGML is to manage and to operate of all stations, real estate, buildings and industrial installations of both universities' facilities.

By Sane (Own work) [CC BY-SA 3.0], via Wikimedia Commons

financial | strategic

physical | functional

Population campus: 5.800 aprox.
P1-Employees: 1.156
P2-Students: 4.644 aprox.

Orgs. in campus: 14 aprox.
O2: 1 university with 4 faculties
O3: 13 institutions

Facilities in campus: F1:Library
F2: Sport facilities
F3: student housing

F1

F2

F3

Scale campus: M [Area in a district]

Land use area: 30 ha

Density city: 605 inh./sq km [2013]

Transportation City: Regional Railway connections; served by 3 airports [Berlin - Schönefeld, Berlin - Tegel, Dresden] Bus and tram lines.

Population city: 99.470 [2013]

Employment city: 45.734 Jobholders [2011]
Main employers-sector: Service sector with 39.952 jobs.

Tertiary education city: 1university [Brandenburg Technical University Cottbus]
HEI: 1 [Lausitz University of Applied Sciences]

Distance campus from:

Airport	City centre	University
119 km 120'	2,5 km 8'	≤1 km ≤15'
Berlin Schönefeld Airport	Cottbus Bahnhof	Brandenburg Technical University Cottbus

Amenities city: A1:several theatres and stages; museums and galleries; art library; historical buildings; congress venues
A3: parks and green areas [8,4 sq km of Sports and recreational areas]; zoo

A1

A2

A3

Touches

Zhangjiang High-Tech Park

Shanghai, CN

Code: 26-ZJHTP

Year: 1992

Official denomination:

Permanent: as Hi-Tech Park

ZJHT Park was established in 1992 as a national-level scientific park designed for high-technology development. However, the development of biotech industry did not start until 1996, when the agreement of National Shanghai Biotechnology and Pharmaceutical Industry Base (NSBPIB) was singed to support and promote the development of biotech industry in the Park. ZJHT Park is located in the middle part of Pudong New Area with a planned area of 25 sq km, comprising Technical Innovation Zone, Hi-Tech Industry Zone, Scientific Research and Education Zone, and Residential Zone.
Creative industries have been recognised as a key engine of economic growth in China in recent years. Actually, various Special Economic Zones (SEZs) like ZJHT Park have been established to attract advanced technology and talented people to China. (Based on Li and Hua 2009).

Cluster base campus:

SciResearch+R&D: Biomedical, information, integrated circuit, semiconductor, photoelectron, information security, software, culture, research, education, and network game and animation industries

Economic base city:

Consolidated: tertiary sector currently accounts for 58% of Shanghai's GDP
Key Sectors: Information services, financial services, commodities and trade, real estate; automotive and equipment (instruments) as new key manufacturing sectors, all closely related to high-technology industry and services than the old key industry sectors. [Based on Chen, 2012].

Vision city: V1-Plan: 12th five-year plan focuses on building the city into the four centres and a socialist modern international metropolis.
V2-Ambition:The municipal government is working towards building Shanghai into a modern metropolis and a global economic, financial, trading and shipping center by 2020.

Ext. Promoters: Prom1:The city of Pudong actively promotes ZJHTP as an economic development zone or a key site for investment in business.

Vision campus: V1-Plan: 10-year "focusing on Zhangjiang" strategy implemented in 2009
V3-Concept: Zhangjiang Hi-tech Park implemented the standardized investment attraction strategy, and gave priority to introduce and cultivate six types of enterprises: high-end industrial core technology; core products of high added value; overall controlling capacity in the industrial chain; integration solutions; domestic or overseas intellectual rights in the investment structure; and the features of low carbon and clean industry.

Funding campus: **Public and Private**: but most funding comes from the government. In 1999, Shanghai Municipal Committee and Municipal Government declared the strategy of "Focus on Zhangjiang" and identified the leading industries of the Park, and ZJHT Park began to develop rapidly ever since. The main force in ZJHT Park's growth process in the biotech sector is the aggressive intervention of the park administration and the state and municipal governments by providing human resource and financial support.

Google Earth, 2016

Controllers campus: **Defined**: Shanghai Zhangjiang (Group) Co., Ltd. owns and operates the Shanghai Zhangjiang Hi-Tech park. Shanghai Zhangjiang (Group) Co., Ltd. was formerly known as Zhangjiang Hi-Tech Park Development Co. Shanghai Zhangjiang (Group) Co., Ltd. was founded in 2007 and is based in Shanghai, China.

functional | physical

Population campus: **10.400** aprox.*
P1-Employees: 10.400 employees *in Biomedicine [2004]

Orgs. in campus: **430** est.
O1: 387 High-tech enterprises
O3: 43 R&D institutions

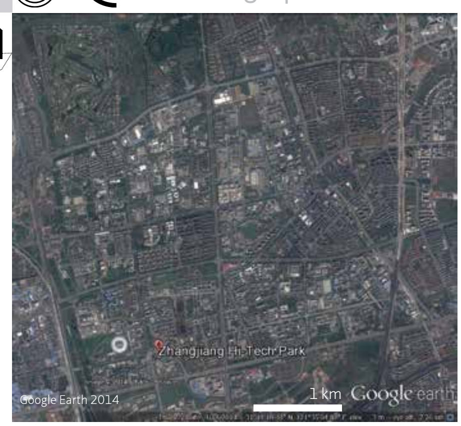
Facilities in campus: F1:commercial area
F2: Zhangjiang Sports & Leisure Centre
F3: Residential area

F1

F2

F3

strategic | financial



Population city: **23.000.000** [Civil Affairs Bureau, 2010]

Employement city: **6.480.000** [Civil Affairs Bureau, 2010]
Main employers-sector: Service sector with 3.530.000 workers

3rd education city: **66** HEIs

Amenities city: A1: 27 cultural centres; 112 art troupes; 28 public libraries; 50 archive offices; and 114 museums; several cultural and historical sites
A2: several shopping areas and catering enteprises
A3: green areas accounts for 38% of city area; several multifunctional sport venues including shanghai stadium;

A1

A2

A3

Scale campus: **M** [Area in a District]

Land use area: **2.500 ha*** [*planned]

Density city: **3.632** inh./sq km [Civil Affairs Bureau, 2010]

Transportation City: Public transport system, largely based on metros, buses and taxis. The Shanghai Metro rapid-transit system and elevated light metro [12 lines] Shanghai Bus; Trolleybuses; Shanghai Maglev Train, connecting Pudong to Pudong International Airport; 2 railways lines and The high-speed railway]

Distance campus from:

Airport	City centre	University
35 km 90'	25 km 60'	22 km 80'
Shaghai Pudong International Airport	Shanghai Railway Station	Shanghai Jiao Tong University

Taguspark

Lisbon, PT

Disjoints

Code: 27-TP

Year: 1992

Official denomination:

Permanent: Science and Technology Park

Taguspark is an science and technology park located in the Lisbon and Tagus Valley region, 15 km from Lisbon, at the junction of three municipalities: Oeiras, Cascais and Sintra.

Ext. promoters: Prom2:The Municipality of Lisboa identifies TP as a location in a map of a wide ecosystem of university, R & D and innovation of Lisbon within the initiative. The Map of Knowledge and Innovation Lisbon (MCIL) is a digital platform that allows to know and explore the ecosystem better.

Funding campus PPP: Taguspark was set up in 1992 by a government initiative, as a private company, with mixed capital. It has 16 shareholders, from the banking sector (31%), university and R&D institutions (26%), local authorities (17%), enterprise sector (17%), central government agencies (7%), and others (2%). The shareholders are active partners of the park as all of them are interested in reinforcing the regional innovation system in the Lisbon region.

Controllers campus: Defined: Taguspark - Society for Promotion and Development of the Science and Technology Park Area of Lisbon, SA - is a private limited company. The main activity is the establishment, development, promotion and management of the Science and Technology Park as well as to provide all supporting services necessary to this activity. The governing bodies are organised in Councils, within with there are two offices responsible for the case: Planning area and Management control - Direction of projects, planning and urban development.

Vision city: V1-Plan: Lisbon City of Knowledge and Innovation. V2-Ambition: Knowledge economy may contribute to generate skills and competitive advantages for cities and companies, creating and strengthening partnerships between the city's agents, improving cooperation between the public and private sectors, and strengthening the urban economy on the basis of knowledge and intangible capital.

Vision campus: V2-Goals: Promoting a sustainable urban environment; Promoting the interaction between companies, Institutions of R & D and Universities; Developing business activities, of innovation and education; Promoting an environment of international competition.
V3-Concept: The Taguspark is developing a strategy for urban development through the creation of a Multi-functional Center to induce the urban life in the Taguspark including residential units in the Taguspark for students.

Fred mendonca from pt [GFDL, CC-BY-SA-3.0], via Wikimedia Commons

financial | strategic

Scale campus: S [Portfolio in an Area]

Land use area: 145 ha [60 ha occupied]

Density city: 1.483 inh./sq km [Greater Lisbon]

Transportation City: Underground Metro system, trains, trams, buses, and taxis; served by Lisbon Airport connected by metro and buses.

Distance campus from:

22 km 20'	18 km 40'	≤1 km ≤15'
Lisbon Portela International Airport	Lisbon Rossio train Station	Open University and ITS
Airport	City centre	University

physical | functional

Population campus: 6.000
P1-Employees: 6.000 workers

Orgs. in campus: 116 est.
O1: 77 companies; 23 service companies; 9 start-ups
O2: 2 universities
O3: 5 R&D institutes

Facilities in campus: F1: Congress Centre; Central facility with space for meetings and social interaction, exhibitions, seminaries, conferences and debates and commercial areas with restaurants, pharmacies and banks.

F1

F2

F3

Population city: 2.042.477 Greater Lisbon [Eurostat, NUTS 3, 2011]

Employment city: 898.041 [Greater Lisbon, 2011]
Main employers-sector: >80% in the service sector

Tertiary education city: 3 universities [the University of Lisbon, the Technical University of Lisbon and the New University of Lisbon]

Amenities city: A1: 41 Museums, 182 art galleries; several heritage buildings, architecture; >9 international schools
A2: shops, restaurants, bar, cafes
A3: beaches, 11 main parks and gardens;

A1

A2

A3

Cluster base campus:

R&D: technology-based companies, which are 80% in the domains of information, communication and electronics technologies, and 20% in the areas of bio-technology, environment, energy, materials and fine chemistry.

Economic base city:

Key sectors: Information and Communication Technologies (ICT); Renewable Energies; Tourism; Marine Economics; Creative Industries including Cinema and Audiovisuals and urban recovery; Health ,Provision of services for companies; Trade and finances.

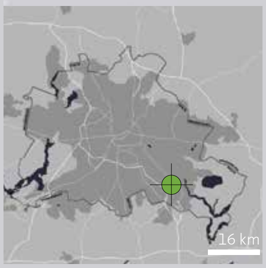
Berlin Adlershof Humboldt University

Berlin, Brandenburg, DE

Touches
Contains

Code: 28-BAHU

Year: 1994



Official denomination:

Permanent: as science and technology park [regarded some times as High-Tech Park]

Berlin Adlershof is regarded as one of Germany's most successful high-tech parks and site of the so-called Berlin's Media City. It is located in Adlershof, a quarter at the south east of Berlin. At the core of the concept is a Science and Technology Park. In addition, six of the Berlin Humboldt University's scientific institutes are based here. Media City comprises commercial businesses, including shops, hotels and restaurants, a 66 hectare park and 380 residential buildings share the site with science, technology and media. The surrounding areas offer opportunity for further growth and development. The decision to develop an integrated landscape combining commerce and science was made on 12th March, 1991 by Berlin's federal state government.

Cluster base campus:

SciResearch+R&D: Photonics and Optics; Microsystems and Materials; IT and Media; Biotechnology and the Environment; Renewable Energies and Photovoltaics.

Economic base city:

Key sectors: Berlin is on the way to becoming a modern center of service providers. The city identifies locations of the future where it promotes knowledge-based sectors such as Electromobility
Emerging secotrs: The tourist industry is experiencing higher growth rates than any of the city's other business sectors.

Vision city: V1-Strategy:The "Joint Innovation Strategy of the States of Berlin and Brandenburg (innoBB)" was adopted by the Berlin Senate and the Brandenburg Cabinet on 21 June 2011
V2-Ambititon: Berlin will become a forward-looking center of technology and service providers out of a traditional industrial city
V2-Goal:to develop the cutting-edge fields, identified as important to both states in 2007, into the following cross-border clusters:Life Sciences & Healthcare; Energy Technology; Mobility, Transport and Logistics; ICT, Media, Creative Industries; and Photonics

Vision campus: V2-Ambition: Adlershof Projekt GmbH aims at further developing the city for Science, Business and Media and improving the quality of living.
V3-Concept: "Living on campus" project which will provide 1,200 living quarters and a student housing project. It will add to the urban culture of the Adlershof site.
V4-Motto: City of Science, Business and Media.

By Brücke-Osteuropa (Own work) [CC BY 3.0], via Wikimedia Commons

Ext. Promoters: Prom1: City of Berlin promotes Adlershof Science and Technology Park in Berlin is promoted as home to one of the most successful high-technology projects in Germany.

Funding campus: **Public:** The decision to develop an integrated landscape combining commerce and science was made in 1991. Berlin's federal state government established the development agency Adlershof GmbH (WISTA-MANAGEMENT GMBH since 1994) and commissioned a master plan for the area. In August 1993, the Johannisthal Adlershof Aufbaugesellschaft mbh (JAAG, later to become Johannisthal Adlershof Aufbaugesellschaft mbh, BAAG) was awarded fiduciary duty and appointed development agency for the project. For 12 months, the 420 hectare compound was declared an urban development zone. Shareholders: Land Berlin (98,93 %),WISTA-MANAGEMENT GMBH (1,07%)

Controllers campus: **Defined**: The organisation of the campus is structure by a Committee of Shareholders' Meeting, Supervisory Board, Advisory Council. WISTA-MANAGEMENT GMBH is the operating company of the Science and Technology Park Berlin-Adlershof. It establishes, rents out and operates modern technology centres, makes properties available for sale, supports new start-ups, advises companies, promotes networking between science and business, encourages national and international cooperation, and handles PR for the entire Adlershof site. Adlershof Projekt GmbH is an urban development agency and trustee of the State of Berlin. Tasks: development, lead planning and management of urban land-use plans, lending support with land-use planning procedures, infrastructure project management and the administration of trust assets in the Adlershof development area. Selling of properties to companies and investors. Marketing for the entire Adlershof development area.

strategic | financial

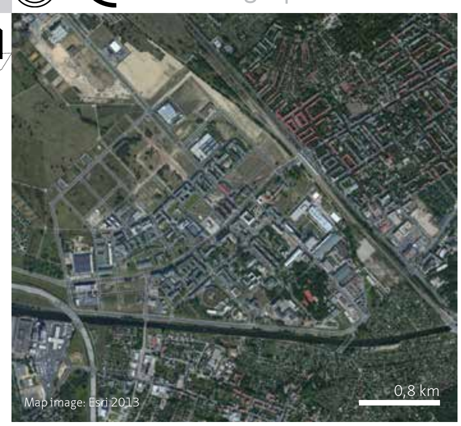
functional | physical

Population campus: **23.380** aprox.
P1-Employees: 14.942 staff
P2-Students: 8.438

Orgs. in campus: **456** est.
O1: 445 companies
O2: Berlin Humboldt University including 6 scientific institutes
O3: 10 non-university scientific institutes

Facilities in campus: F1: Shops,and restaurants, café bars, and printing shops.
F2: a 66 hectare park, golf and tennis court
F3: hotels, 380 residential buildings, Day care centres and Medical Services

F1
F2
F3



Population city: **3.501.872** [Eurostat, 2012]

Employement city: **1.759.000** [2013]
Main employers-sector: Public and private service provider accounts for 39,5% with 694,400 employees

3rd education city: **4** universities
HEIs: 35 [including 3 art colleges, an international business school]

Amenities city: A1: 56 theatres; 157 museums; 247 Movie theaters; major trade show and congress venues
A2: 4,650 restaurants, around 900 bars and 190 clubs and discotheques
A3: 435,680 Trees along roads; 74,094 garden plots; 1.842 playgrounds; 1.931 sports clubs; 20 courts

A1
A2
A3

Scale campus: **M** [Area in a District]

Land use area: **467 ha**

Density city: **3.921** inh./sq km [Eurostat 2011 NUTS2]

Transportation City: Subway, suburban rail [U and S-Bahns], and bus lines. Berlin has two commercial airports. Berlin Tegel Airport (TXL) and Schönefeld Airport (SXF). Berlin Brandenburg Airport (BER) these two as single commercial airport of Berlin

Distance campus from:

7 km 20'	15 km 35'	≤1 km ≤15'
Schoenefeld Airport, Berlin	Alexanderplatz, Mitte, Berlin	Berlin Humboldt University
Airport	City centre	University

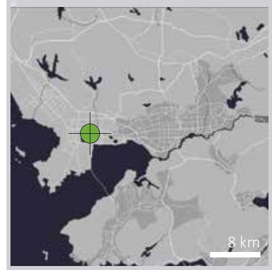
Shenzhen Hi-Tech Industrial Park

Shenzhen, CN

Contains
Touches

Code: **29-SHIP**

Year: **1996**



Ext. promoters: Prom1: the Municipality of ShenZhen outline the park as an important location in the Economic profile of the city. The city profile itselft as "strong in research and development of new technology and a good environment for industry have made the high-tech industry". SHIP is actively supported by the Chinese central government and addressed as a key project for FDI as being located in an Especial Economic Zone.

Funding campus: **Public**: Supported by the municipal government, the industrial park provides integrated services to enterprises, researchers and investors.

Vision city: V2-Ambition: Shenzhen will be a pilot zone for a national comprehensive reform program and will be built into a national economic hub
V3-Concept: As a State-level innovative city or model city with Chinese characteristics and an international metropolis, Shenzhen has chosen independent innovation as the dominant strategy for its future development.

Vision campus: V2-Ambition: to promote the development of key industries and to establish complete industry chains in the park.
V3-Concept: innovation culture
V4-Motto: "Fertile soil for business venturing and paradise for success".

Controllers campus: **Defined**: The Shenzhen High-tech Industrial Park Office is deployed by the municipal government to provide administrative services in the park. Shenzhen Municipal Government is responsible for the leadership, decision-making, planning and macro-management of SHIP. The decision-making body is the Administrative Group of SHIP with the mayor of Shenzhen as the head, supervising the implementation of the relevant policies on the development of SHIP. The management body is the Administrative Office of SHIP, responsible for the routine daily work in SHIP. The service body includes the Service Centre of SHIP, the Service Centre of Shenzhen Virtual University Park and the Service Centre of Shenzhen Software Park providing the complete service to the enterprises and scientific research institutes in SHIP.

