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Hein, Carola; van Mil, Yvonne

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ABSTRACT

Researchers from multiple disciplines study ports and port cities using various forms of visualization. To better understand port cities' challenges and opportunities, some use mathematical modeling of economic flows or shipping, while others use geo-spatial mapping of land and water territories. In the visualization of port city regions, economic geography has made especially valuable contributions. However, one limitation of the more quantitative and abstract data-based approaches is that they often fail to consider qualitative aspects and local particularities. Examining the challenges and opportunities of geo-spatial mapping, the article calls for a methodology that parallels abstract quantitative economic modeling of port city regions and their networks with historical investigation of individual port city regions with their specific local challenges and opportunities. The article develops visualizations of the historical development of three port city regions that have developed in relation to each other around the North Sea and that we are using as pilot studies: Rotterdam, Hamburg, and London. The article concludes that this type of geo-spatial analysis can connect quantitative and qualitative approaches, help identify historical forms, spatial structures, and governance patterns with lasting importance for decision-making in port city regions.

Towards a Comparative Spatial Analysis for Port City Regions Based on Historical Geo-spatial Mapping

Carola Hein[1], Yvonne van Mil[2]
[1] Professor
[2] Researcher
Faculty of Architecture & the Built Environment, TU Delft. Delft, The Netherlands.

KEYWORDS
Port city regions; Historical geo-spatial mapping; Methodology; Comparative spatial analyses

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Introduction

Port city regions are territories adjacent to large bodies of water, where a changing group of stakeholders and institutions have facilitated a spatial system for the transshipment of goods and people, often for decades or even centuries. When the interests of all stakeholders have been aligned, port city regions have emerged as strong economic, political and cultural centers of trade and travel. Since the late 19th century, and particularly since the 1960s, ports have been detaching from adjacent territories, in terms of both occupied space and institutions. The traditionally close relationship between port and port-related activities in neighboring cities and regions has declined along with the visibility of port activities in the city (Hein 2011, 2016, 2018). During the same period, the growth of the port beyond its traditional urban location has led to an increasing role of the port in the region, both in terms of economic wealth as well as its effect on the environment in terms of noise, pollution, and other nuisances. Meanwhile, cities and their surrounding areas have increasingly adopted strategies for economic growth that are unrelated to ports. Leaders and policy makers have come to view (former) port areas as places of urban expansion. Spatial and governmental fragmentation in the larger port city region can lead to conflicts among relevant stakeholders. This article sets out to explore visual tools, notably GIS-based historical spatial mapping to understand the multiple ways in which port, city, and regional spaces and institutions intersect.

Academic research has evolved based on disciplinary approaches that study port-city relationships independently of each other, with different goals, focused on separate values and at different scales. Professionals concerned with ports, economics, and technology seek to improve the functionality of the port and develop practical policies and engineering solution, often without concern for long-term, social and cultural implications. Academics in the social sciences and humanities explore a broad range of port city-related developments often from a qualitative perspective and aim to understand the larger societal and cultural forces at play, but rarely address concrete issues of development. Contemporary urgencies, including climate change, migration and technological innovation require multidisciplinary collaboration and some level of agreement and coordination of effort among port and city professionals as well as local citizens. Hard values of technology, logistics, and economics can no longer be the main drivers of port and city development, they need to be aligned with a study of soft values, including in the humanities and social sciences. Such a collaboration requires re-conceptualization and multi-disciplinary investigation based on a shared methodology that ideally encompasses quantitative and qualitative aspects. The scale of such an investigation should be that of the port city region - and not just that of the port city -, that is the area where port activities leave their footprint. Such an assessment of conflicts and opportunities at the intersection of port and city interests warrants a consideration of spatial, social and cultural factors.

Common features of ports, cities and their regions around the world have attracted the attention of numerous researchers. Geographers and economists have developed modeling tools and visualizations based on quantitative data on shipping networks (e.g. Verhetsel and Sel, 2009, Ducruet et al., 2018). They have also carefully studied the interactions between ports and cities and their regions notably based on quantitative data but also including some attention to spatial patterns and physical locations. These numbers-based approaches are particularly appropriate for identifying trends and making predictions. Historians and planners have also conducted much port

city research. They have created a large body of literature on specific port cities, often with a perspective from the city, focused on cities and landside development, and following their own methodologies. These authors mostly take a qualitative approach, making it difficult to compare cities with each other another (e.g: Broeze, 1985, Broeze, 1989, Schubert, 2018, Schubert, 2011, Meyer, 2003, Meyer and Nijhuis, 2014, Laar, 2000, Hein, 2012, Hein, 2011, Hein, 2016a, Desfor et al., 2010, Kokot et al., 2009, Porfyriou and Sepe, 2016). Analytical links between the two types of literature are missing, as demonstrated through the absence of shared conferences and publications (Hein, 2016b).

There is a need for information about the physical reality in which human life and work take place in port city regions. The human dimension of port city research is understudied. A methodology which can be used to analyze spatial and cultural patterns can help fill the gap. This raises the question: How can we complement the excellent data produced in economic geography with a space-based methodology? Is it possible to create a new form of abstraction that allows us to consider the spatial, temporal, and functional elements of port, city and region in a geographical context? Can historical geo-spatial maps enrich the abstractions of quantitative approaches and our knowledge about port cities? How can we acknowledge multiple scales through time while providing insight on governance issues? To complement the power of quantitative analysis, we propose mapping as a tool with which to study port-city relationships and to develop a foundation for policy making that acknowledges not only economic, but also spatial, social and cultural factors.

This contribution explores two different sets of literatures and two different types of visualization of port cities: mathematical modeling and geo-spatial mapping. We examine both quantitative and qualitative approaches and discuss shortcomings, challenges and opportunities. We argue that some fundamental questions, such as the scale for comparing spatial patterns and historical developments in port cities and the implications thereof have not been answered with geographical models. In line with recent work that aims to connect abstractions and models with actual spaces, we propose that historical geo-spatial mapping can help develop a method to compare and analyze port city regions, their spaces and governance. We conclude with a tentative examination of the challenges and opportunities of geo-spatial mapping and an exploration of the spatial development of three ports - Rotterdam, Hamburg, and London. Ultimately, we plan to develop geo-spatial mapping as a means to gain insight into historical, political and geographical particularities of select locations and into the institutional structures associated with them. Such a methodology can help form a bridge between abstract economic data and historical investigation in a way that takes into account specific local challenges and opportunities that are difficult to compare and often ignored when using abstractions and models alone.

Quantitative Modeling and Qualitative Mapping

Many scholars use quantitative or geographical models to better understand shipping networks and port-city relations in abstract terms. Such models have advantages and disadvantages. The Encyclopedia Britannica defines scientific modelling as “the generation of a physical, conceptual, or mathematical representation of a real phenomenon that is difficult to observe directly.” It states that “scientific models at best are approximations of the objects and systems that they represent - they are not exact replicas” (Rogers, 2019). Such abstraction allows the author to extract select information; the more detail included, the more difficult the conceptualization. A model involves thus not so much an abstraction of reality, but rather a representation of an insight that could be useful in looking at the real world. Economist Joan Robinson phrased this insight clearly: “A model which took account of all the variegation of reality would be of no more use than a map at the scale of one to one” (Robinson, 1962, p. 33). Models are valuable tools, often designed to facilitate policy making. The information they present is, however, highly selective and can easily be used to suit the goals of their maker. Many economic models of port cities have no relation to physical

space, despite the fact that they show spatial processes. Often city names are the only link to actual places. Abstraction is key to models, but in the field of spatial planning and urban or planning history the absence of physical-geographical, spatial-features is problematic. Mentioning the name of a port or a city doesn't tell us anything about the physical reality of shipping, the environmental, social, or cultural impact on port and city, and may not provide insights for local policy making.

