Factors influencing Physical Distribution Structure Design

Onstein, A.T.C.

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Amsterdam University of Applied Sciences

Factors influencing Physical Distribution Structure Design

Proefschrift

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door

Alexander Theo Christiaan ONSTEIN
Master of Science in Urban and Regional planning
Universiteit van Amsterdam, Nederland
geboren te Maastricht, Nederland

Dit proefschrift is goedgekeurd door de promotoren:

Samenstelling van de promotiecommissie:

Rector Magnificus	Voorzitter
Prof.dr.ir. L.A. Tavasszy	Technische Universiteit Delft, promotor
Dr. J. Rezaei	Technische Universiteit Delft, copromotor
Dr. D.A. van Damme	Hogeschool van Amsterdam, copromotor

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Voor Romee

Propositions

Factors influencing Physical Distribution Structure Design

Alexander Onstein, 1 December 2021

1. The ranking of main factors influencing Distribution Structure Design is similar for several industry sectors (This thesis).

2. Personal preferences of directors can be a decisive factor for Distribution Structure Design (This thesis).

3. Proximity of a DC to an airport is equally important as proximity to a seaport (This thesis).

4. A researcher has to study three disciplines to understand Distribution Structure Design: Supply Chain Management, Transportation and Geography (This thesis).

5. Given there is insufficient land available in the Netherlands, land availability should be a more important factor in Distribution Structure Design.

6. The Netherlands is a preferred logistics location, even if a company's logistics centre of gravity is located outside the country.

7. In the current logistics real estate market there is little incentive to intensify land use because logistics land rents are low.

8. Physical internet will drastically reduce the number of distribution centres in the Netherlands.

9. Despite their ugliness, distribution centres deserve a place in the Dutch landscape.

10. Proposition writing in the Netherlands goes back to 1575 but should be excluded from thesis defence because it is only a Dutch tradition.

These propositions are regarded as opposable and defendable, and have been approved as such by the promotors Prof. dr. ir. L.A. Tavasszy, Dr. J. Rezaei and Dr. D.A. van Damme.

Preface

My curiosity for distribution centers started when I was studying Urban and Regional Planning in Breda. During my internship I analysed old industrial terrains and obsolete warehouses in the provinces of Gelderland and Overijssel, while my bachelor thesis (HBO) dealt with intensified land use for European Distribution Centres - a topic that was not as relevant back then as it is today.

As a lecturer-researcher at HvA, I had the opportunity to pursue PhD research. After exploring multiple research topics I decided to study the factors that influence DC location selection, which is strongly related to the network of DCs used between production and consumption locations. I am grateful to my employer, the Amsterdam University of Applied Sciences (AUAS), and especially the Smart Mobility & Logistics research group, for giving me the freedom to study my beloved subject. Funded by the NWO - Doctoral grant for teachers I started my (part-time) PhD research in Delft in 2016.

Over the last five years many people have contributed to finish this PhD project. First and foremost, I would like to thank my promotors. Lori, thank you for your valuable feedback and insights, and for challenging me to become a better scholar. You pushed me to do better research and improve my work, but what I treasure most is that you are also a good coach and people person. Thank you for the many meetings and discussions we had. Dick, without your confidence and enthusiasm this project would have never started. Thank you a lot for your supervision, valuable feedback, and for helping me with my PhD challenges. I very much appreciate that you always secured time for me to work on my PhD, which was very important to finish the research. It was and is a great pleasure to work together. Jafar, thank you for your supervision, especially on the third and fourth study. Your brilliant ideas contributed a lot. Thank you also for the nice chats we had on non-PhD related topics. Hans, thank you for being my daily TU supervisor in the first two years.

I would also like to thank many HvA colleagues for their contribution. Abdel, you were in practice my daily HvA supervisor. I will never forget the study trips we made to Dubai, Istanbul,

Paris, Athens, Singapore, Guangzhou, Shanghai and Beijing. You are a fine colleague, friend, and a "walking library" of all kinds of theories. Melika, thank you for all your help throughout the project. Your support in finding a promotor and critical feedback on my research proposal were invaluable. Edith, thank you for the meetings in which we discussed the research challenges and for your support with practical issues. Thank you, Pim, for your practical help and listening ear, and Rover and Nanda, for your encouragement at the start. Walther, a genuine thank you for your feedback on my research and for letting me use your broad network, this really kick-started my data collection! Frank and Robert, thank you for your feedback on my research proposal and for your confidence. Frank, now I will finally finish my booklet!!