By Brücke-Osteuropa (Own work) [Public domain], via Wikimedia Commons

Official denomination: **Permanent**: as Hi-tech Industrial Park

financial | strategic

Scale campus: **M** [Area in a district]

Land use area: **1.150 ha**

Density city: **5.265** inh./sq km [*estimated]

Transportation City: Railway network; Shenzhen metro; bus transportation; Shenzhen Bao'an International Airport

Distance campus from:

Airport	City centre	University
20 km / 60'	15 km / 50'	≤1 km / ≤15'
Shenzhen Baoan International Airport	Futian CBD, Shenzhen	ShenZhen University

physical | functional

Population campus: **74.000** aprox.
P1-Employees: 74.000 workers

Orgs. in campus: **1.200** aprox.
O1: 1.200 enterprises

Facilities in campus: F1: Auditorium; Conference Room, Restaurant, Cafeteria, Catering, Shops, Mall
F2: Golf Facilities, Sport Facilities
F3: Kinder Garden, Medical Services; Residential Areas [Houses, and Apartments]

Population city: **10.470.000** [2011]

Employment city: Unknown [2.45% unemployment rate]

Tertiary education city: **8** HEIs [full-time based in Shenzhen. Another 122 HEI have branches in the city]

Amenities city: A1: heritage sites; several cultural festivals
A2: 500 stores with floor space of more than 5,000 sq m; several restaurants and bars
A3:> 310 rivers and streams; 230 kilometers of coastline; several natural attractions in surrounding mountains, natural reserves and 15 golf clubs.

Shenzhen High-tech Industrial Park (SHIP) has been listed among China's five state-level high-tech parks. it is located in Nanshan District in Shenzhen. Shenzhen has been a touchstone for China's reform and opening-up policy since first special economic zone was established here in 1980. Supported by the municipal government, Shenzhen High-tech Industrial Park (SHIP) has grown into a high-tech center of research, development, investment and production. SHIP is part of the high-tech industry zone in shenZhen which includes Shenzhen Bay Area [where SHIP is located], Shiyan Area, South Guangming Area, Guanlan, Longhua Banxuegang Area, Baolong area, Great Industrial Area, Kuichong Dapeng Area, University City Area and Ecological Agriculture Area. Shenzhen Software Park is partly located in SHIP.

Cluster base campus: **R&D+Production**: computer, telecommunication, networking, integrated circuit (IC), optical electronics, biological engineering and new materials

Economic base city: Consolidated:The city is the high-tech and manufacturing hub of southern China, home to the world's fourth-busiest container port, and the fourth-busiest airport on the Chinese mainland.
Key sectors:The high-tech developments, financial services, modern logistics; foreign trade and cultural industries are mainstays of the city.

Disjoints

Tainan Science Park

Tainan City, TW

Code: 30-TSP

Year: 1996

Official denomination:

Permanent: as Science Park

Tainan Sicence Park is one of two sites of Southern Taiwan Science Park (STSP). The Tainan Science Park is situated between Xinshi, Shanhua and Anding District of Tainan City. In Taiwan, science parks are intended as special areas ideal for R&D, manufacturing and living that place equal emphasis on environmental integrity and economic expansion.

Cluster base campus:

R&D+Production: four industry clusters: Intergrated Circuits; Optoelectronics; Green Energy and Energy Saving; Biotechnology.

Economic base city:

Consolidated: manufacturing the construction, wholesale and retail trade, Lodging and Food, cultural and recreational and other service industries. The main manufacturing industries include machinery and equipment, metal product, plastic , transportation, food and beverage, textile, and basic metal.
Key sectors: technology and knowledge-based industry and business,

Vision city: V2-Ambition: to stimulate our international competitiveness and to make Tainan an unique living city.
V3-Concept-Pillars: Tainan City Government proposes "Ten Major Plans for Constructing Tainan": "Investing Tainan", "Water Resources and Tainan", "Cultural Capital and Creative City", "New Agricultural Life in Tainan", "Low-carbon Green and Sustainable Tainan", "Tainan with Love", "Safe Tainan", "Smart Tainan" and "Convenient Tainan".

Vision campus: V2-Ambition: To become an Asian high-tech industrial and talent center that will foster growth among Park enterprises and create local jobs./ V4-Motto: Cultivating Southern Taiwan, Positioning Globally.

Ext. Promoters: Prom1:The city of Tainan promotes TSP as an important element for business investment in their industry profile.

Funding campus: **Public:** The STSP Development Plan (which covered the Phase I Site of the Tainan Science Park) is an State initiative by the National Science Council was approved by the Executive Yuan in May 1995 to mark the beginning of southern Taiwan's high-tech development.

By 劉久弘 (Own work) [CC BY-SA 3.0], via Wikimedia Commons

Controllers campus: **Defined**: Under the jurisdiction of the National Science Council, the Science Park Administration (SPA) is given the responsibility of developing, operating and managing the park. The SPA is composed of six divisions--Planning, Investment Services, Labor Relations, Business, Construction Management and Land Development.

functional | physical

Population campus: **60.531** aprox.
P1-Employees: 60.531

Orgs. in campus: **101** aprox.
O1: 101 companies

Facilities in campus: F1: stores, restaurants
F2: Parks, The Sports and Recreation Center
F3: Community Center; Housing

F1

F2

F3

Population city: **1.881.645** [Tainan City 2013]

Employement city: Unknown

3rd education city: **15** HEIs: [including National Cheng Kung University [technology]; and National University of Tainan]

Amenities city: A1: museums; castles and temples; events and musical festivals
A2: shops; restaurants; traditional markets; cultural zone [with restaurants, shops, cafes, etc];
A3: Tainan coastal and recreation area; several parks;

A1

A2

A3

strategic | financial

Scale campus: **M** [Area in a District]

Land use area: **1.043 ha**

Density city: **858** inh./sq km [estimated]

Transportation City: Bus lines; railway network including Taiwan High Speed Rail; Tainan Airport

Distance campus from:

Airport	City centre	University
30 km 30'	17 km 60'	14 km 80'
Tainan Airport	Tainan Station	Tainan University of Technology

High-Tech Campus Eindhoven

Eindhoven, North Brabant, NL

Ext. promoters: Prom1:The establishment and continuous growth of High Tech Campus Eindhoven is the result of efforts by several (collaborative) partners: Philips; Dutch Ministry of Economic Affairs; Brainport Foundation; Municipality of Eindhoven; Brabant Development Agency (BOM); The cityregion Eindhoven (SRE). These parties aim is to develop the Eindhoven region as an internationally recognised technology region and HTCE as the central high tech hub.

Funding campus: **Private**: The driving force behind the establishment of High Tech Campus Eindhoven was Philips, to act as a single location for all its national R&D activities. To further accelerate this process, Philips decided in 2003 to open up the Campus to other technological companies. The result was massive growth. Since March 2012 the Campus entered a new phase. High Tech Campus Eindhoven is, after being sold by Philips to Chalet Group, an independent organisation.

Controllers campus: **Defined**: HTCE Site Management B.V. Founded by a large private company in 1998, High Tech Campus Eindhoven is since 2012 an independent organisation, after being sold by Philips to Chalet Group (Dutch consortium of private investors lead by Marcel Boekhoorn) the management unit was part of the deal. Philips remains on site, but its status changes from owner and manager to tenant.

Vision city: V1-Strategy: Brainport 2020
V2-Ambition: to develop the Eindhoven region as an internationally recognised technology region; to position the Southeast Netherlands as a leader in the international knowledge economy.
V3-Concept/Pillars: People; Technology; Business; Basics; Governance ; and international cooperation.
V4-Motto: Top Economy, Smart Society
V4-Slogan City: "Leading in Technology" [Eindhoven City Region].

Vision campus: V1-Plan: Campus master Plan 2003, Campus Masterplan 2010
V3-Concept: a technological Open Innovation ecosystem: The clustering of R&D companies where knowledge is central to an attractive and innovative environment. This environment is characterized by shared facilities make this knowledge possible and further strengthen. Collaboration, Partnership, and Share facilities to reduce costs are encouraged in campus
V4-Motto: "The smartest square km in the Netherlands".

http://www.microtoerisme.nl [CC BY-SA 3.0], via Wikimedia Commons

financial | strategic

Scale campus: **S** [Portfolio in an Area]

Land use area: **103 ha**

Density city: **2.499** inh./sq km [2011]

Transportation City: Interlocal Bus lines, National railway network, bike infrastructure, the 'Phileas'; a regional bus rapid transit; served by Eindhoven Airport

Distance campus from:

Airport	City centre	University
10-13 km 15'	6 km 20'	6,5 km 21'
Eindhoven Airport	Eindhoven Central Station	Eindhoven University of Technology

physical | functional

Population campus: **8.000**
P1-Employees: 8.000

Orgs. in campus: **120**
O1/ O3: 120 companies and research institutes

Facilities in campus: F1, F2, F3
F1: Central facility with shops, restaurants, supermarket, cafes and bar, auditorium, conference center, Library and Wellness centre
F2: Sport forest and soccer fields, landscaped area with water corps, several bicycle and pedestrian paths
F3: Childcare centre.

Population city: **219.173** [CBS, 2013]

Employment city: **>145.000** [2009]
Main employer-sector: Consultancy, Research and Specialised services

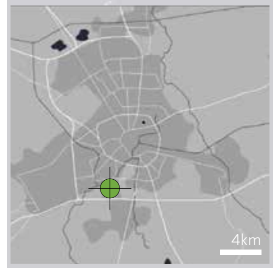
Tertiary education city: **1** university [Technology University of Eindhoven,R-115]
HEI:2 [Fontys Fontys University of Applied Sciences and the Design Academy]

Amenities city: A1, A2, A3
A1: 4 large museums and serveral smaller museums; 1 international school; big public library
A2: shopping centre 'De Heuvel Galerie', amusement park "Efteling"
A3: Genneper Parks, Stadswandelpark, Dommeldal and the wood at Strijp

Touches

Code: **31-HTCE**

Year: **1998**



Official denomination: **Changed**: from Philips High Tech Campus to High Tech Campus Eindhoven in 2005

High-Tech Campus has been designated by the Dutch Ministry of Economic Affairs as a 'campus of national significance'. The site is responsible for nearly 50% of all patent applications in the Netherlands [Source: EPO Worldwide Patent Statistical Database]. The Campus site was originally founded as Philips Research Laboratories in the terrain where the Dutch section of the Philips research department or NatLab [Philips Physics Laboratory] was located; south-west of Eindhoven. After opening the site to other technology companies in 2003, the Philips Campus was renamed High Tech Campus Eindhoven.

Cluster base campus: **R&D +** small Production: Health, Experience & Energy. Main technology domains: Microsystems; High Tech Systems; Embedded Systems; Med Tech; and Infotainment.

Economic base city: Consolidated: high-tech industrial clusters include mechatronics, the automotive industry and electronics.
Emergent: industrial distribution, environmental technology, medical technology and information technology.

Touches
Contains

Science Park Amsterdam

Amsterdam, North Holland, NL

Code: 32-SPA

Year: 2003

Official denomination:

Permanent: as Science Park

Science Park Amsterdam is located in the eastern part of the city, not far from its historic centre. The park was designed to keep an urban character in which buildings, landscape and open space are closely interwoven. The area has been planned to accommodate education, research and business. In 1996, the City of Amsterdam designated Science Park Amsterdam as a major project and agreed to develop the location as a priority area for knowledge-intensive industry, eventually leading to the Masterplan in 2003.

Cluster base campus:

SciResearch: The academic cluster in Biology, Computer Sciences, Astronomy, Chemistry, Mathematics, Physics and Physical Geography

R&D: The research cluster into fields including multimedia, grid computing, visualization, system biology, nanophotonics, cryptology, smart grids, particle physics and microscopy. Many of the businesses operating from Science Park Amsterdam specializes in IT and Life Sciences.

Economic base city:

Consolidated: Finance is the most important sector in the Amsterdam Area, generating approximately 20% of the region's GDP and providing 15% of its jobs. Many international companies in Amsterdam, operate in sectors such as ICT, Fashion, Logistics, Creative and Financial & Business Services.
Emergent: advertising sector.

Vision city: V1- Strategy: Structural vision Amsterdam 2040 [Structurrvisie Amsterdam 2040, DRO 2011]
V2-Ambition: strengthening the economy of the Amsterdam Metropolitan Area [Amsterdam Economic Board]
V3-Concept-Pillars: seven main economic clusters were designated for the Amsterdam Area. Sustainability, the primary driving force behind innovation, is a significant theme evident in all of them. The clusters are: Creative Industries; ICT/e-Science; Life Sciences & Health; Financial & Business Services; Logistics; Flowers & Food; Tourism & Conferences
V4- Motto: "Structural Amsterdam 2040: economically strong and sustainable"

Vision campus: V1-Plan: Science Park Amsterdam Masterplan 2003
V3-Concept: In the urban development plans, Science Park Amsterdam is designed like a network: a structure of semi-public meeting places in and between the buildings, connected by system of public open spaces
V4-Motto: a place where Education, Exploring and Enterprising interact.

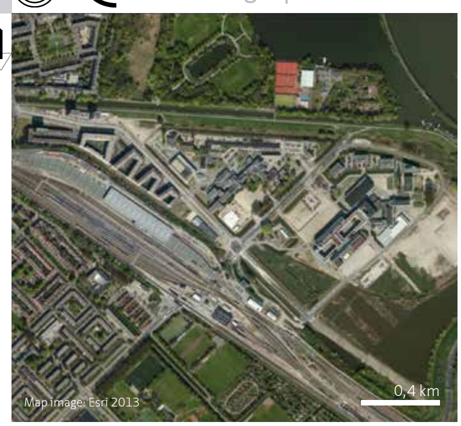
Ext. Promoters: Prom1: Amsterdam Development Corporation; Amsterdam Economic Board presents SPA as one of the Assets of Amsterdam metropolitan area in The Knowledge and Innovation Agenda for the Amsterdam Metropolitan Area.

Funding campus: **PPP:** Science Park Amsterdam is a joint development being fronted by the University of Amsterdam (UvA), the City of Amsterdam and the Netherlands Organisation for Scientific Research. Altogether own the land.

By Jvhertum (Own work) [CC BY-SA 3.0], via Wikimedia Commons

Controllers campus: **Defined**: the Amsterdam Development Corporation (Ontwikkelingsbedrijf Gemeente Amsterdam - OGA) is responsible for the development of Science Park Amsterdam on behalf of the university of Amsterdam and the City. that means that the OGA acts as the client for all required public work, and it prepares the required leases for all areas.

strategic | financial



functional | physical

Population campus: **6.000** aprox.* [*excluding companies]
P1-Employees: 1.200 researchers and 1.500 staff from UvA Faculty of Sciences
P2-Students: 2.500 from UvA Faculty of Sciences and 600 - 900 students from AUC

Orgs. in campus: **84** est.
O1: 80 high-tech, knowledge-intensive companies
O2: UvA Faculty of Science [4 departments]; Amsterdam University College
O3: 3 Netherlands Organisation for Scientific Research institutes.

Facilities in campus: F1: catering and conference facilities
F2: sports amenities
F3: student housing
F-Plan: a hotel and conference facilities are under construction.

F1

F2

F3

Population city: **801.847** [CBS, 2013]

Employement city: **422.000** *labour force [2011]
Main employers-sector: the Dutch financial sector employs 270.000 people

3rd education city: **2** universities [the University of Amsterdam, R-92; and the VU University Amsterdam, R-159]
HEI:17 institutions of applied sciences.

Amenities city: A1: 51 museums; 55 Theatres and concert halls; 1 Music theatre; 15 cinemas;
A2: 32 markets; 6.159 shops; 1.515 cafés and bars; 36 clubs; 1,150 restaurants; 398 hotels;
A3: 40 parks; 165 canals; Zoo; 5 campsites.

A1

A2

A3

Scale campus: **S** [Portfolio in an Area]

Land use area: **70 ha**

Density city: **4.791** inh./sq km [Gemeente Amsterdam, 2012]

Transportation City: Tram lines; bus lines; and metro lines;12 ferries; bike infrastructure; national railway; served by Schiphol Airport

Distance campus from:

Airport	City centre	University
24 km 45'	5,5 km 20'	≤1 km ≤15'
Schiphol Airport	Amsterdam central Station	University of Amsterdam

TOC

Biopolis

Singapore City-State, SG

Ext. promoters: Prom1:The Ministry Of Trade and Industry, Singapore Government and A*STAR, the Agency for Science, Technology and Research, promote Biopolis, Fusionopolis in One-North location.

Vision city: V1-Plan: The Strategic Economic Plan [1991]
V2-Ambition: to attain the status and characteristics of a first league developed country within the next 30 to 40 years;
V3-Concepts: economic dynamism, a high quality of life, a strong national identity and the configuration of a global city.
V4-Motto: "A Developed country in the first league"

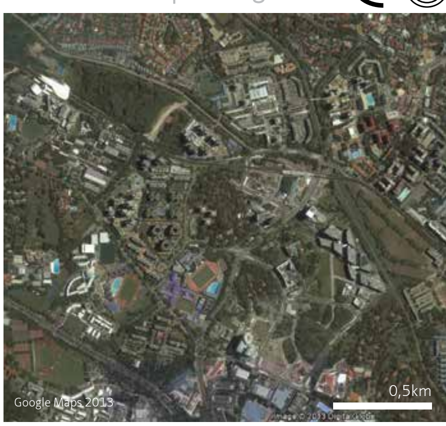
Funding campus: **Public**: Government initiative. The masterplan for the area One North was commissioned by the Science Hub Development Group (SHDG) and Jurong Town Corporation (JTC)

Vision campus: V1-Plan: One North Masterplan 2001 - 2021
V2-Ambition: to meet government's current plan to develop Singapore into a bio-medical hub and to create new engines of growth.
V3-Concept: The Biopolis master-plan bears reference to the flowing ground form, undulating terrain and the dramatic skyline. The building forms are never rectilinear, thus reflecting the dynamism of the interaction between physical and human "force-fields".

Controllers campus: **Defined**: JTC Corporation, is Singapore's principal developer and manager of industrial estates and their related facilities. Its mission is to plan, promote and develop a dynamic industrial landscape, in support of Singapore's economic advancement. [Parent agency: The Ministry Of Trade and Industry, Singapore Government]

By Henry Leong Him Woh [CC BY-SA 2.0], via Wikimedia Commons

financial | strategic



physical | functional

Population campus: **2.000** aprox.
P-1 Employees: 2.000 scientists, researchers, technicians and administrators

Orgs. in campus: unknown

O1/O3: public and private biomedical research institutes and organisations

Facilities in campus: unknown

F1

F2

F3

Scale campus: **S** [Portfolio in an Area]

Land use area: **65 ha**

Density city: **7.497,9** inh./sq km

Transportation City: Network of 4 Mass Rapid Transit - MRT train lines, Light rapid transit [LRT] or shorter trains. 387 bus services and 8 taxi companies; Changi International Airport

Population city: **5.353.494** [2012]

Employment city: **3.290.000** [*national labour force 2012]

Tertiary education city: **4** universities [the National University of Singapore, R-40; the Nanyang Technological University, R-169; the Singapore Management University; and the Singapore University of Technology and Design]

Distance campus from:

Airport	City centre	University
28 km 25'	9 km 15'	2,5 km 20'
Changi International Airport	Downtown Core Singapore	National University of Singapore and UTD

Amenities city:

A1:>50 Museums, several multi-cultural festivals
A2:>140 major shopping centres; several restaurants and bars that open 24/7; thematic attractions and parks [Universal studios; and the oceanarium]
A3:>300 parks and 4 natural reserves, 2800 trees/sq km

A1

A2

A3

Contains

Code: **33-BPS**

Year: **2003**

Official denomination:

Permanent: Biopolis [referred as a cluster and/or location]

Biopolis was conceived as the cornerstone of a vision to build up the biomedical sciences as a key pillar of the Singapore economy. It accommodates public as well as corporate research laboratories in one location of the biomedical development called "One North." Biopolis and later on, Fusionopolis located next to it, are today regarded as part of a greater eco-system in One-North, where working, living, and playing comes together as one. The development of Biopolis was undertaken in 5 phases since 2003.