In contrast to models, a map shows the impact of data in a geographical context and thus allows for better spatial embedding. Maps can help us see patterns and outliers and derive meaning from huge, complex territories (Robinson and a.o., 2017). They are less abstract than models and contain more localized information, but maps are also influenced by politics and mapmakers. Like a model, a map is a representation of the space, reduced to a two-dimensional shape, in a manageable scale, with a limited amount of detail. Many cartographers have commented on the role of maps in creating select realities. As Denis Wood (Wood, 1992, Wood, 2010) asserts in his book *The Power of Maps*, maps, like photographs, represent a subjective point of view. The effectiveness of maps is a result of selectivity. Because of selectivity - the choice of word or sign or aspect of the world to make a point - the map is enabled to work. Geoff King (1996) concludes that there can be no such thing as an objective map reproducing a pre-existing reality, as powerful choices will always have to be made about what to represent and how, and what to exclude. Mark Monmonier (Monmonier, 1996/2014) even maintains that maps lie, and the choices that cartographers make - either consciously or unconsciously - mean that a map is far from objective. Darren Dalcher adds that the "process of mapping, as opposed to blindly following a map, enables reasoning and adjustments to emerge so that corrections can facilitate improved performance and a more purposeful journey" (Dalcher 2018). James Bird pointed out already in 1984 that "A map of a seaport can be particularly misleading" (quoted by Olivier and Slack, 2006). Many authors, like Wood (2010) and Monmomier (2014), have felt the need to revise their books following the digitization of large amounts of spatial data, signaling the need for a careful reflection on what data can tell us today and how it can be used to facilitate our understanding of (and co-existence in) port city regions. Mapping is just a tool, but a potentially powerful one to gain better understanding on historical development, to communicate the findings and to engage in discussions on future development.

Visualization of Quantitative versus Qualitative Data

Geographers have used various models to visualize changing shipping networks and to understand the similarities and particularities of port cities and their evolution over time has inspired geographers to develop numerous models. Economic geographers have visualized datasets through geometrical shapes interconnected with lines of different thicknesses to aid comparison of shipping networks, port-city relations and their development over time. The literature in the field of economic geography on port-city relations is vast with important contributions in port geography (Rodrigue et al., 2009, Notteboom et al., 2009, Wang et al., 2007). As Ng and Ducruet demonstrate, the literature on port-city relationships evolved from descriptive monographs and a focus on morphology to include spatial models and a concern with real actors. Only in the 2000s did researchers start exploring port-city relationships using quantitative methods (Ng and Ducruet, 2014). Often the goal of these publications is geared towards policy making and economic development assessment. In their piece entitled Building a Bridge Between Port and City, Zhao and colleagues use statistics to show that the port still matters for the city (Zhao et al., 2017). The work of the French geographer Cesar Ducruet stands as emblematic for this approach (Ducruet et al., 2017) (Figure 1). His visuals clearly identify shipping networks in relation to specific ports and city locations, exploring for example, the interrelationships between the size of the port and the size of the city (and its region), as well as the relevance of a port within the global system (Ducruet et al., 2017). The research takes a macro rather than a micro perspective. It explores inter-city relationships rather than inter regional ones.

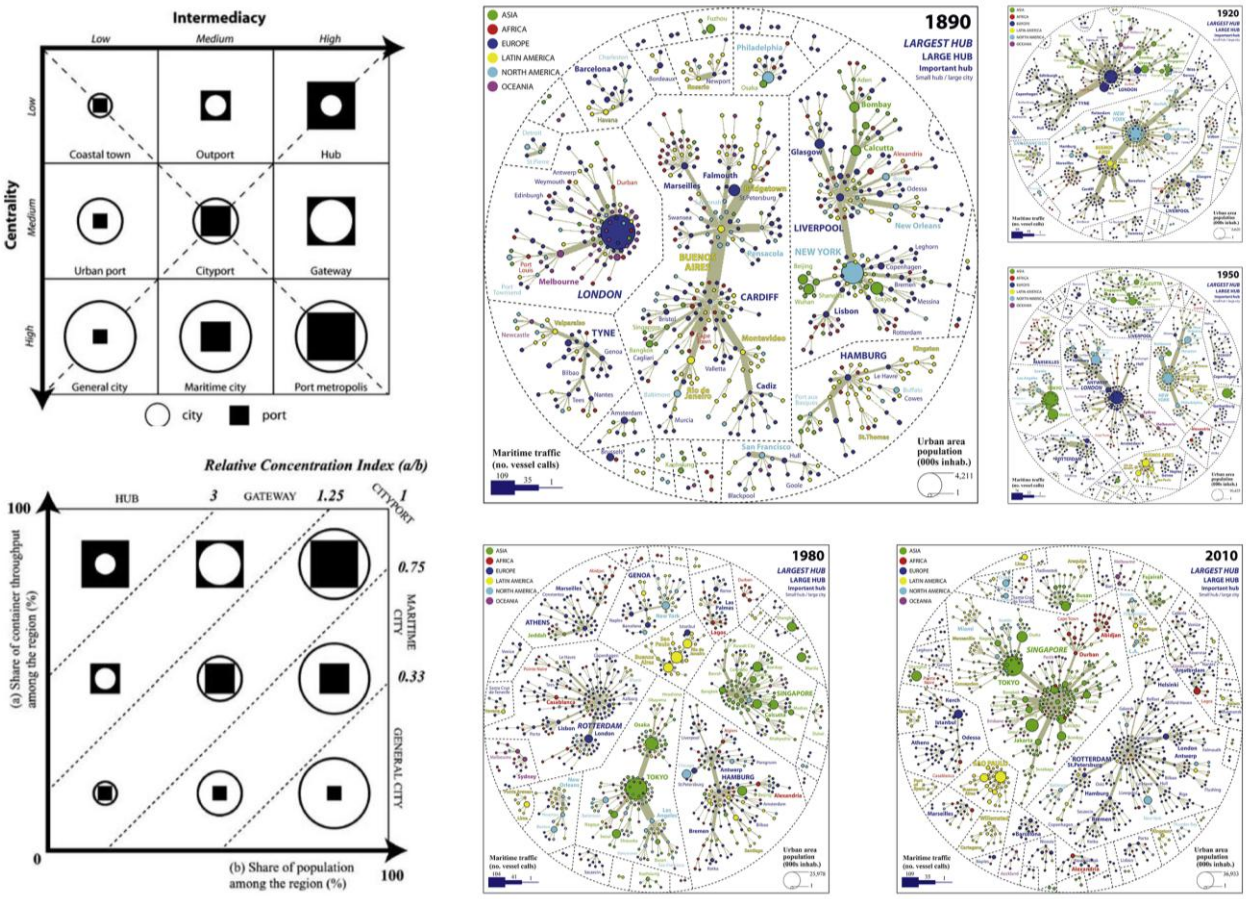

Figure 1. Visualizations of the port-city relationship (Ducruet, 2005, Ducruet and Lee, 2006) and shipping networks in relation to ports and city locations, 1890–2010 (Ducruet et al 2018).