There is one TU Master student that I would like to mention in particular; Mehrnaz, without your help the BWM study would have not been possible. I hope to visit you one day. Ishani, thank you for your help on the data for the DC typology. Robbert Janssen, the discussions on research methods really helped me in the first year.

My fellow PhD students at the Amsterdam University of Applied Sciences. Rick ('just keep on going'), we often worked in the same room and discussed a lot of PhD stuff, this made PhD life a lot easier for me. Kasper and Jurjen for being masters in word jokes during lunch. And my TU Delft fellow PhD students Ronald, Ahmad, Baiba, Patrick, Masoud, Lizette, Bing, Lucky, Xiao, Shahrzad and Yashar. Although I was only in Delft one day per week, you made me feel at home. Niek, thank you for your help with the TSTI interview method. Ellen and Betty from the secretary, Patricia from HvA, and Conchita from TRAIL for practical issues.

All HvA Logistics colleagues: Simon, Caroline, Martijn (also for the three-step test interview), Johan and Tom (I will never forget you, nor the great dinners at Hesp), Pascal and Ymke. Lieke thank you for asking about my PhD research, Kees-Willem, Claudine, Maarten, Paul, Fred, and all the others. René and Gerrit thank you for supervising two bachelor thesis students (thank you Nicole and Joey) on the BWM study. Over 20 Logistics student teams (AUAS) participated over the last five years.

My HvA Urban Technology colleagues for their chats, lunch and coffee breaks. Yannick (coffee chats were often hilarious), Simone, Yanti, Marion, Michael, Gideon, Milan, Renee, Bronia and Bas (Overbeek). Susanne, you already helped me while working at TNO. Also thanks to Miguel and Paolo from the Aviation Academy. Christiaan, thank you for the talks on both PhD and non-PhD related topics.

Adeline, nice to work together on the sectoral study (chapter 5), thank you and the French research group for discussions on PhD research at Metrans and in Paris.

I would like to mention René Geujen, Kees Verweij, Bert Angel and Arthur Zondervan for interviews, discussions and guest lectures at HvA. Mieke Damen for introducing me to your extensive network of Fashion companies. EVO and Amsterdam Logistics for advertising my survey on their websites. The studies included in this thesis have gained some media attention. News items have been published on news channels of RTL Z and Radio 1, as well as logistics expert websites.

I am particularly proud that the chapter published in Transport Reviews belongs to the top 10 of the journal's most viewed articles. I am also proud to receive the VLW best paper award for a conference article in 2018 (results included in chapter 5).

To my dear friends Tim and Elmar for supporting me in my PhD journey. Elmar for your help that summer in Amsterdam. Tim I will never forget the motorbike trips in Holland and abroad.

To my family, my brother Ruben and sister Claudia and your families, thank you for listening to me when things got difficult and for your respect as I was often busy with PhD. To my parents, Hans and Christine, you were always there for me. I am very proud of you and hope this will make you proud as well.
Romee, for your unconditional love, kind-heartedness, and trust in my progress as a PhD student. I cannot describe in words how much your support helped me. Thank you for being the most important person in my life.

Sander Onstein
Amsterdam, July 2021

Content

1. Introduction

1.1 Background

Physical distribution includes all activities related to storage and transportation of goods within a supply chain. Physical distribution activities occur between all the stages in the supply chain. Components are transported from suppliers to manufacturers, while finished products are moved from manufacturers to traders, retailers and/or final customers. Physical distribution influences customer service levels and logistics costs (Chopra, 2003; Van Thai and Grewal, 2005). Organizing physical distribution is challenging to companies. At the demand side, there are customers expecting high distribution service levels, i.e. fast delivery times (for example, next day or even same day deliveries), flexible delivery locations (at home, at work, or at public transport locations) and multiple distribution options, i.e. online or offline (Agatz et al., 2008; Christopher, 2011). Products need to be delivered at the right location, at the right time, in the right condition. At the supply side, globalisation and supply chain fragmentation (i.e. more stages in the supply chain) are factors that complicate physical distribution processes. Globalisation of production has created large transport distances between production and consumption locations, while supply chain fragmentation has increased the number of nodes in which transport problems may occur (Rodrigue, 2006).