Cluster base campus:

R&D+Production: biotechnology and biomedical sciences [life sciences value chain, from R&D to manufacturing and healthcare delivery]

Economic base city:

Key sectors: biomedical sciences, engineering, logistics, healthcare, maritime, info-communications and digital media.
Consolidated: 48% Electronics industry; 26% Manufacturing; 26% Financial business
Emergent: centralised or "shared services" such as IT, finance, and logistics.

Disjoints

Taichung Science Park

Taichung,Central Taiwan, TW

Code: 34-TCSP

Year: 2003

Official denomination:

Permanent: as Science Park

Taichung Science Park is one of four sites of CentralTaiwan Science Park located in Taichung City at the border between Daya and Shituen Districts. On September 23, 2002, the National Science Council ratified the foundation of Central Taiwan Science Park. The construction of Taichung Park started ten months after the plan was ratified. On July 28, 2003, private firms were introduced.

Cluster base campus:

R&D+Production: semiconductors, optoelectronics, IC and precision machinery ventures.

Economic base city:

Consolidated: manufacturing; service-industry markets
Emergent: high-tech industries. Today, the broad-based economy continues to thrive in a variety of sectors--from aerospace to agriculture--thanks to continuing, growing investments from local and international companies.

Vision city: V4-Motto: "Taichung: Creative, Alive, Cultural" It is The Intelligent Communities of the Year 2013.

Ext. Promoters: Prom1: Taichung City government promotes the TCSP as an important development project in the economic profile of the region.

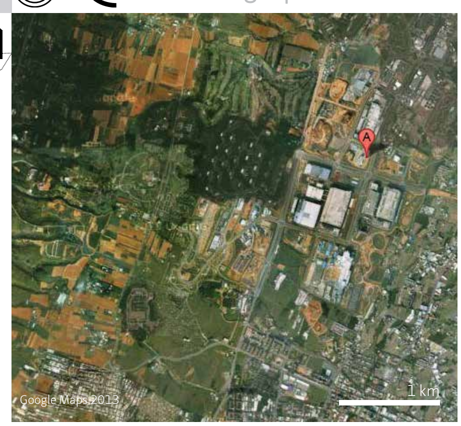
Vision campus: V2-Ambition: is to build a green park, featuring "sustainable development" and "localized charm"
V4-Motto: Taichung Park: "a Prosperity Powerhouse of Central Taiwan"

Funding campus: **Public:** founded by the National Science Council

By Fcuk1203 (Own work) [CC BY-SA 3.0], via Wikimedia Commons

Controllers campus: **Defined**: Under the jurisdiction of the National Science Council, the Science Park Administration (SPA) is given the responsibility of developing, operating and managing the park. The SPA is composed of six divisions--Planning, Investment Services, Labor Relations, Business, Construction Management and Land Development.

strategic | financial



functional | physical

Population campus: 21.862 aprox.
P1-Employees:21.862 [2011]

Orgs. in campus: 86 aprox.
E1: 86 companies [2011]

Facilities in campus: Unknown

F1

F2

F3

Population city: 1.081.500 est.* [2010] *Only Taichung City

Employement city: 465.000 [Taichung city, 2007]
Main employers-sector: Service sector

3rd education city: 14 Universities [including two medical universities]
HEIs: 17 [1 nursing college, 3 colleges, 1 junior college, 9 vocational schools, 3 institutes of technology]

Amenities city:

A1: 2 international schools; 7 museums; 5 art galleries and centres; several cinemas
A2: several comercial districts and shops; traditional markets; art district; restaurants and bars
A3: sport facilities, including sports stadiums, baseball fields, golf courses, swimming pools, public basketball courts and soccer fields, rock-climbing walls, bicycling paths, hiking trails and public parks

Scale campus: M [Area in a District]

Land use area: 413 ha

Density city: 1.200 inh./sq km [estimated]

Transportation City: National railway network and Taiwan High Speed Rail (THSR); Taoyuan International Airport connected by bus and HSR; Taichung Airport connected by bus; Kaohsiung International Airport connected by railway; Bus network

Distance campus from:

Airport	City centre	University
7 km 100'	13 km 120'	12 km 120'
Taichung Ching-Chuang-Kang Airport	Taichung Station in central district	National Taichung Educational University

Biocant Park

Cantanhede, Coimbra, PT

Disjoints

Code: 35-BP

Year: 2005

Official denomination: **Permanent**: as Park

Biocant is located 25km from Coimbra and it was created through a partnership between the Municipality of Cantanhede and the Center for Neuroscience and Cell Biology of Coimbra - CNC [a National Research Centre linked to the University of Coimbra]. BIOCANT Park is the first Portuguese venue entirely devoted to Biotechnology. [Based on Carvhalo, 2013]

Cluster base campus: **R&D**: Biotechnology and Life Sciences

Economic base city: Consolidated: Coimbra has a service-based economy [retail, horeca, education,public administration] resulted from the decline of its manufacturing activity [ceramics, food and textiles] during the last decades.

Ext. promoters: Prom1: the Municipality of Cantanhede, the Center for Neuroscience and Cell Biology of the University of Coimbra and Associação Beira Atlântico Parque.

Vision city: V1-Plan: Municipal The Master Plan is Currently under revision and expected it to be Concluded in November 2013

Funding campus: **PPP**: investments by the Municipality of Cantanhede and by the Center for Neuroscience and Cell Biology of Coimbra. Taking advantage of the last years' national investment in Life Sciences, it was possible to set out an integrated development strategy to promote entrepreneurship and economic growth.

Vision campus: V2-Ambition:to create value for the region and for the country by stimulating investment and commercial initiatives based in scientific and technological knowledge.
V4-Motto: Creating Value in Biotechnology.

Controllers campus: **Defined**: Beira Antlantic Park Association [Associação Beira Atlântico Parque] is the managing institution of the biotechnological park, in association with five municipalities and several institutions. The association is private non-profit organization that integrates multiple investors with capital mainly owned by the Municipality of Cantanhede

Google, Street view September 2014

financial | strategic

Map image: Esri 2013

physical | functional

Population campus: **210** aprox.
P1-employees: 60 workers and 150 researchers from the Center for Neuroscience and Cell Biology of Coimbra - CNC

Orgs. in campus: **37** aprox.
O1:28 permanent and affiliated biotechnology companies
O3: 8 specialised technology transfer centres; 1 venture capital firm

Facilities in campus: F1: bar and restaurants; conference centre

F1

F2

F3

Scale campus: **S** [Portfolio in an Area]

Land use area: Unknown

Density city: Unknown

Transportation City: Bus network and the Coimbra trolleybus system; accessed by railway network and served by the airport "Aeródromo Municipal Bissaya Barreto"

Population city: **38.032** [Cantanhede 2013]

Employment city: **17.920** [Cantanhede]
Main employer-sector: 36% in the agriculture sector, 26% in Manufacturing and 38% in Service

Tertiary education city: **1** university [University of Coimbra]

Distance campus from:

Airport	City centre	University
40 km 35'	30 km 30'	32 km 30'
Coimbra airport	Coimbra-A railway station	University of Coimbra

Amenities city: A1: several museums and monuments; art galleries and antique shops
A2: shops, bar and restaurants;
A3:parks and gardens; leisure and sport facilities including stadium

A1

A2

A3

Chemelot Campus

Sittard-Geleen, Limburg, NL

Touches

Code: 36-CRDP

Year: 2005

Official denomination:

Permanent: as Campus and Industrial Park.

Chemelot R&D Park is located in Sittard-Geleen; south of the Netherlands. With two large chemical companies [DSM and SABIC] on the site, the name Chemelot was introduced in 2002 and comprises the Industrial Park and the Campus. At the end of 2004, based on new DSM's strategy that decentralized research activities from the business activities, DSM, the Municipality of Sittard-Geleen, the province of Limburg and the trade unions, made and agreement with the aim to develop the former DSM site into an open industrial site for chemical production, research and development. The name DSM Research disappeared, the research site is now called Chemelot Campus; accomodating DSM, SABIC and, increasingly, other companies' activities in the field of research and development.

Cluster base campus:

R&D+Production: Chemical industries. The focus is on five primary sectors: performance materials, bio-based materials, biomedical materials, biotechnology (biosynthesis) and analytical R&D support.

Economic base city:

Key sectors: industry and construction; trade and services.
Consolidated: chemical, automotive and logistics. at international level. Construction, retail, hospitality, healthcare, commercial services and other services sectors strongly represented at regional-local level.

Vision city: V1-Strategy: Brainport 2020 program in South Limburg and Limburg Economic Development (LED)
V2-Ambition: Brainport 2020 aims to position the Southeast Netherlands as a leader in the international knowledge economy. The three central municipalities in South Limburg (Heerlen, Maastricht and Sittard-Geleen), jointly with the State, business and educational institutions, will cooperate economically.
V3-Concept/ Pillars: People; Technology; Business; Basics; Governance ; and international cooperation.
V4-Motto: Top Economy, Smart Society.

Vision campus: V2-Ambition: Chemelot has been planned around one central idea to bring together the knowledge and skills normally found only in major organizations, and to apply these within a flexible community of small and large chemical businesses, radically changing the view of the chemical industry
V3-Concept: Open Innovation.
V4-Motto: The chemical innovation community.

By Michiel1972 (Own work) [CC BY-SA 3.0], via Wikimedia Commons

functional | physical

Population campus: **1.185** aprox.
P1- Employees: 1.185

Orgs. in campus: **54** est.
E1: 34 companies on Chemelot Campus and 20 companies on Chemelot Industrial Park.

Facilities in campus: F1: staff restaurant and auditorium

F1

F2

F3

Population city: **93.914** [CBS, 2013]

Employement city: Unknown
Main employers-sector: Industry with 11.191 jobs and Health care sector with 8.995 jobs [Kerncijfers Sittard-Geleen 2011-2012]

3rd education city: **1** university in the region [Maastricht University, R-197] + HEI: 2 in Sittard-Geleen [Fontys School of applied sciences and Hogeschool Zuyd orLeeuwenborgh] and 6 in Maastricht.

Amenities city: A1: Historic city centre with heritage sites; 2 museums; 10 art galleries; 5 theatres; 2 cinemas; shopping areas
A2: several cafes and restaurants
A3: green areas with an extensive network of hiking, cycling, and mountain biking trails; 2 large parks and other forests in the surroundings; urban gardens; wellness and swimming facilities; sport and recreation centre; 2 large Sports Halls

A1

A2

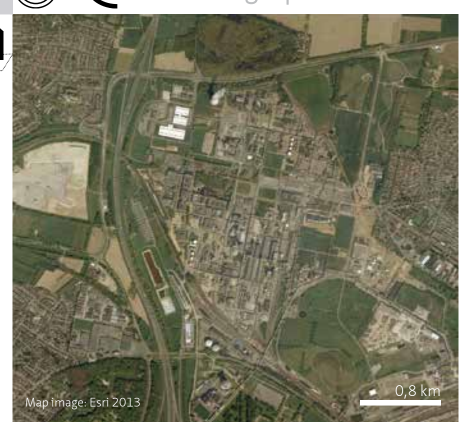
A3

Ext. Promoters: Prom 1: The Chemelot Campus Consortium
Prom2: Maastricht Region; Brainport; Maas Valley Frontier (Grensmaasvallei) Westelijke Mijnstreek, the Tourist Office for South Limburg; Limburg Economic Development; Gemeente Sittard-Geleen

Funding campus: **PPP:** DSM invested in acquisition and real estate; Sittard-Geleen invested in infrastructure. Chemelot Campus B.V. is established to further develops Chemelot Campus and it is the legal person that gives shape to the Chemelot Campus Consortium. The initiators of this consortium, the Province of Limburg, Maastricht University/ Maastricht UMC+ and DSM, each holding a total of 33.3%.

Controllers campus: **Defined**: Chemelot Campus B.V. provides supporting facilities and shared services ('fitting' real estate) for the educational and research activities and the industry at the campus and manages, operates and exploits all the Chemelot buildings.

strategic | financial



Scale campus: **M** [Area in a District]

Land use area: **800 ha**

Density city: **1.217** inh./sq km

Transportation City: Bike infrastructure; national railway; bus network. The city is served by Maastricht Aachen Airport

Distance campus from:

Airport	City centre	University
12 km 90'	6 km 12'	24 km 80'
Maastricht-Airport	Geleen Central Station	Maastricht University

Barcelona City of Knowledge

Barcelona, Catalonia, ES

Ext. promoters: Prom2: The area is adressed several times as a site for business investments in Strategic sectors of the City of Barcelona.

Funding campus: PPP: BKC is a collective project which aims to strengthen the idea of a participative and cooperative government. The Barcelona City Council, the Chamber of Commerce of Barcelona and the Spanish National Research Council (CSIC) are partners of this project along with the University of Barcelona and the Polytechnic University of Catalonia.

Controllers campus: Planned: BKC is aimed at a common governance structure through a single committee; a social, business, & scientific council; and a coordination and management unit. A Unit Governance Committee will be created comprising the rectors of the University of Barcelona and the Polytechnic University of Catalonia, the Mayor of Barcelona, the Chairperson of the Barcelona Chamber of Commerce and the Chairperson of the Spanish National Research Council (CSIC).

Vision city: V1-Strategy: Barcelona Vision 2020
V2-Ambition: "Reinforce its relationships with the emerging cities of the world and hold capitality of the Mediterranean"
V2-Goals: the stimulus of clusters and new transversal growth-driving sectors on a world scale; the creation of new companies and better trained and educated staff; and the revitalisation and updating of traditional industrial capital and local economies of agglomeration.
V3-Concepts: economic and social leadership; competitiveness and sustainability.

Vision campus: V1-Plan: Convertion Plan 2015 - campus model
V2-Ambition: to establish a framework for strategic collaboration aimed at building a knowledge ecosystem to promote employability, social cohesion and territorial economic development.
V2-Goals: be an international benchmark in teaching, research, knowledge transfer,innovation, and lifelong learning; attracting and encouraging talent, based on full internationalization; developing a comprehensive model of campus committed to the environment in a sustainable manner and student-oriented.

Google Earth, 2016

Contains

Code: 37-BCK

Year: 2009

Official denomination:

In transition: regarded as City of Knowledge, Gateway of knowledge and Territorial campus.

Barcelona City of Knowledge or "Gateway to Knowledge" is a project regarded as one of the most active scientific, technical and economic hubs in the country. This zone encompasses a number of physical clusters of knowledge activity including the Diagonal Campus of the University of Barcelona, the North and South campuses of the Polytechnic university of Catalonia [UPC] established in the area since 1980, the Technology Park of Barcelona, the institutes of the Spanish Council for Scientific Research (CSIC), the Advanced School of Business Administration and Management and the Faculty of Law ESADE – part of the Ramon Llull University– and the Hospital de Sant Joan de Déu, among others.

financial | strategic

Scale campus: M [Area in a District]

Land use area: 227 ha

Density city: 15.813 inh./sq km [2011]

Transportation City: Regional and metropolitan [underground] railway network; buses lines; taxis, funicular; trams.
Served by Barcelona-El Prat Airport and the Port of Barcelona

Distance campus from:

Airport	City centre	University
12 km 40'	7,5 km 30'	≤1 km ≤15
Barcelona-El Prat Airport	Estació del Nord	University of Barcelona and UPC

physical | functional

Population campus: 54.750 aprox.
P1-Employees: 3.700 academic staff ; 2.250 administrative and service staff
P2-Students: 42.000 students and 6.800 researchers and postgraduate students

Orgs. in campus: 73 aprox.
O1: >70 companies in Barcelona Science Park in [1997]
E2: 2 universities
E3: 3 research institutes

Facilities in campus: F3: housing for students & guests

F1

F2

F3

Population city: 1.615.448 [Census 2011]

Employment city: 853.132 [2001]
Main employers-sector: Service with 747.943 workers or 87,7% of employement [2001]

Tertiary education city: 8 universities [University of Barcelona; Autonomous University of Barcelona; Polytechnic University of Catalonia; Pompeu Fabra University, R-186; Ramon Llull University; University of Catalonia; International University of Catalonia; Abat Oliva CEU university]

Amenities city:
A1: 37 libraries; >20 Museums, collections, and exhibition centers; 203 commercial cinemas rooms; >50 Theatres and other places of performing arts; 3 large music auditoriums
A2:several shops and commercial districts
A3: >1.700 Sport facilities; 559 Urban parks; 10.981.127m2 of urban green area

A1

A2

A3

SciResearch: Life sciences, social sciences and technologies. BKC also covers other thematic areas following the same standards of excellence: architecture, engineering, sciences and Fine arts.

Economic base city:
Consolidated: service sectors [87% of jobs]; Industry [8,8% of jobs] and Construction [3,5% of jobs] [2011]
Key sectors: knowledge-intensive sectors: information and communication technology (ICT), media, biotechnology and life sciences, energy, design, sustainable mobility and aeronautics, agrofood, etc.

GIANT Innovation Campus [GIANT-Grenoble Innovation for Advanced New Technologies]

Grenoble, Isère, Rhône-Alpes, FR

Touches
Contains

Code: 38-GIANT

Year: 2009

Official denomination:

Permanent: as Campus

GIANT is located in Grenoble, at the heart of the French Alps. Spatially, the campus is divided into three technological districts supported by three so-called cross-competence centres. Technological districts are: Information and Communication; Energy; and Healthcare. GIANT's development plan embodies a radically new carbon-neutral approach, underpinned by three key principles: cooperative energy management; a combined transport system; and integrated urban blocks. Grenoble has been regarded as one of the most innovative territories of France with its development model built on a historic partnership between academia, research and industry.

Cluster base campus:

SciResearch+R&D: Communication technologies; Renewenable energies and environmental problems; Bioscience and healthcare

Economic base city:

Emergent & Key sectors: three growth sectors: Micro-nanotechnologies and software; Biotechnology and Life Sciences; New energy technologies.
Grenoble is also a rich diversified industrial fabric where traditional sectors (mechanical, chemical) still play an important role in the economic fabric and local employment.

Vision city: V1-Policy: national industrial policy [2004] to mobilize the key competitiveness factors as the ability to innovate.
V1-Plan: "Grenoble Factor 4" for an inclusive and sustainable city [City Council, 2008]
V2-Ambition: Support for competitiveness clusters is a priority for the City of Grenoble which financially supports research and development worn by actors in Grenoble poles, mainly SMEs and laboratories
V2-Goal: fourfold emissions greenhouse gas emissions by 2050.

Vision campus: V2-Ambition: Companies, researchers and students working together to drive innovation.
V2-Goals: to address the major societal challenge on Information and communication, energy, healthcare; To decompartmentalise and create technological districts and centres of excellence focused on key application areas; To harmonise urban and scientific development.
V3-Concept: the GIANT partners, together with their regional and national authorities, have launched a major urban transformation of the campus to shape it into a vibrant and attractive urban district.
V4-Motto: GIANT The Campus of Technological Innovation.

By Christian Hendrich, 2004 [CC BY-SA 3.0], via Wikimedia Commons

Ext. Promoters: Prom2: GIANT partners include research organisations, local authorities, players in higher education and industry whose academic and economic goals are aligned with its approach. Local governments partners are: Etat; Région Rhône Alpes; Département de l'Isère; la Métro - Communauté d'agglomération; Ville de Grenoble

Funding campus: **Public & Private:** Public & Private: Founding members include three in university sector [Grenoble ecole de Management (GeM); Institut Polytechnique de Grenoble (Grenoble InP); Université Joseph Fourier (UJF)]; two major French research institutions and three leading european laboratories. An investment of 1.3 billion Euro was launched by architect Claude Vasconi for urban development.