These elegant explorations feature names of ports and cities like Hamburg, Rotterdam, or London. These names appear in different network constellations and with different sized population circles. The goal of these visualization was to provide a framework for a global analysis. They tacked existing models, rather than continuing them, and highlighted local particularities, within a complex framework. The reader gains important insights on changing port-city relationships through a quantitative approach, but the model doesn't aim to provide insight into the spatiality of these ports, the physical reality of the city or the region that hosts the port, the type of technology used, particular systems of governance, development of infrastructure or the relation to the hinterland, location on the globe, presence of smaller port cities or their physical interaction with neighboring coastal places. There is no information on decision-makers, institutions, economic or political systems. Nor do the visualizations address what the presence of the port means for urban development, for the people living in the city or for local mindsets and cultures.

Going beyond the visualization of global networks, many scholars, notably in the field of geography, have zoomed in further on the territory and analyzed patterns in the shifting relationship between port cities and their regions over time. The work of Brian Hoyle stands out in this context (Hoyle, 1989a). These models have attempted to capture similarities and dissimilarities in global patterns with the use of abstract forms. They are important for understanding changing patterns in global shipping flows, in identifying leading cities and in understanding evolving port-city-region relationships. These abstractions can help us understand spatial or temporal development, but they are also abstract and often unrelated to physical spaces, their locality, form, function and use in specific cities.

Perhaps the most influential model made by Hoyle is his analysis of five steps in port-city development focused on the evolving port-city interface (Hoyle, 1989b). He shows how ports and cities first intersected, then detached and more recently reconnected. This model emerged in the late 1980s, at a time when waterfront development became a theme for many cities dealing with abandoned inner-city port areas. The model has been picked up, refined and expanded by numerous scholars. Each aimed to add new temporal, spatial or other information. For example, Dirk Schubert proposed a sixth phase with a renewal of port-city links (Schubert, 2011). Karel van den Berghe added a seventh phase and exemplified the abstraction through case studies of Gent, Brugge and Antwerp (Schubert, 2011, Berghe, 2016). Lee and Ducruet have shown the relevance of the model for Asian cities (Lee et al., 2008). Ducruet has further explored the relationship between city and port and provided insight into the continuous redevelopment of port areas (Lee and Ducruet 2009, Ducruet et al., 2015, Ducruet et al., 2017) (Figure 2).

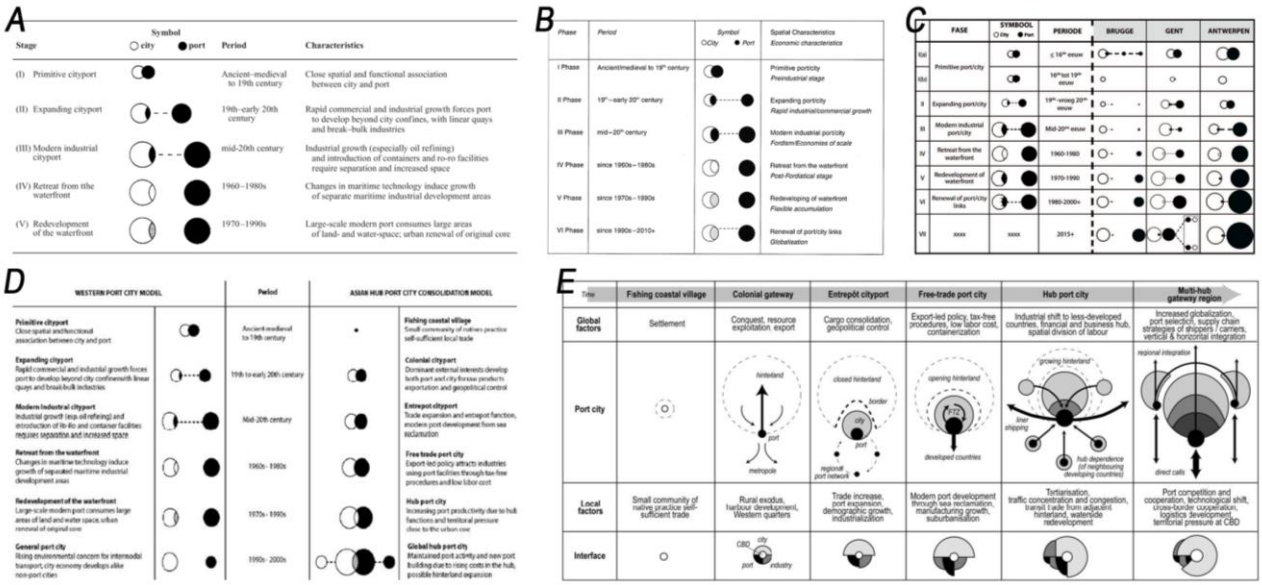

Figure 2. A. evolution model of the Port City Interface by Hoyle (1989);
B. Schubert's adaptation of Hoyle' model with proposed sixth phase (2011);
C. Van den Berghe's adaptation of the Port City Interface model of Hoyle;
with case-studies of Gent, Brugge and Antwerp (2016);
D. Asia Port City Interface model by Lee, et al, (2008);
E. Spatial evolution of the hub port city by Lee and Ducruet (2009).

These models are highly relevant and intriguing, but they also risk establishing a discourse that limits the analysis of port-city relationships. For example, the question of the revitalization of the waterfront (the transformation of former port areas into urban areas), is a theme scholars have explored from multiple perspectives including geography, planning, and architecture (e.g. Van den Berghe 2018; Daamen 2007; Bird 1982; B. S. Hoyle 1989; B. Hoyle 2000; Wiegmans and Louw 2011; Daamen and De Vries 2013; Porfyriou and Sepe 2017; Schubert 2011; Meyer 1999; Hein 2018). Research on the waterfront and the reuse of former port areas for urban purposes is relevant but it also ignores the complexity of port city regions. In recent years, many scholars have recognized the relevance of the region as a spatial framework for port city studies, but a clear and strong sense of how to define and analyze the space of the region is still needed. Ducruet and colleagues use the concept of extended city-region to capture urban growth, but their definition of the city, a key element in port city region studies remains vague (Ducruet, 2018, Meyer 1999, p. 381-382; Van der Berghe, 2018 p. 14-15; Van den Berghe, 2015).

Combinations of abstract models and historical morphological ones

Many geographers use their models to introduce an analysis of specific case studies. One of the earliest attempts to capture the particularities of port-city relations is James Bird's Anyport Model (Bird, 1963). The images combine abstractions with some version of reality. Meant as an abstraction of the historical evolution of the port-city relationship focused on British port cities, it seems to (perhaps unintentionally) more adequately capture the situation of London than other port cities. Hoyle refined his model of the waterfront with a close-up of the "zone of conflict and/or cooperation" at the interface of port and city and then applied it to the case of Marseilles (Hoyle 1989). Van den Berghe appropriately critiqued modeling and its inherent lock-in in terms of the conceptualization of port-city relations. He presented abstract historical-morphological maps of Brugge, Ghent and Antwerp in conjunction with Hoyle's model, thus trying to build a bridge between one and the other. With this he shows that the spatial history of these Belgian port cities cannot be explained on basis of the "ideal typical models" (Van den Berghe, 2016). Further steps are needed to develop a space-based methodology that allows both for comparative research and that provides critical insights into spatial development that can serve as a foundation for future planning.