In order to fulfil high distribution service levels, while maintaining or reducing logistics costs, companies must select a fitting *Distribution Structure Design (DSD)*. Distribution structure design includes the spatial layout of the distribution channel - i.e. the freight transport and storage system between production and consumption – as well as the location(s) of logistics facilities, i.e. warehouses and distribution centres (DCs) (Christopher, 2011; Chopra and Meindl, 2013).
Different distribution channel layouts or combinations of layouts may be used by companies to serve their customers. Figure 1.1 presents some typical distribution channel layouts and Box 1. provides explanations on these layouts. Companies can use different types of logistics nodes in their distribution structures, e.g. manufacturing facilities, freight terminals, storage facilities, distribution facilities, or parcel facilities (Rodrigue, Comtois and Slack, 2017).

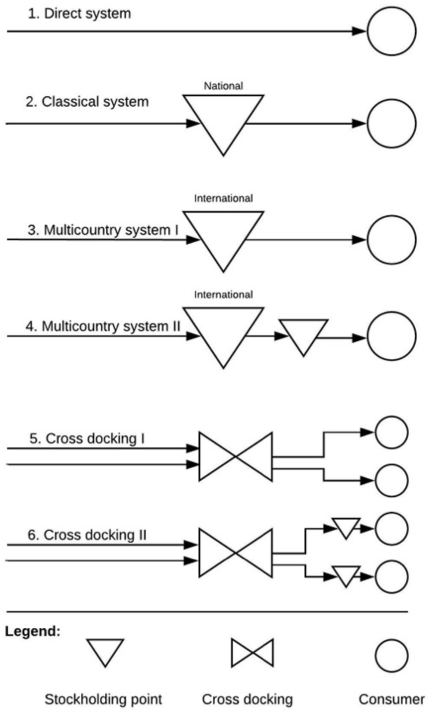


Figure 1.1 Distribution channel layouts (adapted from Kuipers and Eenhuizen (2004))

Box 1. Centralised and Decentralised distribution channel layouts

Firms that sell high value, low demand products, such as operation room devices, often use a centralised distribution channel layout (Layout 1, 2 and 3, Figure 1.1) because inventory costs make up a large share of the total logistics costs. Centralised layouts use single storage location or no storage locations at all, often in combination with fast transport modes for highly responsive distribution. The location of a single distribution centre serving the whole customer target market can be expected to be located in the companies' customer centre of gravity, because this location minimises transport costs. Dell (PC manufacturer), for example, applied a direct channel layout (Layout 1, Figure 1.1) between manufacturing locations and the final customer to save high inventory costs, but later started selling PCs through retailers to reduce delivery times (Chopra, 2003; Chopra and Meindl, 2013). Many consumer electronics and fashion companies, e.g. Timberland, Michael Kors, Tommy Hilfiger (PVH), use a single distribution centre in The Netherlands to supply their European customers.

Firms that sell low value, high demand products such as office supplies often use a decentralised distribution channel layout (Layout 4 and 6, Figure 1.1) because transport costs make up a significant share of the total logistics costs. This may be combined with low-cost transport modes (sea, rail) to further reduce transport costs (Chopra and Meindl, 2013). Decentralised layouts include multiple storage locations. Decentralized layout 4 in Figure 1.1, for example, could include a central DC located in the Netherlands combined with regional distribution centres in other European countries. Online retailer Amazon currently implements a decentralised distribution channel layout consisting of 1,300 local distribution hubs to serve European customers (EcommerceNews, 2017) - especially in 2020 there was a huge implementation of Amazon hubs. Fashion company Zara (Inditex) decentralised its distribution structure by adding a DC in the Netherlands to serve their Northwest-European customers.