Controllers campus: **Defined**: GIANT partnership is addressed as the management body controlling the campus. Nevertheless, information about this entity and its organisation structure was not found.

strategic | financial

functional | physical

Population campus: **16.000** aprox.* [*excluding residents]
P1 Employees: 6.000 researchers; 5.000 industrial jobs
P2-Students: 5.000
Planned Residents: 30.000 [10.000 researchers; 10.000 industrial jobs; 10.000 students; 10.000 residents]

Orgs. in campus: **48** est.
O1: 40 companies;
O2: Grenoble Ecole de Management; 5 schools of Grenoble Institute of Technology and schools of Joseph Fourier University in MINATEC clusters
O3: 3 centres; 2 research Institutes

Facilities in campus:
F1: restaurants, leisure facilities
F2: parks and abundant green spaces
F3: housing

Population city: **156.000** [Grenoble, 2013]

Employement city: **166.000** [2012]
Main employers-sector: 36% in Services and 23% in Industry [CCI Grenoble, 2012]

3rd education city: **4** universities
HEI: 9 grandes écoles.

Amenities city:
A1: 17 museums; 6 dance theatres; 15 music stages; 13 theatres; 9 cinemas; 19 libraries; 3 major congress facilities; many historical sites and architectural heritage
A2: streets with commercial sites;>15 traditional markets
A3:>50 parks and gardens; 3 natural parks in the surroundings;
several squares

Scale campus: **M** [Area in a District]

Land use area: **250 ha**

Density city: **8.496** inh./sq km

Transportation City: Served by Grenoble-Isère Airport, Lyon Saint-Exupéry Airport and Geneva International Airport; Metyrovelo [bike rents]; bus and tram lines; the campus is accessed through railway network with high speed trians [TGV]

Distance campus from:

Airport	City centre	University
40 km 30'	1,5 km 15'	≤1 km ≤15'
Grenoble-Isère Airport	Gare de Grenoble	Grenoble Ecole de Management & Grenoble Institute of Technology

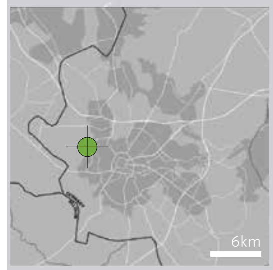
RTH Aachen University & Research Campus Metalen

Aachen, North Rhine-Westphalia, DE

Disjoints

Code: 39-RWTH-RCM

Year: 2011



Official denomination:

Permanent: as Campus

RWTH Aachen, aims at becoming one of the leading technical universities worldwide with the new RWTH Aachen Campus. Campus Melaten is in the first phase of construction for RWTH's new research park which overall is planned to accommodate 19 research clusters over a 800,000 m² site. Within the next 6-8 years, up to 150 national and international companies with direct connections to institutes and research centers are expected to settle in a mixed functional area. A resolution for the development plan was then passed on December 16, 2009. The first phase of construction for the first six research clusters on Campus Melaten is to take place from 2011-2012 [Based on Van Winden, 2011]

Cluster base campus:

R&D: The initial six clusters include Logistics, Integrative Production Technology, Photonics, Bio-Medical Engineering, Heavy Duty Drive Systems and Components, and Eco-friendly Sustainable Energy.

Economic base city:

Key sectors: Automotive and Rail Technology; Chemical Industry; Electronic & optical industry; energy & climate protection; Healthcare; Forest & Wood; ICT; Life Sciences and Medical Technology; Logistics; Mechanical Engineering and Industrial Engineering; Modern Materials and Plastics; Food; Paper and specialised supply industries; Textile technology.

Ext. promoters: Prom1:The city of Aachen and RWTH Aachen University.

Vision city: V1-Strategy: Aachen Mission 2020s aligned to strenght collaboration.
V3-Concept: Aachen. Knowledge creates the future the profile of the Science and Technology Region Aachen is outlined. Aachen today is a recognized center of knowledge and technology region.
V-4 Motto: "Aachen, we all are"

Funding campus: **Public:** The expansion areas of the RWTH Aachen Campus are owned by the Bau- und Liegenschaftsbetrieb NRW (BLB NRW) which is a building and real estate management authority owned by the State of North Rhine-Westphalia.

Vision campus: V4-Motto institution: Excellence through achievement.

Controllers campus: **Defined**: RWTH Aachen Campus GmbH (Campus GmbH) is responsible for the development, planning, realisation and safeguarding of the overall campus concept. RWTH Aachen Campus GmbH was founded specifically to assume the management of the RWTH Aachen Campus. As a joint subsidiary of RWTH Aachen University (95%) and the City of Aachen (5%) it coordinates all activities relating to RWTH Aachen Campus and represents the interests of all key stakeholder groups, both internally and externally. RWTH Aachen Campus GmbH has the exclusive right to decide on the utilization of the new campus premises as the contracting authority.

Google Earth, 2016

financial | strategic

physical | functional

Population campus: Unknown

P1-Employees:120 aprox.
P-2 Students: unknown
Plans: 11.000 employees expected

Orgs. in campus: Unknown*

*In 2011, 81 firms are matriculated from the 100 expected; 31 departments from the RWTH and one department from the FH Aachen, have already committed themselves to a long-term cooperation and to relocate to the RWTH Campus in Melaten.

Facilities in campus: F1 F2 F3

F-Plan: hotels and restaurants, shops and services.

Scale campus: S [Portfolio in an Area]

Land use area: 47,3 ha

Density city: 1.541 inh /sq km [estimated]

Transportation City: Bus and railway [Euroregio train and 2 HSL; Thalys and ICE] networks. The nearest airports are Düsseldorf International Airport, Cologne Bonn Airport and across the border in the Netherlands, the regional Maastricht Aachen Airport.

Population city: 248.137 [2012]

Employment city: 110.114 [employed with social security]
Main employers-sector: the Service sector employs 90.293

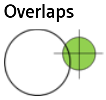
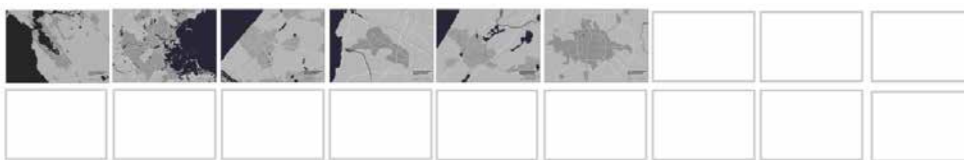
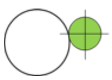
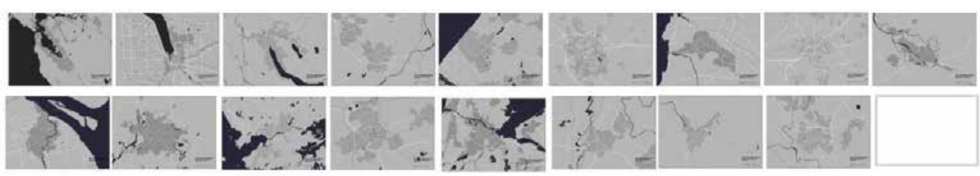
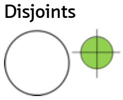
Tertiary education city: 4 HEIs [including RWTH Aachen, R-168]

Distance campus from:

Airport	City centre	University
35 km 30′	5 km 30′	≤1 km ≤15′
Maastricht Aachen Airport	Aachen Hauptbahnhof	RWTH Aachen

Amenities city: A1 A2 A3

A1: 1 International School; 6 theatre, concert halls and 8 museums; numerous castles, fountains and springs
A2: several restaurants, caf'es pubs, and bar gardens
A3: 230 sport clubs; 35 sports grounds, 75 indoor sports centres and 14 gymnasiums; large wooded area in the surrounding.

RELATIONSHIP	*DESCRIPTION*
Equals 	
Contains 	
Overlaps 	
Touches 	
Disjoints 	

Equals

City is the same as Campus

This group includes four areas that were newly built as towns and/or cities. These four cases are located in Asia and were planned and built based on wide government initiatives between the years 1957 and 1986; one during the period regarded as the Atomic Age and the remaining three during the Spatial Age and the ICT Industrial revolution. All of them have been conceived as very new areas to encourage academy and sciences. Nowadays, two of them have been designated as special zones for economic development in their hosting regions. Due to their large scale, they accommodate one or more cases recognised as science parks, industrial parks, university campuses, and/or development areas. The clusters these cases accommodate are focused on R&D mainly on Information Technologies and Biotechnology.

Strategic Data

- The ambitions framing these four cases are originated at national scale and they all pursue "Innovation" [Scientific or Industrial] as source for economic development.
- The cases of this group, which are in fact towns or cities, are developing specific measures to attract business and promote themselves in an international context. Some of these zones give advantage on regulatory standard requirements and financial help from governmental body and local autonomy.

Financial Data

- Originally, these four cases are funded with public capital only. Nevertheless, changes in their socio-economic contexts have evidenced the influence of private capital in their developments. In most of the cases, public and private parties have initiated cooperation but the funding structures of the cases seem to be in transition since their partnerships are not officially established as a recognised institution. However, they present themselves as such.
- In most of the cases [with the exception of Akademgorodok] the management unit that control the cases is clearly defined by a management unit. However, they are diverse.
- The regions and/or countries are official promoters of the cases in this group addressing them as pillars for their economic development. In two of the four cases especial promotion bodies has been set up which are actively and formally marketing the case.

Functional Data

- The mean population accommodated in these cases is 100.000. Nevertheless, their composition is varied given the diversity of the data found. For instance, the population of Akademgorodok [70.000] and Tsukuba [214.000] is measured by the amount of residents [including students and researchers], while in Deadeok [62.689] and Sendai [53.431], this data is found by the amount of employees.
- The amount of organisations accommodated in these cases is also varied in number and types. For instance, these cases accommodates between 59 up to 550 companies. They all accommodate at least one university and several research institutes and centres.

Physical Data

- According to their perceived physical boundary, all the cases of this group are perceived as Large-scale cases.
- Their size in area vary widely ranging from 1.000 ha [Sendai] to 28.500 ha [Tsukuba].
- They all have nearly the same distance to the closest airport [50km] with the exception of Daedeok [150km].

1957 - 1986

YEAR	NAME OBJECT	NAME CITY
1957	Akademgorodok Academic Town	Novosibirsk, Siberia, RU
1968	Tsukuba Science City	Tsukuba, Ibaraki, JP
1974 -78	Taedok Science Town & Daedeok Innopolis	Daejeon, Hoseo, KR
1986	Sendai Technopolis & Izumi Park Town Industrial Park	Sendai city, Miyagi prefecture, JP

Contains

City contains Campus

1957 - 2009

YEAR	NAME OBJECT	NAME CITY
1957	TU/e Sicence Park	Eindhoven, North Bravant, NL
1982	Singapore Science Park	Singapore City-State, SG
1984	Leiden Bio Science Park	Leiden, South Holland, NL
1985	Western Australia Technology Park	Perth, Western Australia, AU
1985 -86	Otaniemi Science Park & Otaniemi Technology Hub	Espoo, Greater Helsinki, FI
1991	Brandenburg Technical University Campus	Cottbus, Brandenburg , DE
1994	Berlin Adlershof Humboldt University	Berlin, Brandenburg , DE
1996	Shenzhen Hi-Tech Industrial Park	Shenzhen, CN
1996	Tainan Science Park	Tainan City, TW
2003	Science Park Amsterdam	Amsterdam, North Holland, NL
2003	Biopolis	Singapore City-State, SG
2009 *	Barcelona City of Knowledge	Barcelona, Catalonia, ES
2009	GIANT Innovation Campus [Grenoble Innovation for Advanced New Technologies]	Grenoble, Isère, Rhône-Alpes, FR

This group includes 13 areas located inside the urban fabric, but they are perceived as distinct cases from the city. These cases are mainly surrounded by physical elements that create boundaries between them and the cities [e.g. main roads, fenced walls, distinct shapes of the built environment or specific access points disconnected from the main city structure].

Most of these areas have kept their official denomination, mainly Park or Campus. The type of cluster base they represent are, for the most, R&D clusters [16 in total out of 17] in combination with Scientific or fundamental research [6 in total] and a small share in combination with Production [4 in total], which is possible giving their border conditions at the edge of the cities. This is the case of two areas in Asia and two in Europe [one of these combines only small production]. The research areas of these clusters are very diverse. Nevertheless, Biotechnology is addressed in the majority of the cases [10 out of 17] as the most common research field, as well as Energy & Health, Electronics, ICT and Materials. An important observation is that in nine cases, the cities hosting these campuses addresses Biotechnology, Health or Life Sciences as a key or emergent sector for their economic development.

These areas accommodate different types of research clusters. Most of them are R&D clusters [11 cases] in combination with scientific research clusters [7 cases] and/or Production clusters [3 cases]. Equally, these three production clusters are located in Asia [Taiwan, China and Singapore]. The fields represented in these research clusters are also varied in most of them, with exception of two cases, which specialize in Biotechnology [Biopolis Singapore], and Medial life Sciences [Leiden Bio Science Park]. For the most, they are combinations of these major fields: Biotechnology, Health & Life Sciences [11 cases]; ICT [7 cases]; [Energy [6 cases]; Materials [4 cases]; Electronics [4 cases]; Mobility [2 cases]

Strategic Data

- Few cases [5 out of 13] have an intended strategy as a framework for their development.
- Innovation and economic growth are the main drivers in the strategic ambitions of these cases. The most sounded concepts aimed to achieve their strategic goals are Cooperation [7 cases]; International Attractiveness [4 cases]; Urban Integration [4 campuses].
- In contrast to the cases, most of their hosting cities [10 out of 13] have designated strategies [e.g. plans, policies, visions, etc]. The ambitions are diverse and combined but most of them are based on Differentiation, Strong Economy, and Competitiveness.
- The concepts the hosting cities in this group are using to accomplish their ambitions are diverse and they use combinations of concepts. The following are the most common: Attractiveness [5 cases]; Knowledge [3 cases]; Science & Technology [3 cases]; Sustainability [3 cases]; Innovation [2 cases]; and Cooperation [2 cases].

Functional Data

- The mean population accommodated in the cases in this group is 24.600. Nevertheless, the differences between the populations of the case are large, varying from 1.156 [Brandenburg Technical University Campus in Cottbus] up to 74.000 [Shenzhen Hi-Tech Industrial Park in Shenzhen]. These differences seem to be relative to the size of their hosting cities. In fact, the larger populations accommodated in this group refer to two cases in Asia and one case in Europe. This is the case of Barcelona City of Knowledge, which density of its hosting city is the largest of the group.
- The population accommodated in these cases is mainly represented by the amount of employees in the cases. Only six cases count the student population.
- The number of organisations in these cases varies also widely. Its variety ranges using the same examples from 14 [Brandenburg Technical University Campus in Cottbus] up to 1.200 organisations [Shenzhen Hi-Tech Industrial Park in Shenzhen].
- The types of organisation accommodated in all the cases are mixed. The most represented type is "companies". Only Brandenburg Technical University Campus in Cottbus does not register a company accommodated on campus. Likewise, three campuses do not accommodate universities and they are the three research production clusters located in Asia [Shenzhen Hi-Tech Industrial Park; Tainan Science Park and Biopolis]

Financial Data

- In contrast to the previous group, the cases in this group are predominant funded with public capital. Seven of the cases have been developed with public funding and are owned or supported by national or municipal governments. These cases are mainly in Asia-Pacific [Singapore, Taiwan, China and Australia]. Nevertheless, two European cases were found both in Germany, and in the same region Brandenburg. The other funding structures are more represented by both public and private funding [5 cases in which 3 official partnerships have been established]. Only one case is funded with just private capital, which is the case of Eindhoven University of Technology, originally public funded until 1995 when ownership of the campuses was transferred from the Dutch government to the institutions.
- The management structures that control the cases in this group are clearly defined except from one case [GIANT Innovation Campus]. These management structures are equally represented by real estate management units [in 5 cases] and wide central management units in charge of other tasks besides the management of the built environment [in 6 cases]. Depending on the cases, these last types of controlling units are part of external governing bodies at municipal or national level or their compositions involve several external parties. These two examples are correspondent with the cases that have Public and PPP funding structures respectively.
- External governing parties, from municipal to national scale levels, actively promote most of the cases in this group [at least 10 of them]. Few of them have established designated marketing bodies to promote these cases. Those are the cases of Otaniemi Marketing in Espoo and Brainport Development in Eindhoven, an agency represented by members of the triple-helix, including the university, which task is to drive the region forward and make the economy of the region 'future proof'. This agency is marketing several campuses in the region.

Physical Data

- In relation to its urban context, the scale of these cases is mostly perceived as medium to small campuses. At least eight of them are perceived as areas which are part of the city. The remaining 5 cases are seen as portfolios or group of buildings in defined areas.
- The areas occupied by the cases in this group ranges from 30 ha up to 1150. Again, the extreme cases are the cases located in Cottbus and Shenzhen respectively. Thus, affirming that size is relative to the context. However, it is observed that the majority of the campuses [8 of them] occupied no more than 100 hectares.the scale and the mobility patterns in the different regions.

Overlaps

City and Campuses have multiple points in common

This group includes six areas which settlements are [partly] integrated in the urban fabric of their hosting city. In many cases the boundary of the cases is not clearly defined or perceived. Thus, the physical infrastructure of these cases [e.g. roads, public space, parks and water, buildings, etc.] and that of the city have multiple points in common. This relationship is also present in some cases included in the previous group [City Touches the Campus]. Three of the cases "touched" by the city, have already multiple commons with the city [Stanford Research Park, TU Delft District & Technopolis and Innovation Campus Delft; and Hsinchu Science and Industrial Park]. This group is evenly distributed among the three regions where the total sample is located: 2 cases in North America; 2 in Europe and 2 in Asia-Pacific. The first four campuses are owned by universities. They all are built before the Digital age, between 1951 and 1988. MIT Campus is part of this sample since major developments in this campus - settled in Cambridge since 1916- took place during the 1960s and the development of University Park at MIT in 1983.

Most of the areas present combinations of R&D clusters with Scientific research or Production. The production clusters are located in the two Asian cases that are part of this group. The campuses in group 3, accommodate research in a variety of fields. Thus, most of them focus on the fields of Biotechnology [5 cases]; Electronics [3 cases]; ICT [3 cases]. It is outlined, the presence of Design and Engineering research in two of these cases. Correspondingly, High-tech business is addressed as a consolidated and/or key sector in the economic base of five of the hosting cities of these campuses. Likewise, creative industry is addressed as a key industry in two of them.

Strategic Data

- Two out of the six cases have an intended or defined strategy. These are campuses of universities of technology [MIT and TU Delft]
- The driving concepts more popular in the strategic ambitions of these cases are Innovation, Collaboration, Sustainability and Knowledge & Technology as source of economic development.
- The hosting cities of these cases have intended knowledge or innovation-based strategies [e.g. policies, visions, plans] with the exception of the two American cities.
- The most popular drivers for the strategic ambitions of the hosting cities in this group are innovation, competitiveness & attractiveness, diversity, entrepreneurship and knowledge.