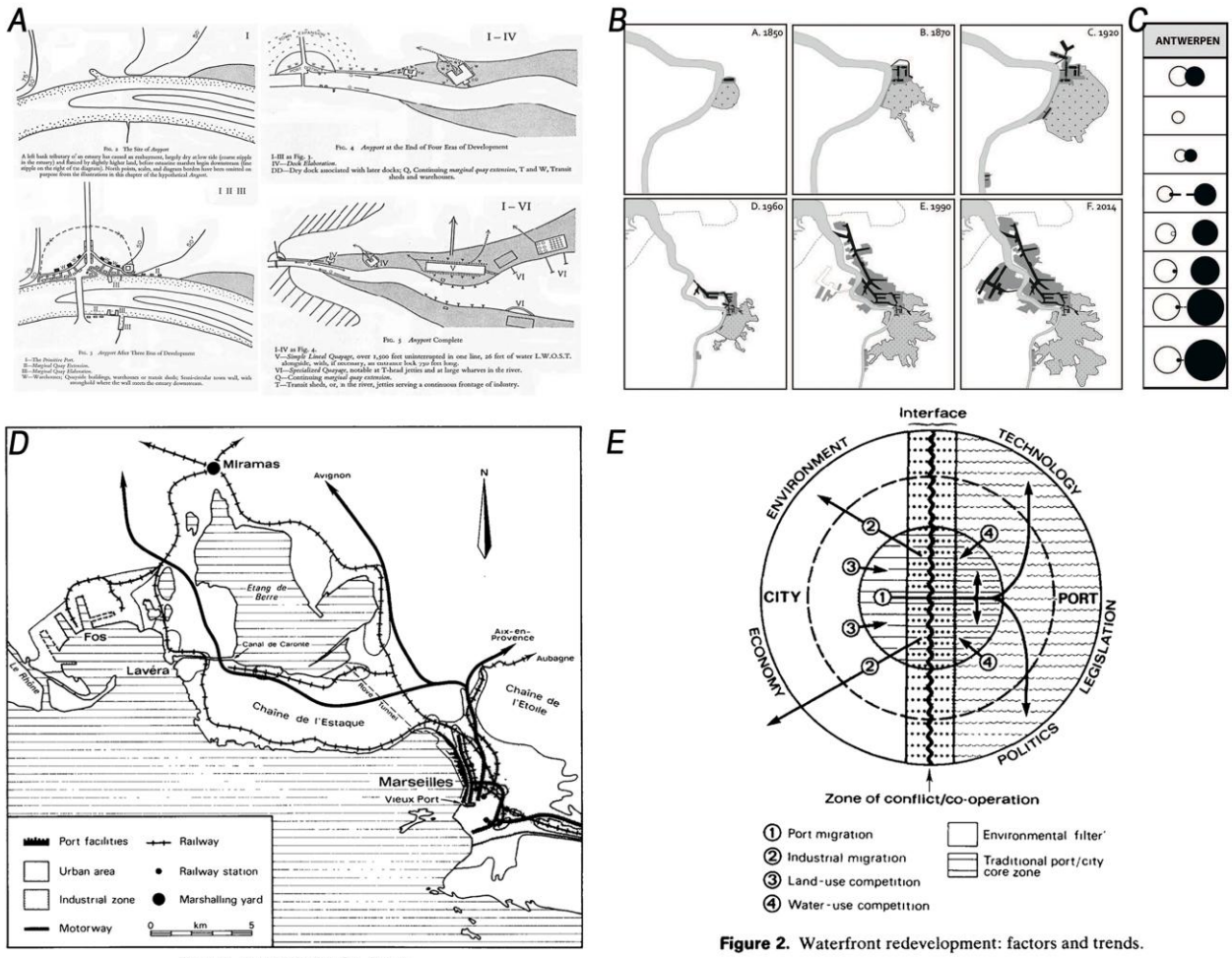

Figure 3. A. Bird's Anyport model (1963);
B. historical morphological analysis of Antwerp by Van den Berghe (2016);
C. fragment from Van den Berghe's adaptation of Hoyle's Port City Interface model, see fig. 2c (2016);
D. Map of the port of Marseille-Fos port by Hoyle (1989);
E. Hoyle's model of the waterfront development of Marseille (1989).

While geographers have made important steps towards analysis (providing opportunities for global comparison of economic patterns, shipping etc.), there is no methodology for the analysis of port-city relations from a spatial perspective. As a result, many aspects, particularly spatial, social and cultural elements are insufficiently analyzed. Depictions of concrete physical forms are often provided for select locations as part of individual urban investigations, but they are difficult to compare. Once we go beyond these abstractions, each of these locations shows complex patterns and intricate socio-spatial particularities. As the urban planner Han Meyer (1999) noted in his comparative study *City and Port,* port cities '[...] differ from one another not only in terms of territorial features and typology of port infrastructure, but also in terms of the size of the cities and of the amount and development of port activities: areas in which substantial differences can be found' (Meyer, 1999). Meyer introduces abstractions and analytical maps to gain further insight into the spatiality of port cities (Figure 4) and proposes yet another abstraction, aimed at capturing changes in spatial relations over time. His visual explores both the role of the port for the city and that of the city for the port. He also tests his model with the case of Rotterdam, showing the relationship between growing/transforming port space and urban areas.