This thesis studies companies' distribution structure design (DSD) from the manufacturing part of the supply chain up to the customer (B2B, B2C), including storage and distribution facilities. The focus of the thesis is on the factors that determine distribution structure design. Note that this thesis studies DSD as a single, composite decision. The thesis does not study the influencing factors at the level of sub-issues such as decisions on the number or size of warehouses in DSD, inventory allocation, or the layout (storage, routing) of individual warehouses. Typical factors that influence DSD are the expected service levels and various drivers of logistics costs (McKinnon, 1984; Chopra, 2003; Sheffi, 2012). Despite the frequent treatment of DSD in supply chain handbooks (e.g. Christopher, 2011; Chopra and Meindl, 2013), it is surprising that there has been little systematic and descriptive research into the factors that influence DSD. Most studies are prescriptive in nature, i.e. they calculate and prescribe an optimal design (with lowest logistics costs given the required customer service level) for a company by using a set of factors from literature. However, descriptive research into these factors is lacking (Mangiaracina et al., 2015) and it is unknown whether the appropriate factors are used in DSD calculations. In conclusion, an empirically validated conceptual framework of these influencing factors is missing (Olhager et al., 2015; Heitz and Beziat, 2016). We aim to fill this gap.

In our empirical studies, we choose to focus on firms who have a presence with one or more DCs in the Netherlands (note that the role of investors in DSD is outside our research focus). The Netherlands is a particularly interesting case for our study since it is a major logistics node and gateway for goods transport into Europe. Around 30% of goods volume imported into the European Union enters via the Netherlands (Holland International Distribution Council, 2018). The country is an attractive place to locate logistics facilities (Figure 1.2).

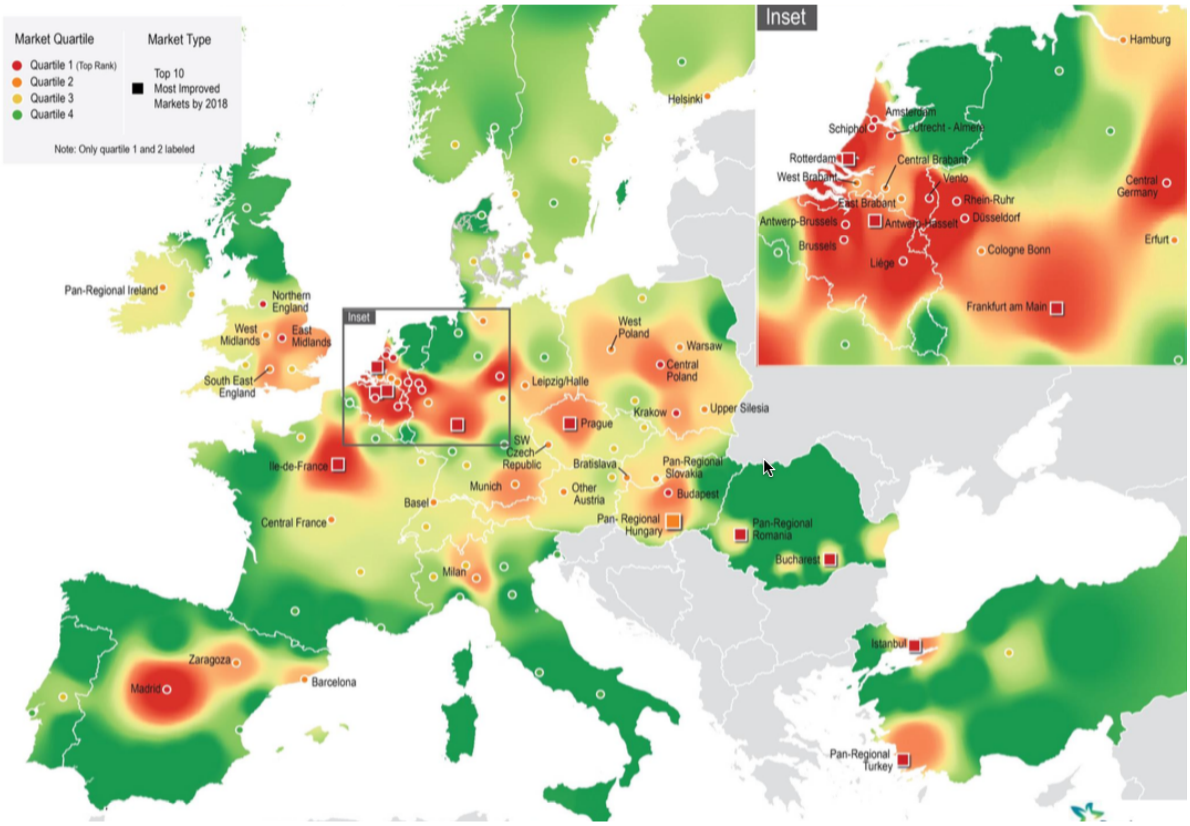


Figure 1.2 Attractive regions in Europe to locate logistics facilities (Prologis, 2017)