Financial Data

- The cases in this group are predominant funded with private capital. Three of the cases have been developed with private funding and are owned by universities; one with public funding and the two remaining have both public and private funding, from which, one is officially constituted as a public private partnership. University boards manage these three private funded campuses.
- All campuses have defined management units. Established real estate management units control the three private funded campuses. Centralised units that also perform other tasks besides real estate management manage the remaining three campuses.
- In the European and Asian cases, the hosting cities and/or regions of these cases are actively promoting them as flagship in their strategies. In some cases, they are actively involved in the spatial development of these campuses. On the contrary, in the two American cases, their hosting cities play a passive role as promoter in branding and marketing those areas as business location due to their international reputation.

Functional Data

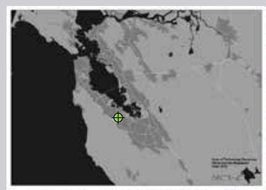
- The population of the cases in this group varies from 15.500 [Leiden Bio Science Park] up to 131.168 [Hsinchu Science and Industrial Park]. Excluding the two Asian cases, the population of these cases is rather similar with a mean of 21.900 people approx. studying and/or working on these campuses. Similarly, the population of the hosting cities is similar in the American and European cases. These cities have population from 66.000 to 106.000 inhabitants approx.
- The number of organisations accommodated in this cases varies largely from 16 [MIT campus and University Park in Cambridge] up to >2.000 [Zhong Guan Cun Science Park Beijing] organisations. The large difference might also be related with the regional context. Overall, most of the cases accommodate companies, except from MIT campus due to MIT's tax-exemption status. Similarly, most of them accommodate universities except from Hsinchu Science and Industrial Park.
- The knowledge base of the hosting cities of these campuses is strong. All of them host at least a university. Indeed, these 6 cities hosts four universities ranked in the Top 100 university rankings [THE higher education university rankings 2011-2012]. In the two American cities, the universities are the top employers per number of staff [e.g. Stanford University in Palo Alto and Harvard University and MIT in Cambridge]. In fact, these three are within the top 10 universities. In the two European cities, Education is one of the top employers sector in this cities.
- Only three campuses accommodate residential functions besides the central facilities with amenities and sports.
- The majority of the cities hosting the campuses in this group are rich in cultural amenities such as heritage buildings.

Physical Data

- The scale of the campuses in this group is mostly medium size. They are perceived as areas that are part of their cities. Only one of the six campuses is perceived as a large-scale size, in which the overall is perceived as a large part of the city. This is the case of Zhong Guan Cun Science Park Beijing.
- The area they occupied in the cities differs largely from 68 ha up to 7.500 ha.
- Similarly, as in the previous group, the transportation means offered by their hosting cities is diverse depending on the scale and the mobility patterns in the different regions.
- In terms of distance, all the campuses are in proximity to a university. Four of them host universities. The maximum distance from the cases to the universities is 4km and 30 minutes by public transport. In relation to the city centre, almost all of the cases are within 5km distance except from Zhong Guan Cun Science Park Beijing. In some cases [e.g. TU Delft, Cambridge], the city centre can be reached from the campus by walking distance of 10 minutes on average.
- The international accessibility by airport is varied. The distance from these cases to their regional airports varies from 8 up to 50 km. Most of them are accessible within an hour by public transport except from Hsinchu Science and Industrial Park.

1951 - 1988

YEAR	NAME OBJECT	NAME CITY
1951	Stanford Research Park	Palo Alto, California, USA
1960 *	MIT Campus & University Park at MIT	Cambridge, Massachusetts, USA
1961 -65	TU Delft District & Technopolis and Innovation Campus Delft	Delft, South Holland, NL
1980	Hsinchu Science and Industrial Park	Hsinchu City, Northwestern Taiwan, TW
1984	Leiden Bio Science Park	Leiden, South Holland, NL
1988	Zhong Guan Cun Science Park	Beijing, CN



Touches

City touches Campus

1951 - 2011

YEAR	NAME OBJECT	NAME CITY
1951	Stanford Research Park	Palo Alto, California, USA
1952	Cornell Business & Technology park	Ithaca, New York, USA
1959	ETH Hönggerberg Science City	Zurich, Zurich, CH
1961	Drienerlo Campus University of Twente & The Innovation Campus Kennispark Twente	Enschede, Overijssel, NL
1961 -65	TU Delft District & Technopolis and Innovation Campus Delft	Delft, South Holland, NL
1970	Cambridge Science Park	Cambridge, Cambridgeshire, UK
1980	Hsinchu Science and Industrial Park	Hsinchu City, Northwestern Taiwan, TW
1984	Surrey Research Park	Guildford, Surrey, UK
1988	Technology Park Bremen & University of Bremen	Bremen, Bremen, DE
1992	Zhangjiang Hi-Tech Park	Shanghai, CN
1994	Berlin Adlershof Humboldt University	Berlin, Brandenburg, DE
1996	Shenzhen Hi-Tech Industrial Park	Shenzhen, CN
1998	High-Tech Campus Eindhoven	Eindhoven, North Bravant, NL
2003	Science Park Amsterdam	Amsterdam, North Holland, NL
2005	Chemelot Campus	Sittard-Geleen, Limburg, NL
2009	GIANT Innovation Campus [Grenoble Innovation for Advanced New Technologies]	Grenoble, Isère, Rhône-Alpes, FR
2011	RWTH Aachen University – Research Campus Metalen [expansion]	Aachen, North Rhine-Westphalia, DE

This group includes 17 areas that are located in a border condition in relation with the city. In most of the cases, they are located at the edge of the city. In some cases, they are in the city but their locations hold a border condition e.g. separated by a river, or a highway. For the first kind, it can be said these areas were built outside the city centres but because of the urbanisation process, the urban fabric of the city is reaching their locations. As the urbanisation process, this border condition of technology campuses is observed at a global scale. In fact, the sample of this group is representative of the total. Overall, nearly the half of the total sample falls in this group and it is similarly distributed per region, with 2 out of 4 cases in America; 4 out of 14 cases in Asia-Pacific; and 11 out of 21 cases in Europe. These areas were built between 1951 and 2011: three of them during the period regarded as the Post-war & Atomic age; six of them during the space age & ICT industrial revolution; and 8 during the Digital & Information age. Thus, if half of these campuses have been built after 1989, their border condition in relation to their hosting cities might tell us something about the speed of the urbanisation processes in some places [e.g. Shanghai or ShenZhen] or the intention of locating these campuses in a convenient distance from the city centre.

Most of these areas have kept their official denomination, mainly Park or Campus. The type of cluster base they represent are, for the most, R&D clusters [16 in total out of 17] in combination with Scientific or fundamental research [6 in total] and a small share in combination with Production [4 in total], which is possible giving their border conditions at the edge of the cities. This is the case of two areas in Asia and two in Europe [one of these combines only small production]. The research areas of these clusters are very diverse. Nevertheless, Biotechnology is addressed in the majority of the cases [10 out of 17] as the most common research field, as well as Energy & Health, Electronics, ICT and Materials. An important observation is that in nine cases, the cities hosting these campuses addresses Biotechnology, Health or Life Sciences as a key or emergent sector for their economic development.

Strategic Data

- The drivers behind the strategic goals of these 17 cases are diverse. It is observed that the economic driver based on innovation and entrepreneurship is the most popular among them. In 14 cases, these two topics are mentioned in their defined strategies, ambitions, or mottos. Other topics key addressed as common are Urban attractiveness [5 cases] and Sustainability [2 cases].
- In several campuses [10 out of 17], the city or the region is mentioned as an important part linked to their general ambitions.
- Some campuses, internationally known as successful cases [e.g. Stanford Research Park or Cambridge Science Park] do not state an intended campus strategy. Only a motto, apparently denoting the reason of their successes or their branding, is found. For example, "Great ideas growth here" in Stanford is presenting the campus as the core of the Silicon Valley's growth; or "40 years of Innovation" in Cambridge. No link to their regional or urban contexts is addressed in the sources found in this exploration.
- All the cities that host the campuses in this group want to become an attractive city. The primary concepts of their strategies are varied and based on combinations of topics. Few of them appear to be commonly addressed: Technology as core of Innovation [8 cases]; Sustainability [7 cases]; Collaboration [5 cases]; Diversity [5 cases]; Knowledge [4 cases].

Functional Data

- The mean population accommodated in the cases of this group is 25.400 approx. Nevertheless, the difference among the cases is large, ranging from cases that accommodate 1.185 employees [Chemelot Campus] up to 131.168 employees [Hsinchu Science Park]. This difference is relative to the size of their hosting cities. When comparing these two, one can also notice the difference in populations [Sittard-Geleen: 93.000 and Hsinchu: 393.000] and densities [Sittard-Geleen: 1,217 inh./sq km and Hsinchu: 3,952 inh/sq km] of both cities.
- The number of organisations accommodated in these cases also varies widely from 10 [ETH] up to 1.200 [Shenzhen]. Nevertheless, when looking at the composition of these organisations it is observed that all the campuses accommodate companies but only 11 accommodate universities and 7 of them accommodate research institutes. Yet, their hosting cities seem to have a proper knowledge base since all the cities host at least a university. Indeed, six of them host a university in the Top100 rankings [THE university rankings 2011-2012].
- Besides the common leisure, cultural or sport facilities present in most of the campuses, ten of them offer residential areas [e.g. student housing, residential districts for researchers or hotels]. Some cases, addresses residential areas in their planning.
- Comparing hosting cities and their functional attractiveness was difficult, for this group considering the sizes and characters of these cities are very diverse. They range from university towns [e.g. Cambridge, Ithaca, Delft, or Aachen] up to capital and/or global cities [e.g. Amsterdam, Berlin, Shanghai, or Zurich] and their amenities offering widely differs among them.

Financial Data

- The funding of this group of campuses comes from different sources. Funding from only private capital [6 campuses] is more dominant in this group than only public capital [3 campuses]. Nevertheless, a combined public and private funding is observed as relevant in this group. For instance, 7 campuses are funded this way, from which, 3 official Partnerships are established. In some cases, these partnerships are not clearly established as source of funding since collaboration among partners just started as result of changes in their contexts. An example of this is the transitions observed in the Innovation Campus Kennispark Twente in Enschede. For instance, the Foundation Kennispark Twente is a joint initiative of the University of Twente, the City of Enschede, the Region of Twente, the Province of Overijssel and the Saxion University of Applied Sciences. The University of Twente and the City of Enschede have partnered up to make sure the area becomes and stays a state of the art innovation campus and have initiated several projects. The University of Twente and its campus was originally public-funded until 1995 when ownership of the campuses was transferred from the Dutch government to the institutions.
- The management units controlling these cases are clearly defined. Nevertheless, some distinctions are identified. In seven of them, the units responsible for their management are designated Real Estate units or departments. This is common in private funded campuses. The remaining ten cases are controlled by large and centralised management units responsible not only for the performance of the case but also combine tasks as the performance of R&D in these cases.
- In this group, the hosting cities/regions actively promote the campuses as pillars for their economies and participate in their planning. This is the case in eleven campuses.

Physical Data

- The scale of these 17 cases is perceived as uniformed and distributed in two groups from small [portfolio in an area] to medium [area in a district]. Indeed, 8 of them are perceived as groups of buildings in a defined area, while the other 9 are perceived as areas that are part of the city.
- The mean area occupied by these cases in their hosting cities is 420 hectares approx. Nevertheless, the differences are large ranging from 47 ha [RWTH Aachen University -Research Campus] up to 2.500 ha [Zhangjiang Hi-Tech Park in Shanghai].
- According to the border condition of their locations, the accessibility of these cases seems to be an important issue. The transportation means offered by their hosting cities is diverse depending on the scale and the mobility patterns in the different regions. Despite the fact they are mostly accessible by car, all of them are covered in term of public transportation.
- In terms of proximity [distance], these cases are also diverse. The mean distance from these cases to the core city centre is 8km. They range from 1,5km [GIANT Innovation Campus in Grenoble, which border condition, is determined by its island location within the city] up to 25km [Zhangjiang Hi-Tech Park in Shanghai]. They all are accessible from the city centre within an hour using public transportation. Similarly, the distance of these cases from their local airports varies from 6km up to 92km. All of them can be accessible from an airport in less than on hour by car and/or public transport. Some cases are exceptional such as Cornell Business & Technology Park served by its own airport on campus. Lastly, those campuses, which do not accommodate universities, are distant between 2 km and 25 km from them and all of them can be reached within 2 hours by public transport.

Disjoints

City shares nothing with Campus

1957 - 2005

This group includes seven cases located in areas outside the city borders but they are not recognised as a city itself. Some of them hold a title as unincorporated areas. This group have cases located in all the regions of this exploration: 1 case in North America; 4 cases in Europe and 2 cases in Asia. They are built in different periods from 1957 until 2005: 2 cases in the atomic age; 2 cases during the space age and ICT revolution; and 3 cases during the Digital and Information Age. The all have held a permanent name since their origins, except from one case that have change from Science City to a Strategic General Special Zone.

The research's clusters the cases in this group represent are singular types of cluster rather than combinations. Thus, it is predominant in this group the R&D cluster type [6 cases]. One combination of R&D and Production is identified and one cluster of Scientific research. The predominant fields of research are similar to the ones present in the other groups: Biotechnology [5 cases]; ICT [5]; Electronics [4 cases]; and Energy [4 cases]. Likewise, the economic base of these cases is target at the following key sectors: Biotechnology [3 cities]; High-tech businesses [3 cities] and IT [3 cities]. Very few cities have a consolidated economic base in those sectors.

YEAR	NAME OBJECT	NAME CITY
1957	Research Campus Garching - Technical University of Munich	Garching, Munich Metro Region, DE
1959	Research Triangle Park	The "Triangle region" between Durham, Raleigh, and Chapel Hill, North Carolina, USA
1972	Sophia-Antipolis Park	Côte d'Azur Region, FR
1987	Kansai Science City	Kansai [unincorporated city], JP
1992	Taguspark	Lisbon, PT
2003	Taichung Science Park	Taichung, Central Taiwan, TW
2005	Biocant Park	Cantanhede, Coimbra, PT

Strategic Data

- Four of the cases in this group have an intended strategy. The main drivers behind their strategic ambitions are recognised as Sustainability [4 cases]; Innovation [2 cases]; and R&D [2 cases].
- Similarly, few of their hosting cities [4 in total] have an intended strategy. Nevertheless, the main drivers identified in their ambitions or goals are Knowledge [3 cities]; Collaboration [3 cities]; Innovation [2 cities]. Few hosting cities in this group have vague strategic goals.

Financial Data

- The funding of the cases in this group comes predominant from Public and Private capital sources [6 in total, from which 5 have an official partnership structure]. Only one of the cases in this group has funding from public capital.
- The controllers of the seven cases of this group are defined in management structures. The majority of them [6 in total] are managed by bodies conformed by several stakeholders who are in charge not only of the physical structure of the cases but they perform other task such as promotion of the research clusters and marketing of the cases. A Real Estate Management unit controls only one of the cases in this group. This one is a university campus funded by public and private capital without an official established partnership.
- Since most of these cases are PPP owned campuses, they are actively promoted and marketed by the agencies that control their assets, which are indeed, composed by several external stakeholders at municipal, regional, and even national levels.

Functional Data

- The mean population of these cases is 50.000 aprox. Nevertheless, the population of these cases is not normally distributed. It ranges from 210 [Biocant Park in Coimbra] up to 238.341 [Kansai Science City in Japan]. These variations might relate to their contexts in terms of population and densities of their hosting cities.
- The population accommodated in these cases in mainly represented by number of employees. Only three cases possess data distinguishing number of students.
- The number of organisations accommodated in the cases also differs widely. The range is from 15 [Research Campus Garching – TUM] up to 1.400 organisations [Sophia-Antipolis Park]. Similarly, the most represented type of organisations are companies [present in all the cases]; and universities [present in 5 cases].
- Similarly to the previous group, the hosting cities of all the cases in this group has a knowledge based represented by more than one higher education institution including at least one university. Indeed, four of the Top 100 universities [The rankings] are located in the cities of this group.
- Only two of the seven cases have residential facilities accommodated on campus. These are hotels or congress-like facilities
- The amenities of the hosting cities in this group are difficult to analyse and compare since due to the location characteristics, the data is collected mainly at regional level from different cities. Thus, the observations in this aspect have been avoided.

Physical Data

- The scales of the cases in this group are very different. They range from small to large distributed as follows: 3 cases are perceived as small scale [portfolios or group of buildings in defined areas; one case is perceived as medium scale [an area that is part of the city]; and r cases are perceived as large scale [large part of the city and in some cases, as the city itself]
- The mean area occupied by these cases in their hosting cities is 3.500 ha approx. Their land occupation area varies from 145 ha to 15.000 ha.
- The transportation means offered by their hosting cities is diverse depending on the scale and the mobility patterns in the different regions. Nevertheless, it is observed that in most of the cases [with few exceptions] these areas a car-dependant to be accessed efficiently. For instance, the distances described as follows were measured by using car as transportation means rather than public transport, which in some cases was not covered by the tools used in this exploration.
- In terms of proximity, these cases are within 32km to both universities and core city centre and 45' driving. Five cases accommodate universities, but depending on their size this distance is not always a walking distance and varies according to the departure point from which is measured [e.g. Research Triangle Part accommodates the TUCASI campus -Triangle Universities Center for Advanced Studies Inc. which is the home of the three Founding Universities Duke University, NC State University, and UNC-Chapel Hill. Though, considering the scale of this campus the proximity to these universities might vary].
- The proximity of these cases to an airport varies widely from 7 to 85 km of distance. The larger temporal distance to access the airport, from one of these cases is 1 hour and 40 minutes by car.