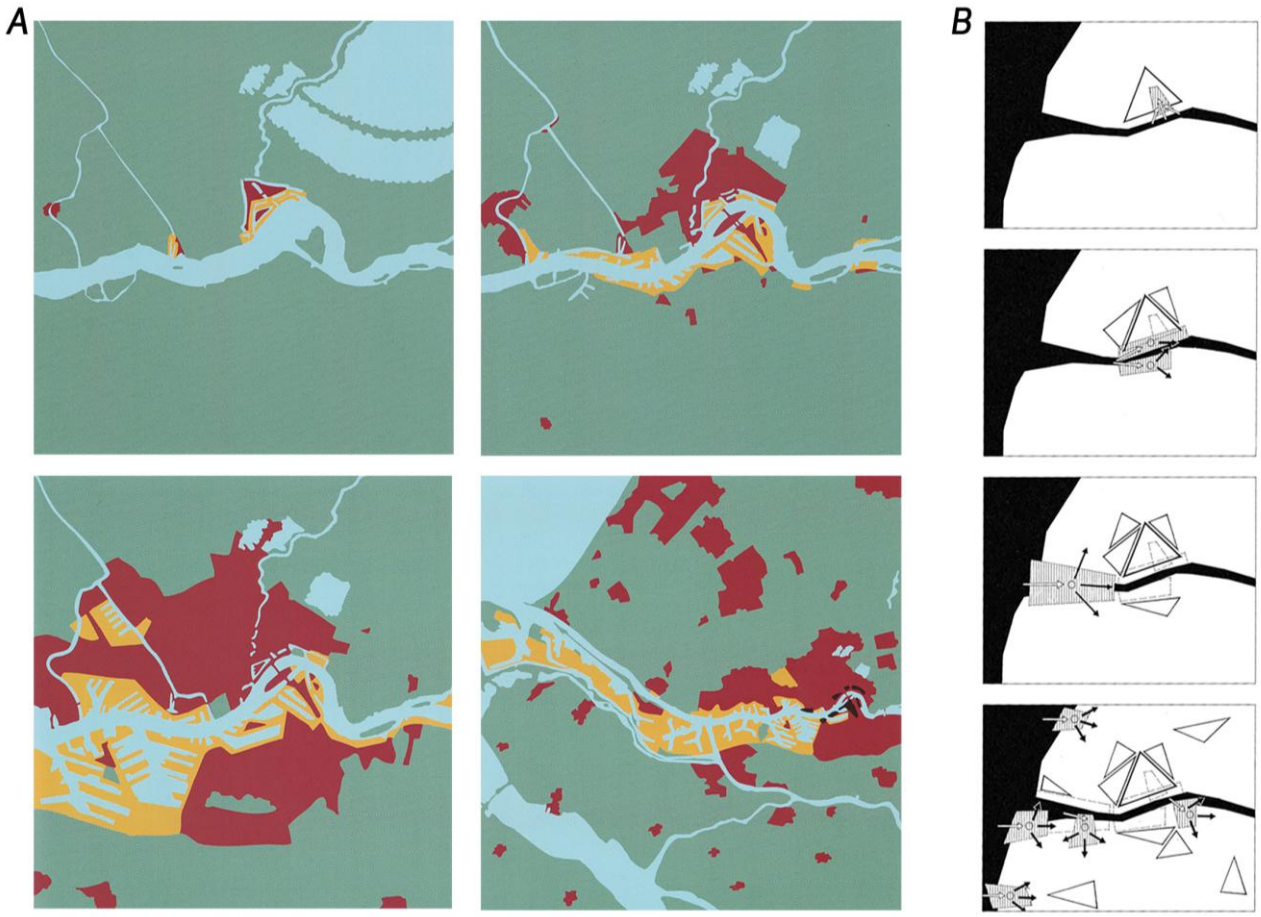

Figure 4. A. Meyer's abstract maps of the historical development of the relation between port and city areas in Rotterdam (1999); B. Meyer's analytical maps of the historical development of port regions (1999).

These explorations fail to address what these economic and shipping flows mean for the built environment in which people live and work. They don't indicate how these global flows translate into local physical patterns, and why ports and their neighboring cities adopt some spatial models rather than others. We don't know whether the fate of a port, its growth or decline was driven by local forces and innovation, by regional or national ones or by the power of the global shipping companies. To get a better understanding of how global and local forces shape the built environment, how the long-term interaction between physical spaces and social structures shapes

port-city relationships, or how far the port reaches into the hinterland, we need a methodology. We need to develop a systematic way of connecting abstractions of port cities and concrete situations. The following section explores the opportunities and challenges in historical geo-spatial mapping, using ongoing research into North Sea port city regions by the Chair History of Architecture and Urban Planning at Delft University of Technology as a starting point.

Challenge and opportunities of geo-spatial mapping. What can geo-spatial analysis add to the models?

To complement the comparative models used by geographers, we aim to assess the role that geo-spatial mapping can play in understanding individual cities and to provide a tool for comparative analysis of port cities over time and through space. Such a tool can also help planners and policy makers identify relevant hotspots of potential spatial conflict and opportunities for future development. We argue that such GIS-based geo-spatial mapping allows us to expand on the traditional methods of historians such as archival research, local observation or interviews. All of those methods are very time- and knowledge-intensive. The use of data sources or big data promises to facilitate such investigation. Geo-spatial mapping using big data sets can help provide a standardized foundation of comparison. Although there is no widely accepted common definition for what big data is, the most cited definition suggests that big data is characterized by the three-dimensional data management framework Volume, Velocity, and Variety (later known as "the 3Vs"), that was introduced in 2001 by data analyst Douglas Laney (2001). In the field of geo-spatial mapping this means that large data sets can be displayed and analyzed in a comprehensive fashion, potentially providing insights beyond those available using traditional methods. Such an approach has both opportunities and challenges.

According to Anthony C. Robinson, the emergence of big data is a call to action for cartographers, because 'The process of making a map is, at its core, an act of generalization to make sense out of an infinitely complex world. As data sources creep closer towards the ability to describe every detail, all the time, for every place, the ways in which we make maps to make decisions must adapt to handle this data windfall. [...] New data sources are of limited use if we find no meaning in them; therefore, an overarching goal for cartographers is to find a way to use this data to create maps that people consider important' (Robinson et al. 2017). Here we will focus on spatially grounded data and only identify how geo-spatial mapping can help to efficiently and effectively visualize complex spatial data to support decision making and reasoning. Geographic Information Systems (GIS) enables us to combine and compare large amounts of data. But, considering and combining all this data involves particular challenges and potential benefits.

The use of (historical) geo-spatial maps offers notable advantages for the analysis of port cities. GIS allows researchers to combine various data and to compare port cities on multiple scale levels. It allows researchers to visualize geo-spatial data at a similar level of abstraction, without losing context and too much detail. Potential problems involve the availability and quality of datasets. The increasing number of datasets (freely) available on the internet makes it easier to collect data. But, the available data along with their quality and consistency vary greatly for different geographic regions and through time. Since we investigate port city regions around the North Sea, it is important to find datasets that cover several nation-states with sufficient spatial resolution to analyze and compare port cities in a consistent and systematic way. Global and continental datasets on transport, land use, territorial units, soil and elevation can be suitable for a systematic comparison. Using these datasets and establishing a meaningful methodology requires determining *definitions and decisions* that pertain to the datasets, selecting the right *scales and spaces* for analysis and identifying and mapping the most relevant *temporalities and times*. These steps are essential and need to be carefully assessed and documented.

Definitions and Decisions

Finding -or building- the right reliable data is one of the biggest challenges in research. It requires the necessary knowledge and labour to process datasets to obtain meaningful and reliable results. Existing datasets imply *definitions* and *decisions*; they reflect local particularities and historical choices that may already shape answers. Major differences in interpretation of shared definitions can already occur within a dataset that at first glance appears consistent and uniform, such as the EuroGlobalMap (EGM) from Eurogeographics, an independent international private organization representing Europe's national mapping, cadastral and land registration authorities. The EGM-dataset of EuroGlobalMap covers 45 countries and territories in the European continent and contains data on administrative boundaries, transport networks, settlements and locations. External partners, such as the National Geographic Institute of Belgium and the German Federal Agency for Cartography and Geodesy, are responsible for supplying relevant data on geographical regions.

The information that national institutions provide is not always consistent because definitions and methods vary. For example, a road of national interest can be classified in England as 'Primary route' and in Italy as 'National Motorway'. Without reading 100-page-long attachments it is difficult for a user to verify the distinction. In addition, the majority of mapping and datasets are still produced and owned by government institutions and large corporations (Dodge et al., 2009). Without understanding the definitions and making any adjustments, this can lead to incorrect assumptions or misunderstandings and, as Monmonier (1996/2014) pointed out, maps lie. But, can we prevent maps from lying? As Monmonier puts it, 'There's no escape from the cartographic paradox: to present a useful and truthful picture, an accurate map must tell white lies' (Monmonier 1996/2014). One may also say that a map is an interpretative device. For a comparative analysis of port cities and to highlight relevant aspects, maps must be selective. Perhaps the biggest challenge in dealing with data is making the right decisions: which elements do we show, how do we define and present them on the map?

Spaces and Scales

Geographers and planners like Ducruet (2017) and Meyer (1999) have questioned the appropriate *scale and space* for the analysis of port-city relationships. The scale of an object of study is important, because any larger size than that of the object supposes a 'larger context'. But any smaller size than that of the smallest detail supposes context as well (De Jong, 2007). Modelling relies on statistics, based on select administrative units, but the scale of these units varies from one place to the other and can shift over time. Mapping thus needs to find ways to acknowledge (and account for) the shifts in administrative boundaries that data sets are based on. Using administrative datasets can also have other shortcomings as administrative borders often don't coincide with actual population patterns or port territories. To avoid incompatibility issues across incomparable administrative definitions, Ducruet adopted in his models a morphological definition of cities (Ducruet 2017). The high level of abstraction inherent in modelling may ignore these shifts, but mapping needs to address them carefully. Furthermore, spatial use (for port or city) is not always clearly identifiable: For example, in the case of historic (port) cities, we often don't have the necessary sources to determine the exact former boundaries or if there even were exact boundaries of a port or city. To (potentially) find this information, we would need highly specialized knowledge, historical research in multiple languages, often using archives that are not easily accessible/digitized etc. Another problem of mapping lies in the fuzziness of use. A waterfront quay has traditionally served multiple functions - as ships' mooring, goods storage, public gathering place. Such multifunctional spaces still exist, notably in areas for people transport-think of the piers in Hamburg and Rotterdam and places where cruise ships moor. Before a cruise ship arrives, the quay is a public place and part of the city; when the ship moors, it

becomes a private area with a port function. Tracing and identifying these non-physical boundaries between city and port or multi-functional zones is a challenge.

Temporalities and Times

Time and *temporality* matter in various ways for geo-spatial mapping. In a data-based historical approach we rely on datasets, but the further back in time the more limited the number of available datasets. The ones that do exist are often not comparable from one place to another in terms of content. Given that historical sources are often incomplete, the quality of the data is uneven and often doesn't permit full understanding or comparison. Translating historical developments into models or maps involves numerous questions about which dates to choose. Maps are not linear in time; they provide a screenshot of a particular moment. As we aim to compare different developments, we find that key transition moments occur at different moments in time. A date that is meaningful in one country may have less relevance for another, making the choice of a date for comparative research particularly difficult.

Selecting time frames already implies interpretation. Ducruet starts his research on port-city relationships in 1890, based on the most essential sources for mapping and analyzing global maritime networks, Lloyd's Shipping Index (as he calls it). He chooses the periods 1890, 1920, 1950, 1980, 2010 - a set of 30-year steps based on historical changes that affected the number of vessel calls and vessel size (Ducruet, 2018). As our research focuses more on the long-term urban development of port cities (from urbanization to present), we opted to start in 1300 and use steps of 200, with more detailed information on the years 1850, 1900, 1950, 1990, 2019 (2020). Selecting particular moments in time has implications. To give just one example: When we skip from 1900 to 1950, the changes in shipping networks due to World War II, the destruction from the bombing and the rebuilding activities are not acknowledged, even though they had a huge impact, particularly on the three ports and cities mentioned here. Additional maps will be needed to analyze such moments. Furthermore, the different temporalities of port and city, the different speeds in which ports function throughout the day, the year and in relation to each other are not visible (Hein, 2016c). Further research through space and time can demonstrate how ideas about port development and urban planning spread among port cities.

Case Study: Comparative geo-spatial mapping of port city regions Rotterdam, Hamburg and London

The next section presents some preliminary notes on decisions that need to be made in the context of geo-spatial mapping. We argue that the choice of a shared body of water - the North Sea - as the foundation for a comparative research program on port city regions allows us to establish and test a shared methodology for historical and spatial analysis (Figure 5). Such an analysis helps us put these cities into a shared context for a historical analysis that is developed from different cultural, historical and disciplinary perspectives. Rotterdam, Hamburg and London emerged as key places to begin. The maps by Ducruet mentioned in Figure 1 confirm the continued importance of these cities as port city hubs. Comparative geo-spatial mapping enriches Ducruet's abstract model as it allows us to provide insights about the relation of city and port, connection to the hinterland and political boundaries based on similar dates in the context of their shared location on the North Sea, their competition for goods, or their shared hinterland.

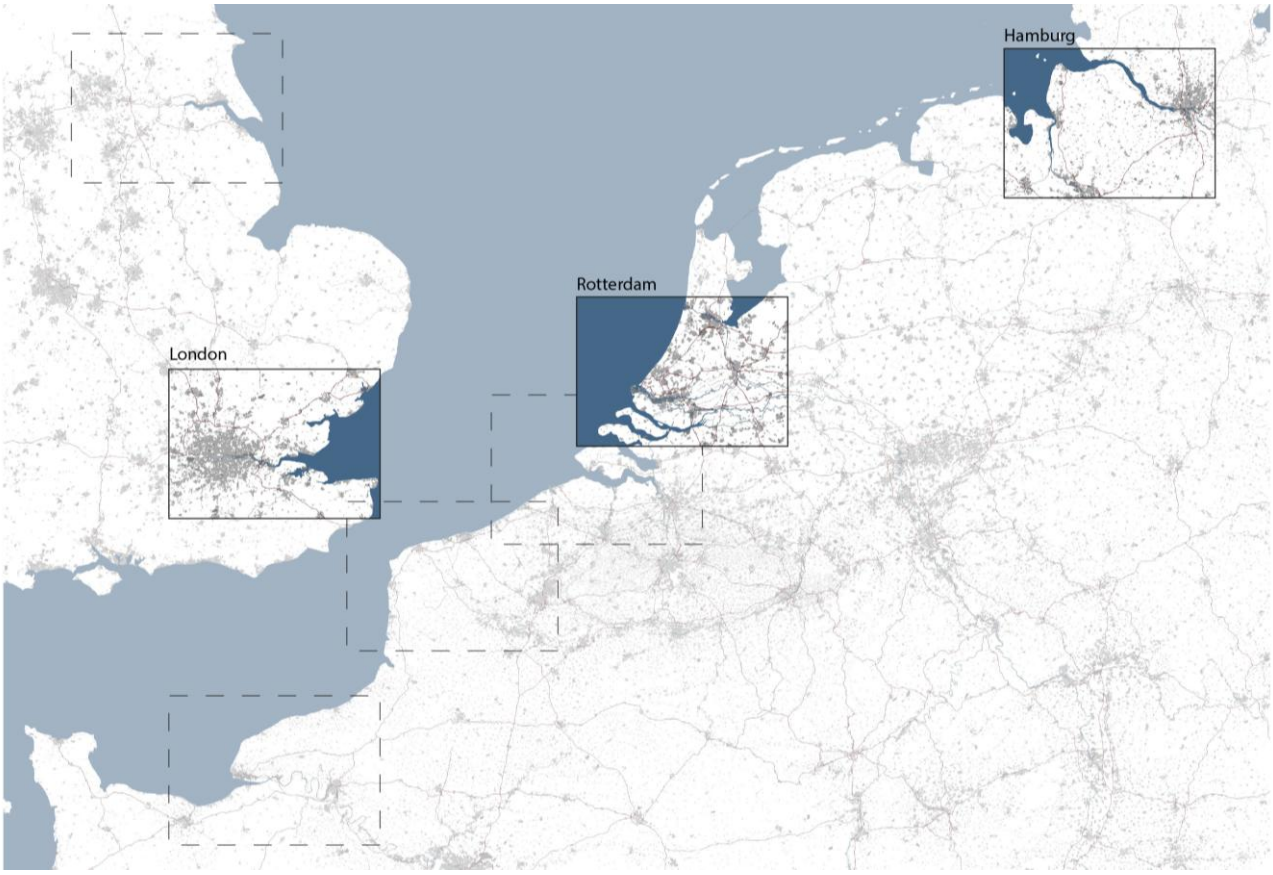

Figure 5. Research area of North Sea studied in the Chair History of Architecture and Urban Planning, with case study of London, Hamburg and Rotterdam highlighted and other potential port city areas framed with a dashed line.