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Photo: By 劉久弘 (Own work) [CC BY-SA 3.0 (http://creativecommons.org/licenses/by-sa/3.0)], via Wikimedia Commons https://commons.wikimedia.org/wiki/File%3ASouthern_Taiwan_Science_Park_Ying_Xi_Lake.JPG

31-HTCE High-Tech Campus Eindhoven Eindhoven, North Bravant, NL

Empirical research:
Borgh, Cloodt & Rommer [2012];
The Campus & the City (Christiaanse & Hoeger, 2007)
Websites:
http://www.hightechcampus.com/about_the_campus/
http://www.sre.nl/english/the-cityregion-eindhoven-sreSRE: Samenwerkingsverband Regio Eindhoven
http://www.eindhoven.eu/en/Introduction/Introducing_Eindhoven/Facts_%26_Figures
http://www.brainport.nl/en/brainport-2020
Photo: http://www.microtoerisme.nl [CC BY-SA 3.0 (http://creativecommons.org/licenses/by-sa/3.0)], via Wikimedia Commons https://commons.wikimedia.org/wiki/File%3A1302_Eindhoven_-_HTC_064.jpg

32-SPA Science Park Amsterdam Amsterdam, North Holland, NL

Empirical research:
The Campus & the City (Christiaanse & Hoeger, 2007);
Managing the University campus [Den Heijer, 2010]
Websites:
http://www.scienceparkamsterdam.nl/
http://www.os.amsterdam.nl/feitenencijfers/amsterdam/
http://www.iamsterdam.com/en-GB/business/About-the-Amsterdam-Economic-Board
Online documents:
The Science Park Amsterdam http://www.watergraafsmeer.org/images/sitedocuments/partners/universiteit_utrecht/case%20 9%20-updated.pdf
http://www.scienceparkamsterdam.nl/fileadmin/site/dokumenten/SPA_bidbook_EN.pdf
Photo: By Jvhertum (Own work) [CC BY-SA 3.0 (http://creativecommons.org/licenses/by-sa/3.0)], via Wikimedia Commons https://commons.wikimedia.org/wiki/File%3AAmsterdam_science_park.jpg

33-BPS Biopolis Singapore City-State, SG
Empirical research:
Singapore Biopolis: Bare Life in the City-State (Waldby, C. 2009);
Singapore: Building a biopolis (Short Survey)(Cyranoski, D. 2001);
Singapore: filling biopolis. (Smaglik, P. 2003)
Singapore to open fusionopolis (Review) Yarbrough, C. 2008
Websites:
http://www.nature.com/nature/journal/v425/n6959/full/nj6959-746a.html http://www.jtc.gov.sg/RealEstateSolutions/one-north/Pages/Fusionopolis.aspx
http://www.a-star.edu.sg/?tabid=860
http://www.jtc.gov.sg/Industries/Biomedical/Biopolis/Pages/Biopolis-Development.aspx
Photo: By Henry Leong Him Woh. (The Singapore Biopolis - (A*STAR) One-North.) [CC BY-SA 2.0 (http://creativecommons.org/licenses/by-sa/2.0)], via Wikimedia Commons https://commons.wikimedia.org/wiki/File%3ABiopolis-Singapore-20080712.jpg

34-TCSP Taichung Science Park Taichung,Central Taiwan, TW
Empirical research:
The integrated spatial planning for Taichung Science Park community and leisure development (Conference Paper) (Hsieh, C.-C., 2011)
Websites:
http://eng.taichung.gov.tw/siteOld/english.taichung.gov.tw/internet/english/docDetail1827.html?uid=4149
http://investtaiwan.nat.gov.tw/eng/show.jsp?ID=325
Online documents:
http://www.sipa.gov.tw/english/file/20130412110153.pdf
http://www.ctsp.gov.tw/files/e77a2d5c-eb75-43bf-856f-56216beaa89c.pdf
Photo: By Fcuk1203 (Own work) [CC BY-SA 3.0 (http://creativecommons.org/licenses/by-sa/3.0) or GFDL (http://www.gnu.org/copyleft/fdl.html)], via Wikimedia Commons https://commons.wikimedia.org/wiki/File%3ACentral_Taiwan_Science_Park_Administration.JPG

35-BP Biocant Park Cantanhede, Coimbra, PT
Empirical research:
Knowledge Locations (Carvalho, 2013)
Websites:
www.biocant.pt
http://www.cm-cantanhede.pt/mcsite/Content/?MID=2&ID=519&MIID=226

36-CRDP Chemelot Campus Sittard-Geleen, Limburg, NL
Websites:
www.chemelot.nl
http://www.insittardgeleen.nl/nl-nl/5/126/cijfers-feiten.aspx
http://sittard.amuseerje.nl/theater
Photo: By Michiel1972 (Own work) [CC BY-SA 3.0 (http://creativecommons.org/licenses/by-sa/3.0) or GFDL (http://www.gnu.org/copyleft/fdl.html)], via Wikimedia Commons https://commons.wikimedia.org/wiki/File%3AChemelot.jpg

37-BCK Barcelona City of Knowledge Barcelona, Catalonia, ES
Empirical research:
The Campus & the City (Christiaanse & Hoeger, 2007)
Websites:
http://www.pcb.ub.edu/
http://pinnova.upc.es/BKC/index.php?cont=campus
http://www.bcn.cat/estadistica/angles/dades/anuari/index.htm
http://w42.bcn.cat/web/en/per-que-barcelona/sectors-estrategics/index.jsp
Online documents:

http://www.pemb.cat/wp-content/uploads/2011/07/PEMB-2020-angles-WEB.pdf
http://pinnova.upc.es/BKC/pdf/Descripcion_del_proyecto_english.pdf

38-GIANT GIANT Innovation Campus [Grenoble Innovation for Advanced New Technologies] Grenoble, Isère, Rhône-Alpes, FR
Websites:
http://www.giant-grenoble.org/en
http://www.grenoble.fr/93-l-economie-grenobloise.htm
Online documents:
http://www.grenoble.cci.fr/medias/fichier/presentation-economie-octobre-2012-nouveau-logo_1352191238589.pdf
http://www.giant-grenoble.org/images/giant_brochure_en.pdf
Photo: Christian Hendrich 2004 CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=232491

39-RWTH-RCM RWTH Aachen University -Research Campus Metalen [expansion] Aachen, North Rhine-Westphalia, DE
Empirical research:
Knowledge Hotspots (Willem van vinden, 2011)
Websites:
http://www.rwth-aachen.de/go/id/ekt/lidx/1
http://www.aachen.de/DE/stadt_buerger/aachen_profil/statistische_daten/bevoelkerungsstand/index.html
http://www.agit.de/en/region-of-technology/overview/the-technology-region-aachen-in-detail.html
http://www.aachen.de/EN/kf/freizeit_en/index.html

Appendix C Analysis of the operational campus

This qualitative survey collected important concepts from design and planning theories to analyse the sample of technology campuses. Simultaneously, it associates these concepts with relevant topics of the context of technology clusters in the knowledge economy.

In this study, the operational perspective of the built environment refers to the formal and functional structures of (the group of) buildings in a designated site, which are part of a context. Therefore, the operational campus is seen just as an area in a city or region. Design theory on the built environment distinguishes several connotations of architectural form. From broad definitions such as 'the articulation between mass and space' (Bacon, 1974) to more concrete definition of elements that suggest reference and gives unity to the whole: Shape, Size, Colour, Texture, Position, Orientation and Visual Inertia (Ching, 1975). Being campuses a cluster of buildings in a site, more views towards built environment are being considered. Urban geography approaches on morphology (Kostof, 1991) considers basic components of 'town plan' such as the street pattern, the land use pattern (land parcels and lots) and the building fabric.

Existing study on campus design in North-American universities and colleges emphasizes the concept of 'place-marking' (Dober, 2003). Accordingly, this study elaborates on a conceptual diagram outlining four important campus design factors: landmarks, materials, landscapes and styles. This study also outlines how 'campus design is itself the art of campus planning' (pp.3). In similar studies, the same author defines campus planning as 'the premeditated guidance of the amount, quality and location of facilities for higher education so as to achieve a predetermined purpose' (Dober, 1996). Accordingly, the plan is illustrated as a physical form that already encompasses design characteristics in an area and a more or less detailed program. Furthermore, the physical form of the campus is listed in three orders of importance: a building, an outdoor space and the supporting site elements such as circulation. In this context, form and function in large-scale built environments such as technology campuses are interrelated.

Overall, given the unique conditions of these built environments in scale and contexts, this study considers five main characteristics emphasizing the operational perspective of technology campuses: Location; Layout; Size and Density; Block pattern; and Appearance. These characteristics and their link to theoretical concepts relevant for this research are described as follows.

1) Location

This physical characteristic that deals with the position of the campus in relation to its hosting city/region and other functional structures identified as relevant in this research. In campus planning the location is the geographic position of the physical area encompassed by the plan. The position of the campus in a city/region is linked to the concept of competitive advantage in research activities, which gives clusters a prominent role. Accordingly, the presence of interconnected companies, specialized suppliers, service providers, firms in interrelated industries and associated institutions in particular fields that compete but also cooperate suggests that much of the competitive advantage resides in the locations of a firm business unit (Porter, 1990).

In further research, Porter (2008) asserts that 'even though old reasons for clustering have diminished in importance with globalization, new roles of clusters in competition have taken on growing importance in the increasingly complex, knowledge-based and dynamic economy of the 21st century' (Porter, 2008). This view is supported by urban studies on the relevance of developing growth clusters as one of the crucial activities of the knowledge city (Van Den Berg et al., 2005) addressing how business companies are more than ever tied to locations because they are dependent on highly-educated staff and on their integration into local networks. Similarly, the concepts of proximity, accessibility and connectivity to specific knowledge networks linked to innovation, are widely discussed in several studies in economic geography [See Chapter 2]. For instance, the roles of effective transportation and mobility infrastructures are emphasised in some approaches.

2) Layout

This physical characteristic interrelates the spatial and functional ways in which the elements of the campus are arranged. Looking at the campus as an urban area but also as a portfolio, this research distinguishes the following as the elements of the campus: buildings and land. The last includes landscaped elements such as roads, squares, green and water. In theory of architectural form (Ching, 1975), clustered organisations such as campuses, group their forms according to functional requirements of size, shape, or proximity. Since the size and the shape of campuses' elements are very diverse, proximity of forms can be used to relate them to one another.

On the latter, the concept of proximity gains relevance. Geographical proximity is 'believed to facilitate the flows of tacit knowledge and the unplanned interactions that are critical parts of the innovation process' (Europe INNOVA & PRO INNO, 2008). Accordingly, these flows rely 'upon the willingness of firms to inform others about their knowledge, which depends upon the trust established between actors. This in turn can be facilitated through continuous face-to-face contacts'. In this regard, a distinction is made about the multiple dimensions of the concept of proximity. In his critical assessment about Proximity and Innovation, Boschma (2005) distinguishes five dimensions of proximity: cognitive, organizational, social, institutional and geographical proximity. Accordingly, cognitive proximity is a prerequisite for interactive learning processes to take place. The other four dimensions of proximity are considered mechanisms that might bring together actors within and between organizations. It is concluded that 'in theory, geographical proximity, combined with some level of cognitive proximity, is sufficient for interactive learning to take place'.

This wide perspective on the concept of proximity has been widely discussed in theory (Boschma, 2005; Boschma & Frenken, 2010; Boschma & Frenken, 2006; Coenen et al., 2004; Lagendijk & Lorentzen, 2007; Torre & Rallet, 2005). One of the most recent contributions of this debate argues that the types and levels of proximity, which are critical for knowledge networks, remains an unresolved question (Huber, 2012). This study examined spatial, social and cognitive proximity of personal knowledge relationships in a well-known Information Technology Cluster highlights the effects of spatial proximity. For instance, the findings of this study suggest that an important benefit of spatial proximity is that it enables knowledge flows with cognitively different actors.

Existing interpretations of intention attributed to form can be found in theory of urban form and design (Lynch, 1981). This study distinguishes three normative models related with the key motivation of the city arrangement. The first is the cosmic city as a spatial diagram of social hierarchy that is characterised by monumental axis, enclosure, hierarchical spaces and dominant landmarks. The second is the practical city as a functional construct of interrelated parts is made up of small, autonomous, undifferentiated parts, linked up into a great machine that has clearly differentiated functions. And the third is the organic city as an indivisible living organism that has a definite boundary and an optimum size, a cohesive, indivisible internal structure and a homologous morphology. Overall, the concept of geographical or spatial proximity can be seen as a practical intention in campus planning and design.

3) Size and density

These two are interrelated physical characteristics of technology campuses. In design theory, the size of the built environment refers to the physical dimensions (length, width and depth) which determine the proportions of the shape (Ching, 1975). Accordingly, this quality can be easily applied when describing the size of buildings types rather than site plans since the later consist of clusters of built environments. Thus, it can be said the size of technology campuses refer to the physical dimensions of the designated area in which the buildings are clustered. In other words, the shape of the land and the clustering of buildings in this shape determine the size of the campus. In that regard, the density of built environments in the land or the density of the cluster becomes relevant when defining the size of this type of built environments.

As mentioned above, clustered organisations such as campuses, group their forms according to functional requirements of size, shape, or proximity. Considering the relevance of proximity described in the previous section, the size of the land and the density of the built environments in campuses might have an influence on the functional and spatial arrangement when enabling social interaction through spatial proximity. Several studies outline the relevance of diversity (of people, ideas and functions) in cities promoting creativity, innovation and growth (Florida, 2002; Glaeser et al., 1992; Jacobs, 1961; Van Den Berg et al., 2005). Indeed, Jacobs (1961) legitimized four spatial conditions generating diversity. These are (1) the need of primary mixed uses that ensures the presence of people who are able to use many facilities in common, (2) small blocks to increase the chances of encounter, (3) the mix of buildings varying in age and condition and so, in the economic yield they must produce, (4) and the dense concentration of people. In campuses, these four spatial conditions might also differ according to the size of the land and at the density of the built environments.

4) Block pattern

The shape and configuration of the streets and the buildings of the campuses determine this physical characteristic. This quality of the built environment is widely discusses in urban studies. In urban planning, the grid is outlined as the most common block pattern for planned cities in history (Kostof, 1991). Accordingly, this rectilinear planning solution is not only outlined as means for the equal distribution of the land or the easy parcelling and selling of real estate but its organization is also attributed to politics and a sense of order in cities. Conversely, spontaneous cities underlines geomorphic, irregular, organic or non-geometric block patterns (Kostof, 1991). Accordingly, this pattern is presumed to be the resultant of the passage of time, the lay of the land, and the daily life of the citizens.

Another well-known pattern for planned cities is the so-called superblock, first introduced in the early industrial model villages in England (Kostof, 1991). The main idea of this block pattern is having houses looking inward toward a central green in which the traffic is excluded. Therefore, the houses are turned back on main streets and the conventional rectilinear grid was abandoned in favour of a curvilinear road scheme. This idea became influential and was popularized by Ebenezer Howard with the model of the English Garden Cities. According to Kostof (1991), the most important patterns of this model were the independence of the building line from the street line and the rejection of the block system of the land division, which turned out into irregular blocks.

In the Modernist era, this idea of an in-turned superblock circumscribed by major traffic arteries was adopted, as a measure to reduce the volume and speed of traffic in urban areas caused by the increasing use of automobiles. Therefore, the provision of cul-de-sacs as part of the street hierarchy became essential in this planning pattern. The so-called Modernist superblock used the grid as a frame but instead of an organising pattern, it was used to separate communities. This planning pattern find inspiration in theories in modern architecture in which freestanding buildings set in a green area organised by a loose-maxi grid of high speed arteries became popular in American cities. These ideas evolved on 'The Radiant City' (Le Corbusier, 1935). Le Corbusier's plan, also known as 'Towers in the Park,' proposed exactly that: numerous high-rise buildings each surrounded by green space. Each building was set on the so-called superblocks and the space was clearly delineated between different uses including 'housing,' the 'business centre,' 'factories' and 'warehouses'. The influence of this planning approach in American neighbourhoods is also critically referred as the Invisible Superblock (Whiting, 2006).

Both theoretical models - the Garden City and the Radiant City- used the superblock as main pattern criticise the use of the land for streets. Instead, the theorists of these models wanted land to consolidate into green and therefore, minimise 'wasteful' streets in cities. This idea is later referred as a destructive myth (Jacobs, 1961) explaining its reasons for much stagnation and failure.

In this regard, a new planning perspective gained importance in the second half of the 20^{th} century. The need for small blocks was legitimised by Jane Jacobs (1961) as one the spatial conditions that generates diversity in cities promoting creativity, innovation and growth. Accordingly, small blocks, more streets that are frequent and opportunities to turn corners, increase the chances of encounter. The author also outline the hindering social and economic effects of isolated and discrete street neighbourhoods hindering the potential advantages that cities offer to incubation, experimentation, and many small or special enterprises, as these depend upon the cross-use among users of a city neighbourhood. Therefore, frequent streets and short blocks become valuable but the growth of diversity only works attracting mixtures of users along then. In this way, small block pattern and the mixture of primary use are outlined as inextricably related.

Currently, the debate about the size of the block patterns and its effect is enduring in city planning. A recent journalism approach (Prize, 2013) emphasizes the relevance of the grid layout and the effect of different street widths and block sizes on land usage and walkability. Accordingly, the trade-off with the grid layout is choosing between walkability (small, finely grained blocks) or efficiency (large blocks, with very few streets).

5) Appearance

This physical characteristic refers to the aspects defining the visibility or image of the built environment characteristics described above. These aspects could be associated with tangible features such as the materials of buildings, public space, landscape, etc., in which the design and construction quality play a key role. However, they can also be associated with the way those tangible elements are perceived by observers, which brings a degree of subjectivity in the definition of this aspect.

In this context, a well-known urban design theory, The Image of the City (Lynch, 1960), seeks for an objective reasoning of those aspects. Accordingly, there is a single public image of the city, articulated through the interrelation of five elements: paths, edges, districts, nodes and landmarks. These elements outline the relevance of several aspects in mobility patterns. For instance, the concentration of activities, character of specific areas, the presence of references, façade characteristics, proximity to special features of the city, visual exposure and prominence, building types, textures, materials, topography or people, among others. These aspects together in a context provide a specific identity to these elements and help to strengthen the image the city.

Notwithstanding, there is still a subjective connotation in appearance, which is attributed to the observers' perception when defining such image. In real estate management, supporting image is related to one of the added values of real estate to realise the objectives of an organisation (De Jonge, 1996; De Vries, 2007; Lindholm et al., 2006; Lindholm & Luoma, 2008). Accordingly, the appearance of real estate helps to strengthen organisational identity. Similarly, this added value has been study in university campuses (Den Heijer, 2011; Den Heijer & De Vries, 2004) outlining the relevance of 'real estate interventions that either support the image to the current users, external parties, or potential employees, for instance emphasizing the innovative, creative, sustainable or exclusive character of an organisation'. Besides, 'supporting image' is closely related to 'supporting culture' as another added value of real estate, which focuses on the internal users by means of building community, or stimulating interaction between groups of users matching the organisational culture.

This latter approach, which involves the supporting role of image not only at organisational level but also from the user's perspective, is relevant when addressing the need for attracting and retaining talent for growth in cities. Research clusters such as universities have emerged not only as engines to attract knowledge workers but also as engines of urban transformations (McCann, 2012). Accordingly, the built environment in which the future knowledge workers develop is shaping their consumption preferences. Current studies (Groot et al., 2011) research cultural factors and consumer preferences as ways to understand why clustering takes place rather than the traditional production type of externalities considered as relevant. Accordingly, it is crucial to understand to what extent location the different types and characteristics of the amenities that cities may offer drive behaviour of people. This approach is supported by similar studies (Faggian & McCann, 2009; Florida, 2008; Glaeser et al., 1992) which insights can be interpreted at the level of the built environment supporting a specific culture of knowledge workers. For instance, the role of green, mix of functions, building style, workplace layout, just to mention few of them, might differ from users' preferences and organisational cultures in technology campuses.

Overall, the appearance of these sites gains importance as a way to perceive the built environment characteristics in relation to the distinctiveness of technology campuses, supporting organisations' and users' image and culture. Nevertheless, the broad scale of the scan of technology campuses in this description provided with data that do not cover the detailed aspects mentioned in these paragraphs. These aspects can be explored in further steps of on-going research.

Appendix D Case Study Protocol - HTCE

Case study overview

- **Objective:** This case study aims to gain and provide an understanding of the roles of the built environment in stimulating innovation in a particular context in which this goal is successfully attained. The context selected in this case is the Brainport-Eindhoven region, a well-known high-tech industrial cluster in the Netherlands and in Europe.
- **Subject or unit of analysis:** The High Tech Campus Eindhoven (HTCE) in Brainport-Eindhoven region is presented as the subject of study or unit of analysis. The HTCE is defined as the land and buildings used by the tenants of HTCE Site Management B.V. in the city of Eindhoven, to fulfil their common core business: advancing research and development (R&D) for economic growth.
- **Object or analytical frame**: the built environment as catalyst for innovation.
- **Questions:**
    - How has the HTCE developed? Why is the 'Touches' characteristic of the HTCE in relation with the city evident?
    - To what extent has HTCE's development been influenced by theoretical discourses of stimulating innovation? Is this influence explicit or accidental? Is it possible that the dynamics accommodated on HTCE have indirectly helped supporting such discourse?
    - What campus' interventions have facilitated the conditions leading to innovation in HTCE and in Brainport-Eindhoven region and how?

Relevant readings about the subject investigated

De Vries, Marc. (2005). 80 years of research at the Philips Natuurkundig Laboratorium (1914-1994): the role of the Nat. Lab. at Philips: Amsterdam University Press.

Huang, Wei-Ju. (2013). Spatial Planning and High-tech Development. A comparative study of Eindhoven city-region, the Netherlands and Hsinchu City-region, Taiwan. (PhD), Delft University of Technology.

Fernández-Maldonado, A. M., & Romein, A. (2009). The reinvention of Eindhoven: From industrial town in decline to capital city of a technology and design region. Paper presented at the City Futures in a Globalising World Conference, Madrid.

Philips-Vastgoed. (2007). Site-Image Plan High Tech Campus Eindhoven. In Juurlink [+] Geluk (Ed.).

Simons, J. et.al. (1999). Masterplan Philips High Tech Campus. Visie in Actie. Philips Vastgoed, Beheer en Diensten, Eindhoven.

Van den Berg, Leo, Pol, Peter, Van Winden, Willem, & Woets, Paul. (2005). European Cities in the Knowledge Economy: The Cases of Amsterdam, Dortmund, Eindhoven, Helsinki, Manchester, Munich, Munster, Rotterdam and Zaragoza: Ashgate.

Van der Borgh, Michel, Cloodt, Myriam, & Romme, A Georges L. (2012). Value creation by knowledge-based ecosystems: evidence from a field study. R&D Management, 42(2), 150-169.

Data collection procedures

This research used a variety of data sources for triangulation with the aim to document campus development as a long-term decision-making process. The main four types of data collection procedures are listed in the table below.

	DATA COLLECTION PLAN	
	SOURCES	EVIDENCE COLLECTED
Type 1: Open and semi-structured interviews	Interviewees Role 1 - Experts subject of study	Targeted and insightful Facts, Opinions, leads of the case study topic – perceived causal explanations
	Interviewees Role 2 - Key-informants subject of study	Facts, context and leads to facts
	Interviewees Role 3 - Experts object of study	Insights, context
Type 2: Site observations	Event 1 – Visit to Campus North and Centre areas, guided by Project Manager and Contractor	Insight into campus development experiences, opinions and leads to the case study facts.
	Event 2 – Visit to shared Laboratories and equipment facilities, guided by a Senior group leader at Philips Innovation Services	Insight into cultural features of the context, opinions and leads to the case study facts. Experiencing events on real time covering the context of the case.
	Event 3 – Visit to the Strip central facility with access to office space, conference centre, restaurants, and stores.	Insight into cultural features of the context and functionality of campus central place. Photography and other records of events on real time covering the context of the case
	Event 4 - Visit to Campus South, West and North area	Insight into cultural features of the context and functionality of campus open spaces. Photography and other records of events on real time covering the context of the case.
	Event 5 – Visit to Office Building guided by a senior manager at Philips Research	Insight into functional and cultural features of the context, opinions and leads to the case study facts. Experiencing events on real time covering the context of the case.
	Event 6 - Informal talk with campus users	Make inferences about the context – clues worthy for investigation. Insight into cultural features of the context, opinions and leads to the facts
Type 3: Documentation	Doc type 1 - Maps of the physical map collection at TU Delft's Map Room, and official plans provided by HTCE Site Management, The Brink Groep, and Juurlink[+]Geluk	Exact information containing references, details of the development of the campus covering a long span of time.
	Doc type 2 - Official briefing and administrative documents and reports	Exact information containing facts, names, references, and details of the subject of study.
	Doc type 3 – Literature of existing empirical research or formal studies of the same case	Broad-coverage information of the subject of study over time, with details of events and references of the subject of study
	Doc type 4 – News clippings and other articles appearing the mass media	Exact information containing facts, names, references, and details of the subject of study.
Type 4: Open access mapping applications	App 1 – Google Earth	Exact information containing details of the physical the development of the campus covering a long span of time – imagery over time.
	App 2 – Esri Maps	Specific information containing physical details of the subject of study - imagery.
	App 3 – Mapnificent and Google maps	Specific information containing physical details of the subject of study – accessibility & connectivity.

Site visits

The data collection of this case required three field excursions to the subject of study. These excursions included the visit of specific buildings with guidance and a tour around the campus' open areas. Each excursion had duration of 2-3 hours depending of the visits. The three excursions took place at different times during 2013 and 2014. The following buildings were visited during these excursions because of permitted access at specific interviews: HTC-34 Philips Research – Office building, HTC-4 and HTC-29 Philips Innovation Services – Shared Laboratory facilities, HTC-1 The Strip – Shared central facility (office space, restaurants, conference centre and stores) and P0 – Parking facility central boulevard.

Interviews

The following table provides a list of the stakeholders interviewed and their association with the case studied:

	NAME	TITLE	INSTITUTION	ROLE: FIELD
1	Frans H. Schmetz	Managing Director	HTCE Site management B.V.	Expert subject of study: Campus management
2	Peter Sillen	Group leader support & services	Philips Innovation Services	Key-informant subject of study: High-tech Facility management
3	Peter Timmermans	Business unit manager	De Brink Groep	Key-informant subject of study: project management
4	Harrie Arends	Operations manager	HTCE Site management B.V.	Key-informant subject of study: campus management
5	Jan Wingens	Finance manager	HTCE Site management B.V.	Key-informant subject of study: real estate management
6	Bert-Jan Woertman	Manager Marketing & Communications	HTCE Site management B.V.	Key-informant subject of study: campus management
7	Monica Daniels	Project manager	Gemeente Eindhoven	Key-informant subject of study: campus planning
8	Ferrie Aalders	Senior Director Business Excellence	Philips Research Eindhoven	Expert subject/object of study: Innovation strategy
9	Theun Baller	Dean 3mE Faculty	Delft University of Technology	Key-informant subject/object of study: Innovation strategy
10	Hans Toornstra	Architect-partner (Design team member masterplan HTCE)	Inbo architects	Key-informant subject of study: urban planning & design
11	Cor Geluk	Director (Design Team member Masterplan HTCE, current urban planning supervision)	Juurlink+Geluk Urbanism & Landscape architects	Key-informant subject of study: urban planning & design
12	Veronique Marks	Directeur Dienst Huisvesting TU/e Science Park	Eindhoven University of Technology	Key-informant subject of study: context
13	Rene Buck	CEO	Buck Consultants International	Expert subject/object of study: campus development
14	Linco Nieuwenhuyzen	Strategy and public affairs advisor on regional innovation, economic development and human capital	Brainport Development N.V.	Expert object of study: Innovation strategy Key informant subject of study: context

Appendix E Output indicators of innovation in HTCE and Brainport-Eindhoven region

These measurements focus on the outputs of the processes of knowledge creation, diffusion and its application to develop new and improved technologies. In the knowledge economy, these outcomes are produced or delivered by different organisations that want to remain competitive in such context. These organisations correspond to three different spheres of the Triple Helix: universities, industry and governments. As shown in Chapter 2, each of these organisations measures innovation according to their different core businesses and aspirations.

This case study focuses on the output indicators of HTCE in relation to its hosting city-region, since both, the HTCE and the Brainport-Eindhoven region explicitly address 'Stimulating Innovation' as a goal in their strategic visions. On the one hand, HTCE measures their outputs based on its users' ambition to stimulate business synergy and R&D activities through the open innovation ecosystem. On the other hand, the Brainport-Eindhoven region measures their outputs based on their explicit ambition to maintain its top position in the Dutch knowledge economy. The following table collect empirical evidence of the innovation outputs, which are targets commonly used to measure innovation at HTCE and its hosting city region.

Output indicator	HTCE	Brainport-Eindhoven region*
Patents	Campus companies are responsible for nearly 40% of all Dutch patent applications (HTCE Site Management, 2014). Only, Philips (main user of HTCE) was Europe's top patent applicant filing 1,435 patents in 2010.	The region is the second region in Europe on high tech patent application with 720,7 patents per million inhabitants (Eurostat, 2006)
Start-ups	Philips spun-out two important companies that established in the region (ASML and NXP). One of them is located in campus and is the second largest company in HTCE. There are about 60 start-up accommodated in campus. The campus is home of two accelerators developed by the Brainport Developed to support young entrepreneurs. HTCE Site Management provides also flexible accommodation for start-up companies in different buildings.	The number of start-ups in the region has increased from 17,900 up to 22,500 between 2005 and 2010 (LISA 2011). In the region, there are ten business incubators and accelerators in three main clusters: Smart materials & chemistry, High tech systems, and Food. In 2011, the region registered 435 rapid growers (i.e. companies with more than 50 FTE that grew by 60% over three years)
Research grants in technology fields	The research institutes housed at HTCE are engaged in top research with Dutch universities. In 2015, 4.5 million euros Vici grants to CTMM researchers (NWO, 2015).	In 2011, the annual participation of this region in European framework programmes was €47 million and it is expected to raise up to €100 million in 2020 (Brainport Development, 2011)
Publications and citations	The research institutes in HTCE are active in research with universities producing publications. In 2013, the Holst centre registered over 100 publications reaching a cumulative of over 750 in total (Holst-Centre, 2013).	The region measures this output according to the publication that result form international collaboration. Between 2005-2008, the universities in this region had co-published 12,900 with international partners (44% of total). The citation average impact of these universities is 1,34.
Collaboration arrangements	The set up of the campus as Open innovation ecosystem promotes the collaboration among the tenants. In 2009, 80% of tenant companies that participated in an annual survey reported working together with other tenants (Blick-Marktonderzoek, 2012). Although 65% of the research institutes in campus reported internal collaborations, they are active collaborating with different partner outside HTCE. In 2015, CTMM is active with 32 research projects involving 133 partners (CTMM, 2015). The Holst Centre is active with Holst Centre is active in EU projects. It collaborates with over 50 partners in industry and has strong links with leading technical Universities in Benelux through at least 3 professorships (Holst-Centre, 2013)	25,9% of companies in the region is considered innovative. From this number, 38,6% are engaged in cooperation also with international partners (CBS CIS, 2006-2008
Research institutes formation	HTCE is home of 5 research institutes. Three of them have been established since 2005. Two of these five institutes are considered as Top R&D institutes focusing on high technologies.	The creation of high quality research institutions is addressed as an important output indicators. Currently there are 8 Top R&D institutes that focus on high technologies in Brainport-Eindhoven. The number expected in 2020 is 16.
Sales flowing from new or improved products - export	HTCE accommodates multinational companies with R&D focus. Only Philips registered profits of over 400 millions in 2014. Specific data on profits coming from innovation products was not found in this analysis.	This region, which is strongly represented by R&D companies, registered €79 billion in exports. (Brainport Development, 2011). In 2008, the High Tech System cluster reported €3,10 billion exports. Furthermore, 11% of SME income flows form innovation.

* Brainport Eindhoven has developed detailed indicators to measure their targets categorised according to its core focus areas (i.e. People, Technology, Business, and Basics). The list used here is based on the review of the literature of innovation in the knowledge economy suitable to compare multiple organisations in this context.

Appendix F Case study Protocol - MIT campus

Case study overview

- **Objective:** This research aims to gain and provide understanding about the roles of the built environment in stimulating innovation in a particular context in which this goal is successfully attained.
- **Subject or unit of analysis:** the MIT campus (land and buildings owned and used by the MIT to fulfil their mission)
- **Object or analytical frame**: the built environment as a catalyst for innovation.
- **Questions**:
    - How has the MIT campus developed? Why is the overlapping characteristic of the MIT campus in relation with the city evident?
    - To what extent have the MIT campus developed influenced by theoretical discourses of stimulating innovation? Is this influence explicit or accidental? Is it possible that the dynamics accommodated on MIT campus have indirectly helped supporting such discourse?
    - What campus' interventions have facilitated the conditions leading to innovation in MIT and in Cambridge-Boston area and how?

Relevant readings about the subject investigated

Castells, M., & Hall, P. (1994). Technopoles of the World. London Routledge.

Lampe, David. (1988). The Massachusetts miracle: high technology and economic revitalization: The MIT Press.

Mitchell, William J. (2007). Imagining MIT: designing a campus for the twenty-first century: MIT Press.

Nelsen, Lita L. (2005). The role of research institutions in the formation of the biotech cluster in Massachusetts: The MIT experience. Journal of commercial biotechnology, 11(4), 330-336.

Saxenian, AnnaLee. (1985). Silicon Valley and Route 128: regional prototypes or historic exceptions. Urban Affairs Annual Reviews, 28, 81-105.

Simha, O. R. (2001). MIT Campus Planning. An annotated chronology. Cambridge: Massachusetts Institute of Technology.

Data collection procedures

This research used a variety of data sources for triangulation with the aim to document campus development as a long-term decision-making process. The main four types of data collection procedures are listed in the table below.

	DATA COLLECTION PLAN	
	SOURCES	EVIDENCE COLLECTED
Type 1: Open and semi-structured interviews	Interviewees Role 1 - Experts subject of study	Targeted and insightful Facts, Opinions, leads of the case study topic – perceived causal explanations
	Interviewees Role 2 - Key-informants subject of study	Facts, context and leads to facts
	Interviewees Role 3 - Experts object of study	Insights, context
Type 2: Site observations	Event 1 - Seminar Understanding MIT at the School of Architecture and Planning (2 sessions, 3 speakers from MIT Corporation)	Insight into cultural features of the context, opinions and leads to the facts
	Event 2 - Seminar Changing Cities at the Media Lab (2 sessions, 3 speakers Lecturer at the Media Lab)	Insight into cultural features of the context, opinions and leads to the case study topic
	Event 3 - Opening of the University Industry Demonstration Partnership Fall Meeting	Insight into cultural features of the context
	Event 4- Site walks	Photography and other records of events on real time covering the context of the case
	Event 5 - Informal drinks at MIT Student Center with lecturer, students and planner,	Make inferences about the context – clues worthy for investigation
	Event 6 - Informal dinner at Kendall Square with Planners (former at MIT and current at Masdar City)	Insight into cultural features of the context, opinions and leads to the facts.
	Event 7 - Informal talk at the Venture Café in the CIC	
	Event 8 - Meeting with students at Media Lab,	
	Event 9 - Informal dinner with Post Doc researcher working at Stata Center.	
Type 3: Documentation	Doc type 1 - Maps and Photos of the campus collection at MIT Museum archives	Exact information containing references, details of the development of the campus covering a long span of time.
	Doc type 2 - Official briefing and administrative documents and reports	Exact information containing facts, names, references, and details of the subject of study.
	Doc type 3 – Literature of existing empirical research or formal studies of the same case	Broad-coverage information of the subject of study over time, with details of events and references of the subject of study
	Doc type 4 – News clippings and other articles appearing the mass media	Exact information containing facts, names, references, and details of the subject of study.
Type 4: Open access mapping applications	App 1 – Google Earth	Exact information containing details of the physical the development of the campus covering a long span of time – imagery over time.
	App 2 – Esri Maps	Specific information containing physical details of the subject of study - imagery.
	App 3 – Mapnificent and Google maps	Specific information containing physical details of the subject of study – accessibility & connectivity.

Site visits

The data collection of this case required a field trip to visit the subject of study and other relevant sites in context. The sites visited were located in the following two cities:

- Field trip to New York: Columbia University campus, NYU district, NYTech Cornell Campus, Brooklynn Tech Triangle (Dumbo) and the Innovation districts at Manhattan Midtown East and Manhattan Chelsea. Contact person: Jesse Keenan, Research director, Center for Urban Real Estate (CURE.) at Columbia University. Duration: 3 days.
- Field trip to Cambridge-Boston area: MIT campus, Harvard University campus, Boston's Innovation District, Kendall Square. Contact person: Bob Simha, Director of Planning for MIT in the period 1960-2000 and Lecturer and Research Affiliate, MIT Department of Urban Studies. Duration: 10 days.

Interviews

The following table provides a list of the stakeholders interviewed and their association with the case studied:

	NAME	TITLE	INSTITUTION	ROLE: FIELD
1	O. Robert Simha	Director of Planning 1960-2000, Executive Manager at University Residential Communities	Massachusetts Institute of Technology	Expert subject of study: Campus planning
2	Steven Marsh	Managing Director MIT Investment management Company	Massachusetts Institute of Technology	Expert subject of study: Campus real estate management
3	Kairos Shen	Director of Planning since 2002	Boston Redevelopment Authority	Key-informant subject of study: urban planning
4	Melissa Ablett	Innovation Cluster Development Leader	Cambridge Innovation Center	Key-informant subject of study: real estate management
5	Timothy Rowe	Founder and CEO	Cambridge Innovation Center	Key-informant subject of study: real estate management
6	Lita Nelsen	Director MIT Technology Licensing office	Massachusetts Institute of Technology	Key-informant subject of study: Innovation Policy
7	JJ Laukaitis	Senior Industrial Liaison Officer – MIT Industrial Liaison Program	Massachusetts Institute of Technology	Key-informant subject of study: Innovation Policy
8	Joost Paul Bonsen	Lecturer MIT Media Lab	Massachusetts Institute of Technology	Key-informant subject/ object of study: Innovation and entrepreneurship strategy
9	Daan Archer	Visiting Researcher MIT Media Lab	Massachusetts Institute of Technology	Key-informant object of study: Innovation strategy
10	Ryan Chin	Managing Director & Research Scientist, City Science Initiative, MIT Media Lab	Massachusetts Institute of Technology	Key-informant subject of study: urban planning
11	Jesse Kenaan	Research director, Center for Urban Real Estate (CURE.)	Columbia University	Expert object of study: Technology companies' real estate in NY
12	James Sanders	Leader 'Building the Digital City' initiative, the Center for Urban Real Estate (CURE.)	Columbia University	Expert object of study: Technology companies and urban growth in NY

Appendix G

Output indicators of innovation in MIT and Cambridge

These measurements focus on the outputs of the processes of knowledge creation, diffusion and its application to develop new and improved technologies. In the knowledge economy, these outcomes are produced or delivered by different organisations that want to remain competitive in such context. These organisations correspond to three different spheres of the Triple Helix: universities, industry and governments. As shown in Chapter 2, each of these organisations measures innovation according to their different core businesses and aspirations.

This case study focuses on the output indicators of MIT in relation to its hosting city-region, since both, the MIT and the city of Cambridge explicitly address 'Stimulating Innovation' as a goal in their strategic visions. On the one hand, MIT measures their outputs based on their mission to advancing knowledge and educating students in science, technology and other areas of scholarship that will best serve society. On the other hand, the city of Cambridge measures theirs based on their ambition to maintain its desirability as the place to work, to live and to do businesses. The following table lists empirical evidence of the innovation outputs, which are targets commonly used to measure innovation at MIT and its hosting city.