We aim to systematically identify and map the extent of the port city region. To do that, we need to understand the scale at which port cities operate. A first step is defining the scales for maps that capture the relationship between port cities and their respective region. The relationship between the size of a port, the size of the metropolitan area and its location in relation to the hinterland has changed over time. A scale of 1:10.000 captures the interaction of ports and cities in medieval cities, but by 1700 we need a scale of 1:25.000. As a result of technological transformation and transportation infrastructure, the footprint of the port has increased extensively. The individual port cities' response to changes in transport connections, like the arrival trains, trucks and container ships may be different, as Schubert (2011) indicates, but their scalar impact is similar. To capture and compare the temporal and spatial dimension of the port cityscape in the years 1900 and 2019, a much larger scale is required. In the case of Rotterdam, Hamburg and London it is therefore necessary to analyze the port cities at not only on the scale of the city 1:10 thousand or 1:25 thousand, but also on a regional scale at 1:100 thousand and 1:150 thousand. Identifying these scales is important, as it helps us identify the scales at which port city regions function.

To better understand port city region relationships in line with decision-making we opted to *show land use, infrastructure, municipal and port boundaries* (Figure 6). As we focus on port city regions, we limited land use to port areas (black) and to built-up areas (grey) - rather than identifying various urban uses - and we present the morphology in an abstract form. More context and detail does not directly lead to more insights about the relationship between the port, city and the hinterland and would suggest a precision that is not (yet) feasible. Even the distinction between port and city raises questions to representation: Before the industrial revolution, many urban areas served multiple functions and there was no clear distinction between public and private or dedicated port areas with fixed infrastructures. In the maps, we have used small black dots to identify these multifunctional areas.

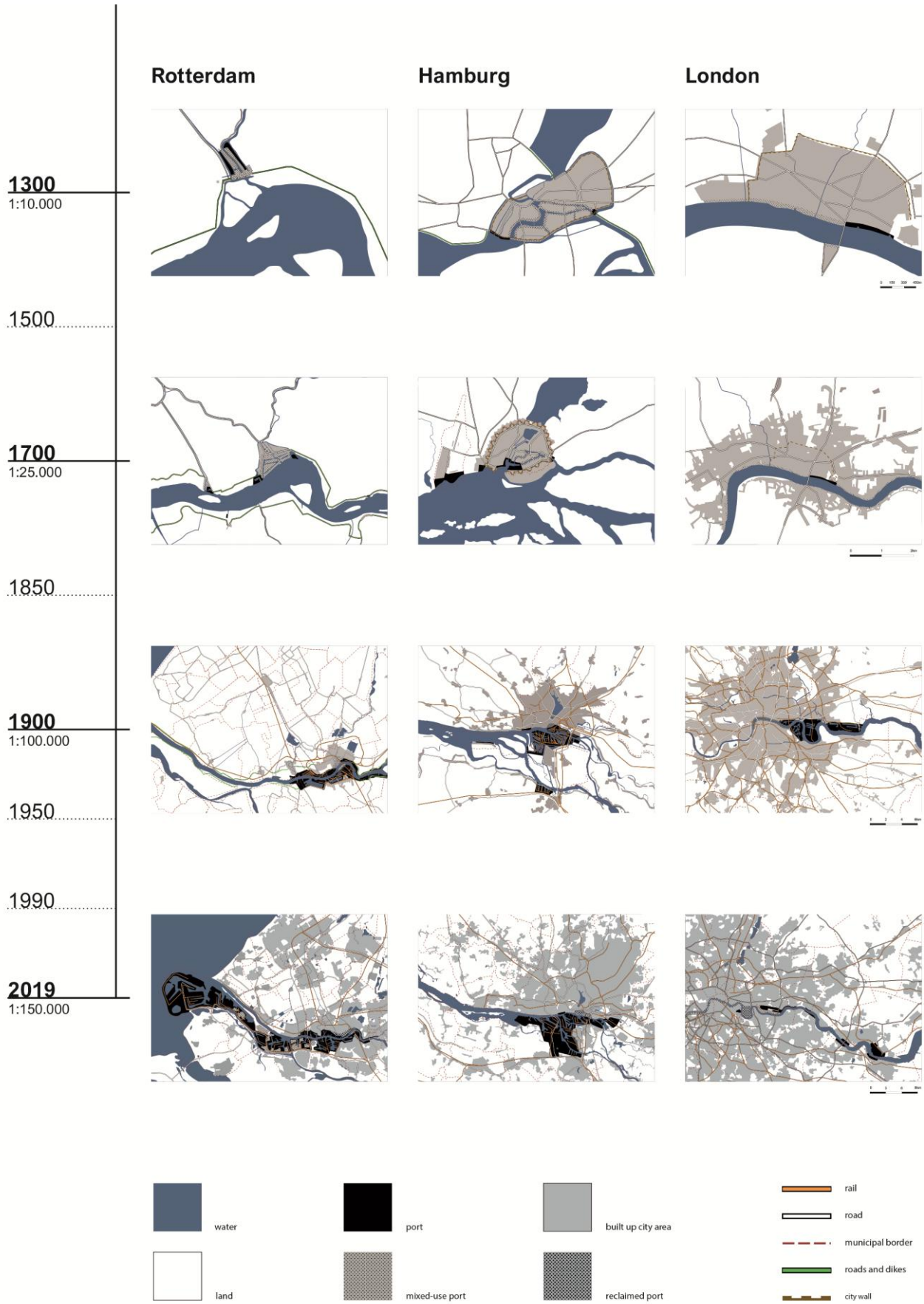

Figure 6. First draft for comparative geo-spatial mapping methodology, with case study of London, Hamburg and Rotterdam. Carola Hein, Yvonne van Mil, Blanka Borbely and Batuhan Özaltun.

The growth of the port in secluded areas and the abandonment of traditional inner port areas led to the transformation of former port areas into urbanized waterfronts. These reclaimed port areas are indicated here with a different pattern of black dots (Figure 6). The second layer is infrastructure: transport systems over water (blue line), land (black lines) and rail (orange line) as well as the dykes (green line) and defense systems (brown). Here we choose to show the infrastructure that is important for the development of the port city region. That includes international and national public structures, but also private roads and the port railway for the transport of cargo in the port area. The government layer is indicated with a dotted red line. Showing political boundaries over time is a challenge because each country uses its own definitions and administrative units. Defining political boundaries over time needs further research. In the case study, we therefore only show the land border between Denmark and Germany in 1300 and 1700 and the municipal borders in 1900 and 2019.