Output indicator	MIT	Cambridge
Patents	In 2013, the Institute filed 387 U.S. patent applications, from which 288 were issued or granted. Over the last ten years, MIT has issued more than 1700+ patents (TLO Statistics, 2013).	Together, MIT and Harvard University reported 618 new patent applications filed and 362 patents issued. In addition, a recent report (Kauffman, 2009) shows that MIT alumni high-tech firms established in Massachusetts hold one or more patents.
Licensing	In 2013, the Institute granted 59 licenses (excluding trademarks and end-use software) and 109 trademarks licenses. In addition, the institute registers 744 invention disclosures, and 463 Material Transfer agreements negotiated. (TLO Statistics, 2014).	
Prototypes	Building prototypes is an important phase of product design and development process, and of engineering research at MIT. The number of prototypes developed at MIT for educational purposes is unknown but it is part of the Institute's curriculum and learning methods. For instance, MIT offers courses on prototyping methods and techniques (e.g. Engineering Design and Rapid Prototyping, Prototyping Avionics, and Prototypes to product) where students learn by doing in different fields. In addition, the MIT Lincoln laboratory -which is a federally funded R&D centre-, is engaged in field-testing of prototype systems as part of their engineering research.	
Start-ups	Over the last ten years, MIT has started an average of 20 companies per year (TLO Statistics, Fiscal year 2013). There are 25.800 active companies founded by MIT Alumni (Kauffman Foundation, 2009). These companies employ about 3.3 million people. The formation of companies by MIT alumni has accelerated since the 1980s. Most of them are primarily knowledge-based companies employing higher-skilled and higher-paid employees. Many of them are in manufacturing (instruments, machinery, electronics, including semiconductors and computers), biotech, software, or consulting firms (architects, business consultants, engineers).	An estimated of 6.900 MIT alumni companies are located in Massachusetts generating employment and revenues for the city. In addition, Harvard University has started 53 companies over the last 6 years (Harvard Office of Technology development). Similarly, the presence of these universities has attracted the Venture Capital firms, which has established in Cambridge-Boston area because of the pool of talent and the opportunities to create new businesses. In 2013, there were 90 biotech VC financings in Massachusetts. 60% of their total funding went to Biotech-firms based in Cambridge (MassBio, 2014).

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Output indicator	MIT	Cambridge
Research grants in technology fields	99% of the research expenditure at MIT campus is external sponsored research. MIT pioneered the federal/university research relationship, starting in WWII up today. Federal-funded research programs are located both in campus and at the Lincoln Laboratory in Lexington. Only in campus, federal research expenditure (69%/ $465 million~) includes all primary contracts and grants from sponsors such as the Department of Defense, Department of Energy, Health and Human Services, NASA, and National Science Foundation. Non-federal research expenditure in campus (30% - US$190 million~) is sponsored by external parties such as industry, foundations and non-profits organizations, and state, local, and foreign governments. Only 1% of the research expenditures come internally from MIT. Over the last ten years, the share of non-federal research expenditures coming from external sponsored has increased from 19% to 30% of the total campus research expenditures (MIT, Briefing book 2013).	
Publications and citations	Each year, more than 750,000 publications carrying the MIT name are disseminated by the MIT Press to scholars and general readers (MIT Facts, 2014). University rankings use data from major sources of publication and citations such as Web of Science from Thomson Reuters, and Scopus from Elsevier and Google Scholar, to indicate the research influence and outputs of universities worldwide. According to the Times Higher Education (THE) World University Rankings 2014-2015, MIT scores 100/100 in the citation performance indicator (30% of the total score)*. Similarly, in the QS World University Rankings® 2014/15, MIT ranks 10/600+ in the citations per faculty indicator (20% of the total score).	Similarly, this indicator also benefits the city of Cambridge when measuring innovation outputs because of the presence of Harvard University. According to the QS World University Rankings® 2014/15, Harvard University ranks 3/600+ in the citations per faculty indicator.
Engineering developments and experiments	There are several historical achievements of the Institute's faculty and graduates such as 'the first chemical synthesis of penicillin and vitamin A, the development of inertial guidance systems, modern technologies for artificial limps, and the magnetic core memory that enabled the development of digital computers'. During the last decade, the institute has accomplished several discoveries in the fields of genetics, IT, energy, materials, computers, physics, and engineering (MIT, 2013).	The city of Cambridge is home of several achievements that have has an impact on society. A project called 'Innovation in Cambridge' documents new ideas, inventions, discoveries and/or new practices that have been emerged and or developed in this city ever since. Examples of those are the first phone call in 1876^, the Microwave Radar in the 1940s, or the EBook in 1997.
Collaboration data developed as research tools	There are several digital projects in which students and faculty have collaborated to develop databases linking challenges and problem solvers (Joost Paul Bonsen, 2006). The number of databases developed at MIT for educational or research purposes is unknown but developing databases as research tools is part of the institute's curriculum and learning methods. For instance, there are several courses at MIT teaching the foundations of database systems. For instance the database groups at the MIT's computer science and artificial intelligent lab conducts research on all areas of database systems and information management, and has an outstanding portfolio of current and past projects including database developments. The MITOpenCourseWare is the most important initiative developed in 1999 to offer distance learning in an e-Learning environment. This initiative served as model for the Massive Open Online Courses MOOCs.	
Nobel Laureates	There are 81 Nobel Laureates affiliated to MIT. Besides, 39 current and former members of the MIT faculty have received the National Medal of Science. Overall, there are several MIT faculty members awarded with different prizes.	In addition to MIT, Harvard University enhances the competitiveness of the city in the knowledge-based economy. For instance, Harvard University registers 47 Nobel Laureates, 32 heads of state, 48 Pulitzer Prize winners (www.harvard.edu, accessed in 2015).

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Output indicator	MIT	Cambridge
Sales flowing from new or improved products	Universities do not use this measure for innovation. However, MIT The active companies founded by MIT alumni generate an annual world sales (US$2 trillion), which is the equivalent of the 11th largest economy in the world. (Kauffman Foundation, 2009 in MIT, 2013). The MIT alumni high-tech firms in software, electronics and biotech hold one or more patents, invest more of their revenues in R&D, and export a large share of their products, and generate an annual world sales of US$2 trillion.	31% of these companies (6.900 approx.) are located in Massachusetts, generating almost 1 million jobs and approximately US$164 billion in sales. This amount represents 26% of the sales of all Massachusetts companies. Without the presence of MIT, these companies would have never located in Massachusetts.

* According to THE, 'the data are fully normalized to reflect variations in citation volume between different subject areas. This means that institutions with high levels of research activity in subjects with traditionally high citation counts do not gain an unfair advantage'. In addition, to make a statistically valid comparison, the rankings exclude from the data any institution that published fewer than 200 papers a year.
^ The first wire conversation took place between Bell's Boston laboratories and was received in Cambridge by Thomas A. Watson.

Samenvatting

Dit proefschrift onderzoekt de ontwikkeling van technologiecampussen en hun rol in het stimuleren van innovatie. Technologiecampussen komen in een variëteit van gebouwde omgevingen voor en zijn ontwikkeld om technologie gedreven onderzoek te huisvesten. Het 'science park' is het meest gangbare type technologiecampus. De definitie van 'technologiecampus' omvat ook de campussen van technische universiteiten en R&D bedrijfsparken.

In geïndustrialiseerde landen is de vraag naar de ontwikkeling van technologiecampussen om innovatie te stimuleren gegroeid, in lijn met de aandacht die kennis krijgt in internationaal, nationaal en regionaal beleid. Er zijn wereldwijd meer dan zevenhonderd technologiecampussen die honderdduizenden hectaren binnen en buiten steden in beslag nemen. Dit type gebouwde omgeving is ontstaan en ontwikkeld ter ondersteuning van de veranderende economie in geïndustrialiseerde landen, gedurende cruciale periodes van technologische vooruitgang in de 20e eeuw. Met de opkomst van de kenniseconomie hebben regeringen in veel landen onderzoek gestimuleerd als een essentiële activiteit in hun wetenschap-, technologie- en innovatiebeleid. Met deze impulsen groeide ook de aandacht voor de bijbehorende infrastructuur. Sinds de tweede helft van de jaren negentig is het aantal geregistreerde 'science parks' gestaag toegenomen. Ook het aantal programma's op de Europese beleidsagenda dat de infrastructuur voor onderzoek ondersteunt, is gegroeid. Gemeentes gaan samenwerkingsverbanden aan met andere publieke of private partners bij het ontwikkelen van stedelijke gebieden die bestemd zijn voor het stimuleren van innovatie. Regeringen, universiteiten en R&D bedrijven investeren miljarden euro's in de ontwikkeling van de infrastructuur die niet alleen hun kerntaak moet ondersteunen, maar ook hun concurrentiekracht moet versterken voor het aantrekken en behouden van talent. Een deel van deze investeringen is bedoeld om nieuwe gebouwen of nieuwe gebieden te ontwikkelen die vaak resulteren in campussen zoals wij die kennen: een concentratie van gebouwen die organisaties, mensen en hun activiteiten huisvesten op één terrein, al of niet in het groen.

De aanname dat de concentratie van onderzoeksactiviteiten op één locatie innovatie stimuleert, bevordert op veel plaatsen de ontwikkeling van technologiecampussen. Het vermogen van deze gebouwde omgevingen om de verschillende processen die verbonden zijn aan innovatie te ondersteunen wordt echter onvoldoende begrepen: technologie campussen zijn stedelijke of perifere gebieden die het vermogen hebben zowel de processen van kenniscreatie en -spreiding te faciliteren als de activiteiten van het aantrekken en behouden van kenniswerkers te ondersteunen. De bestaande kennis over de relatie tussen de gebouwde omgeving en innovatie op gebiedsniveau is beperkt. Deze kennislacune kan leiden tot de inefficiënte inzet van middelen, waaronder het kapitaal, de grond en de tijd die worden aangewend om technologiecampussen te ontwikkelen. Het gebrek aan begrip kan ook een tegenovergesteld effect hebben omdat technologiecampussen gemakkelijk probleemgebieden kunnen worden met leegstand, gebrekkige ruimtelijke kwaliteit en slechte bereikbaarheid, die het maatschappelijk doel van het aantrekken en behouden van talent voor de kenniseconomie belemmeren in plaats van stimuleren. Een potentiele weg om deze problemen aan te pakken is het beschrijven op welke wijze de gebouwde omgeving innovatie in technologiecampussen kan stimuleren.

In deze context adresseert dit onderzoek de volgende hoofdvraag: 'Hoe stimuleert de gebouwde omgeving innovatie in technologiecampussen?' Dit onderzoek is uitgevoerd binnen het vakgebied van Corporate Real Estate Management (CREM), vanuit de veronderstelling dat de gebouwde omgeving een middel is dat gemanaged moet worden om de doelen van organisaties te ondersteunen. Onderzoek op dit gebied concentreert zich op de praktijk van het vastgoedmanagement vanuit het gezichtspunt van de eindgebruiker. Campus ontwikkeling is een veelomvattend voorbeeld van CREM dat zich bezighoudt met activiteiten die variëren van de ontwikkeling van vastgoedstrategieën en de ontwikkeling van bouwprojecten tot aan het onderhoud en management van de vastgoedportefeuille van een organisatie. De relatie tussen innovatie en de gebouwde omgeving is eerder behandeld in theorieën van CREM in brede zin. Empirisch is deze relatie aan de aanbodzijde meer bestudeerd op het niveau van de werkplek dan op stedenbouwkundige schaal ondanks de actuele discussie over innovatie in complementaire onderzoeksterreinen. Aan de vraagzijde zorgt de betrokkenheid van een veelheid van organisaties bij gebiedsontwikkeling ervoor dat de organisatorische scope in CREM ook wordt verruimd naar stedelijk niveau, waarmee publieke partijen ook een rol krijgen.

Dit onderzoek verheldert de relatie tussen de gebouwde omgeving en innovatie op gebiedsniveau. Dit onderzoek ontwikkelt kennis met behulp van een conceptueel model en doet aanbevelingen aan praktijkmensen die zich met campusontwikkeling bezighouden. Deze kennis is vooral gegenereerd door een inductieve benadering in twee deelstudies. De eerste deelstudie is een verkennend onderzoek dat het verband tussen innovatie en gebouwde omgeving opheldert en positioneert door het gebruik van theorie (literatuurstudie) en empirisch bewijsmateriaal (kwalitatief onderzoek naar 39 technologiecampussen). In deze fase van het onderzoek is het verband tussen innovatie en gebouwde omgeving aangegeven in de vorm van een conceptueel kader dat uitgaat van de gebouwde omgeving als een katalysator van innovatie. De tweede deelstudie is een verklarend onderzoek die de relatie tussen innovatie en gebouwde omgeving verhelderd op basis van empirisch bewijs in de praktijk van campusontwikkeling (theorieontwikkeling vanuit case studies). In deze fase is het theoretisch construct van het conceptuele kader toegepast op twee specifieke casestudies - High Tech Campus Eindhoven in Nederland en Massachusetts Institute of Technology (MIT) campus in de Verenigde Staten - en naar aanleiding daarvan herzien. Met als resultaat dat de aanvankelijke kennis vanuit het verkennend onderzoek is ontwikkeld tot een conceptueel model dat bestaat uit een hypothese en vijf stellingen die nauw verbonden zijn met empirisch bewijs.

Het antwoord op de hoofdvraag dat de gebouwde omgeving een katalysator voor innovatie in technologiecampussen is, wordt aangetoond door locatiekeuzes en interventies die vijf onafhankelijke voorwaarden ondersteunen die nodig zijn voor innovatie. De volgende stellingen verduidelijken hoe de gebouwde omgeving ieder van de vijf contextafhankelijke voorwaarden voor innovatie ondersteunt.

- Locatie keuzes en gebiedsontwikkeling faciliteren de concentratie van innovatieve organisaties in steden en regio's op de lange termijn.
- Interventies die de transformatie van de gebouwde omgeving op gebieds- en gebouwniveau bewerkstelligen faciliteren het klimaat voor aanpassing op termijn aan veranderende technologische trajecten.
- Grootschalige vastgoed interventies faciliteren de synergie tussen bedrijfsleven, universiteiten en overheid.
- Locatie keuzes en interventies die het imago en de toegankelijkheid ondersteunen bepalen het innovatie gebiedsdeel door zijn onderscheidende identiteit, schaal en de voorzieningen voor bereikbaarheid.
- Vastgoed interventies die de toegang tot voorzieningen bewerkstelligen bevorderen de diversiteit van mensen en de kansen op sociale interactie, ongeacht de verschillen in geografische ligging van de concentratie van innovatieve activiteiten.

Dit onderzoek geeft aan dat de toevallige locatie keuzes van sommige technologie gedreven organisaties de concentratie van innovatieve onderzoeksactiviteiten bepaald hebben. Na verloop van jaren is de huisvesting van de onderzoeksactiviteiten van deze organisaties mee geëvolueerd met bepaalde sociaaleconomische processen in hun thuisstad, waardoor unieke omstandigheden voor innovatie werden gecreëerd. De concentratie van innovatieve organisaties kan beschouwd worden als een randvoorwaarde nodig voor het naast elkaar bestaan van de andere vier voorwaarden voor innovatie. Hiermee vergelijkbaar geeft dit onderzoek de volgende interventies aan die de voorwaarden voor innovatie op gebiedsniveau ondersteunen, afhankelijk van de specifieke locatie karakteristieken waarin iedere campus zich ontwikkeld:

- Transformatie van gebieden door stedelijke vernieuwing en herontwikkeling;
- Bouwen, aanpassen en hergebruik van flexibele voorzieningen;
- Implementatie van gedeeld gebruik van voorzieningen ten gunste van verschillende functies en gebruikers;
- Ontwikkeling van fysieke infrastructuur die toegang tot en verbinding tussen voorzieningen mogelijk maakt;
- Ontwikkeling representatieve faciliteiten en gebiedsconcepten die het imago ondersteunen.

Het empirische bewijs dat de stellingen ondersteunt in het model, is gestructureerd en omgezet in informatie in de vorm van 'tools' die beschikbaar zijn voor beslissers die bij de ontwikkeling van technologie campussen betrokken zijn. De zogenaamde 'campus decision-maker toolbox' biedt instrumenten als richtsnoer voor planners, ontwerpers en managers tijdens verschillende fases van de campusontwikkeling. De tool voor planners behelst campusmodellen om de campus visie in te kaderen gedurende de initiatieffase van de campus, gebaseerd op locatie karakteristieken . De tool voor ontwerpers bestaat uit alternatieven om het programma van eisen voor de campus te verbeteren bij de voorbereidingsfase van de campus. En de tool voor managers is een informatie kaart om de campus strategie te sturen gedurende het gebruik van de campus.

Deze kennis draagt bij aan het bestaande begrip van de relatie tussen innovatie en de gebouwde omgeving in theorie en praktijk. Met betrekking tot de theorie draagt dit onderzoek bij aan bestaande theoretische concepten die de terreinen van CREM , stedenbouw in de kenniseconomie en economische geografie verbinden. Het conceptuele model biedt een nieuwe combinatie van bestaande theoretische concepten gericht op een nieuwe manier van kijken naar de relatie tussen innovatie en de gebouwde omgeving. Met betrekking tot de praktijk mag verwacht worden dat dit begrip de efficiënte en effectieve inzet van de vele middelen stimuleert die nodig zijn om technologie campussen te ontwikkelen. In het bijzonder door het bieden van informatie die beslissers kan helpen om op zulke middelen te sturen naar strategische beslissingen en interventies die – onder specifieke omstandigheden- innovatie ondersteunen. De kennis die in dit onderzoek is ontwikkeld verhelderd de relatie tussen innovatie en de gebouwde omgeving op stedenbouwkundig niveau, waarin de gebouwde omgeving de voorwaarden voor innovatie faciliteert.

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Curriculum Vitae

Flavia Curvelo Magdaniel was born on the 8th of January 1982 in Riohacha, Colombia. She graduated as an architect from the Universidad Nacional de Colombia in Bogotá in 2004. During her five-year studies at this university, she obtained the 'Scholarship for academic merit of undergraduate students'. Her graduation thesis -A social housing model for La Guajira's Caribbean region- was awarded Meritorious Mention.

From 2004 to 2008, she worked as an architect designer at public and private organisations. During the first three years after her graduation, she was involved in the urban planning and design team of the University City of Bogotá. In this position, she dealt with the design, implementation and management of large-scale projects involving multiple consultants, the municipality of Bogotá, and citizens at large.

In 2008, she obtained the 'Netherlands Fellowship for a Master's Programme' and began her studies at Delft University of Technology. In 2010, she received the degree of Master of Science in Architecture, Urbanism and Building Sciences (Real Estate & Housing master track). She followed a graduation profile combining insights from corporate real estate management and urban area development. Her graduation thesis -The Management of public university campuses: the case of the University City in Bogotá- was awarded Honourable mention.

After her graduation, she joined the Department of Management in the Built Environment (former Real Estate & Housing) at the Faculty of Architecture and the Built Environment of Delft University of Technology as a research assistant. In June 2011, she was appointed as PhD candidate at the same department. While working in her PhD research, she wrote three journal articles and three conference papers. She also contributed to the research projects 'Benchmark Dutch University Campus Projects 2012-2013, commissioned by HOI (14 Dutch universities)' and 'Advice Binnengasthuis site', requested by the University of Amsterdam.

During the same period, she lectured in master programmes at universities in the Netherlands, Germany and Colombia for architecture students. Flavia has been involved in PhD training and development activities while being a member of the A+BE PhD Council as representative of the MBE department. At the end of her PhD appointment, she was the module manager and coordinator of the MSc course Real Estate Management at Delft University of Technology. Since August 2016, she holds a post-doc position in the same department to continue research on European campuses. She is interested is outlining the role of large-scale built environments as resources supporting the needs of different organisations and societies.

Publication list

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2012 Den Heijer, A. C., & Curvelo Magdaniel, F. T. J. (2012). *The university campus as a knowledge city: exploring models and strategic choices.* International Journal of Knowledge-Based Development, 3(3), 21.

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