The remaining section focuses on these methodological implications of geo-spatial mapping and the representation of data through the lens of the three cities to see what historical geo-spatial mapping can add to economic modelling-based research in terms of spatial, institutional and cultural development. Details of the history of these three cities can be found in two forthcoming articles (Hein & Schubert and Hein & van de Laar). The maps presented here (Figure 6) should be considered works in progress based on historical maps and current European data sets. They are aimed at exemplifying the challenges and opportunities of mapping port and city space and regional governance at four moments in time: 1300, 1700, 1900, 2019.

Abstractions for 1300, scale 1:10.000

The series of maps from 1300 shows the estuary, the morphology of port and urban areas and the infrastructure. The fledgling cities controlled dykes and dams, intersections between rivers or bridges. In general, the cities developed alongside the river. Urban spaces and buildings were dense and multifunctional. There was no clear distinction between dedicated port areas with fixed infrastructures nor any specific identification of multifunctional spaces. Ports and their neighboring cities around the North Sea were spatially and institutionally closely intertwined. This is particularly the case in Rotterdam and Hamburg, cities built at the intersection of two rivers. They both developed on one bank of a wide estuary. London, where a bridge had been built in Roman times, began to grow on both sides of the estuary in the 1300s. Hamburg was also a well-established city at that time, both as a river-crossing and a port site. At 1300, the urbanization of Rotterdam had only just begun. The city of Rotterdam is therefore many times smaller than the other two, although the port of the tree cities is almost the same size.

Abstractions for 1700, scale 1:25.000

The relation between ports and cities changed around 1700, as shown on the maps. Water access for traditional industries and for trade became a key element for urban development. In Rotterdam and Hamburg, the ports expanded considerably through reclamation and the formation of new port islands in the rivers Maas and Elbe. New settlements grew also on the estuary near the main cities: Delfshaven near Rotterdam and Altona, the Danish port, near Hamburg. Hinterland access was important and smaller villages grew in the vicinity of trade routes. The form and function of urban areas was closely aligned with the needs of their local geographical, political context. Rotterdam provided - with neighboring port cities Delfshaven and Schiedam - access to inland transportation via Delft to Leiden. Hamburg, a city state without its own rural areas, surrounded itself with strong walls and a dense spatial pattern as another port city, Danish Altona, grew just outside its walls. London did not need that kind of protection anymore and extended far beyond the old defenses. After the construction of two new bridges over the Thames in the 18th century, the built-up area spread along the river and into the surrounding countryside. Within the cities, dedicated port areas emerged and grew for multiple reasons including protecting the wares from theft and protecting citizens from accidents. Multifunctional port areas continued to exist, but the use, rules and so forth changed.

Abstractions for 1900, scale 1:100.000

With industrialization and new forms of transport, private actors, port companies and some city governments created dedicated port areas separate from the urban spaces in all three cities. Water access was a privilege largely reserved for trade. Private and public companies created new land into the estuary and made new docklands. Rapid growth of trade, the emergence of petroleum as a fuel, and urbanization required port and city expansion. Extensive landside route and rail infrastructures connected the port to the hinterland. Specific patterns varied, but in every case, port spaces expanded dramatically and started to occupy land in the estuaries. In Rotterdam, the port expanded and smaller port areas become one, together with the port of Schiedam and the 1886 annexed Delfshaven. The ports of Altona and Harburg grew next to Hamburg, and would be integrated into the city state in 1937. In London, the port grew beyond the administrative boundaries of the city. Beginning in the early 19th century, enormous docklands were carved out of the land and facilitated shipping and warehousing. Key decisions concerning the location of the port, the acquisition of land, the technology used for port infrastructure, the development of plans, their implementation and the construction of a port take decades and resulted in long-lasting changes of the landscape, often for centuries. Decisions made at this time have influenced port city regions until today and they continue to determine future development. For example, in order to keep the port within its boundaries, Rotterdam - since 1882 the operator of the port authority - the municipality managed to annex (parts of) almost all municipalities neighboring the estuary. At the end of the 20th century only a few small cities, Schiedam, Vlaardingen and Maassluis, retained their access to the estuary. Port size can be unrelated to the size of the neighboring city as port start serving a larger hinterland, as Ducruet also showed. Accessibility to the hinterland as the rail and road infrastructure in the region is key.

Abstractions for 2019, scale 1:150.000

As the maps show, the scales of decision-making have shifted over time and no single institution can compete with or control the region that depends or is influenced by the port. Maritime activities have been a key driver of urban growth for several centuries. The cities next to the port have also had other incentives for growth. As nodes in a larger urban conglomeration, as regional hubs or capital cities they have hosted many non-maritime activities. Their economic and spatial focus is no longer on the port. Although the city of Rotterdam is primarily a port city, together with Delft (a university city) and The Hague (a residential and government city), it functions as a port city region. While Hamburg retains these functions within the city itself, London's port has largely moved outside of the governance purview of London. The difference in city size makes it clear that the definition of the concept 'city' and interpretation of city boundaries have become vague, as Meyer (1999) indicated. To adjust to contemporary needs, ports have searched for appropriate spaces, leaving the urban areas to cater for historical ports that has become urban heritage. Containerization played an important role in the separation of port and city as less and different work was available in the port. The arrival of larger and often automated port terminals has pushed the industrial ports outwards, away from the city. In Rotterdam, the port authority has consciously built the port towards the sea, creating new boundaries with rural instead of urban areas where fewer citizens are affected. In Hamburg, port and city are still intertwined in the same city-state, but the river itself has become a barrier. In the case of London, private actors moved the port beyond the boundaries of the city where environmental, infrastructural conditions are less restrictive. New multifunctional spaces have emerged, where heritage ports serve urban functions-often non-maritime one such as dwelling and leisure.

Conclusion

Ports have a foreland that is now global and a hinterland that extends often beyond national borders. They are crucial elements of economic flows and shipping movements, they are also physical entities and socio-spatial constructs. Models and maps offer a means to show similarities and patterns in a world of differences. Models provide a more abstract vision, while maps make it

possible to understand the complexity and diversity of port cities within their context. Both representations gain in effectiveness through abstraction and selection, but at the same time they can become less objective. Historical contexts can be difficult to compare. Cultural aspects are not documentable in a way that lends itself to visualization based on widely agreed upon facts and used for comparative purposes. Any attempt to understand the spatial extent of shipping requires an examination of the spatial footprint of the port beyond its legal or administrative boundaries. Additional conversations are needed to theorizing the study of port city regions.

With this project, we are effectively calling for a methodology that can build a bridge between abstract quantitative economic modelling of port city regions and the abstraction of port-city-region relationships. As well as the historical investigation of individual port city regions with their specific local challenges and opportunities that are difficult to compare and often ignored in abstract models. Using the skills of economic geographers as a starting point, trans-disciplinary collaboration can facilitate planning for port city regions without restricting the focus to the port itself. It can provide an opportunity to understand, but also to influence and design. The goal is to identify how ports and cities have evolved spatially in relation to each other and to identify areas that are going to be under pressure due to competing port and city interests. Port cities around the world experience the same type of challenges. A shared methodology - as introduced here for the North Sea region - can help gain better understanding for many other regions with shared waters, including the Mediterranean, the Black Sea or the Gulf of Mexico, and provide a better foundation for decision-makers.

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