Between 2015 and 2020 logistics floorspace increased from 29 million m^2 to 41 million m^2, which is a growth of 41% in five years. In 2018, there was the strongest growth in logistics floorspace of 10.6% (3 million m^2) compared to 2017. The Netherlands currently hosts around 41 million m^2 of logistics floorspace (NVM, 2021).

1.2 Research objective and questions

The main objective of this thesis is:

To identify the factors that determine companies' decisions on Distribution Structure Design (DSD).

To reach this objective, this thesis investigates the following research questions (RQs):

RQ 1: How can we characterize different types of DCs?

In order to answer this research question we aim to provide a background picture of the types of logistics facilities that can be observed in practice. A wide variety of distribution center facilities has emerged within supply chains to distribute products between production and consumption locations. Scholars and practitioners use diverse terms to denote these facilities (e.g. distribution centre, hub, fulfilment center), but a typology is lacking (Higgins et al., 2012; Notteboom et al., 2017). Previous work proposes typologies based either on size or on functionality of the DC, while our contribution to the literature is a novel typology based on both characteristics that is supported by real-world data of DC facilities. A typology based on size is needed in the recent discussion on the visual intrusion of logistics facilities (CRa, 2019), it is an important characteristic to discuss which types (small or large) cause visual intrusion.

In research questions 2 – 4 we investigate three aspects related to the main research goal, i.e. we review the important factors from literature, measure their importance, and investigate whether factor importance differs between industry sectors.

RQ 2: What are, according to the academic literature, important factors influencing companies' distribution structure design (DSD)?

Here, we aim to review state-of-the-art literature on the important factors influencing DSD and to arrive at a set of factors. There is a lack of descriptive research on the factors that influence DSD and the literature is scattered across multiple research streams. This literature needs to be brought together and analysed systematically, to create a consistent and comprehensive framework of factors. We synthesise the main characteristics, strengths and limitations of the relevant research streams and propose a high-level framework.

RQ 3: What is the importance of factors that determine companies' distribution structure design (DSD)?

The importance of factors influencing DSD has not yet been studied. Empirical research is needed to measure the factor weights. To empirically study the importance of factors, it is required to study decision-makers that are - or were recently - actively involved in DSD. Several methods, such as discrete choice models or multicriteria decision-making models (MCDM), can be used to calculate factor weights. The method used must be suited to consistently study a large set of 33 influencing factors. Best-Worst Method (Rezaei, 2015) is a relatively new MCDM method that is suitable for this purpose. The factors are based on the literature review (RQ 2).

RQ 4: What are the differences between industry sectors in terms of factors influencing distribution structure design (DSD)?
The literature lacks an empirically validated conceptual framework of the factors that drive DSD. Besides producing a general framework, we would like to understand how factors might differ between industry sectors. Studying sectors that sell products of diverse characteristics is needed to understand possible differences in distribution structure design. Sectoral results considering factor importance are stronger if they are confirmed by multiple respondent groups. Therefore, two groups, i.e. experts versus decision-makers, from three industry sectors are studied.

1.3 Research Approach

This subsection describes the approach and structure of the thesis in more detail. Figure 1.3 shows an overview of the research approach including the literature that is reviewed, data that is collected and research methods used.

To answer *research question 1*, a typology of distribution centre facilities is developed, which provides the reader with a background picture of the range of DC facilities in the Netherlands. Although distribution centres are rapidly increasing in size and number, there is little literature that combines size with sectoral and functional characteristics to identify patterns and propose a new typology. Multiple criteria extracted from scientific literature are used to develop the typology, i.e. including activity type (e.g. storage, warehousing), product type, product range and distribution speed, network structure, and market service area. It is an exploratory research that analyses DCs in the Netherlands to develop a typology. The Netherlands hosts many types of DC facilities, it is a popular country to locate logistics facilities (Figure 1.2). An extensive database including 2,888 unique DC facilities is used as input to analyse types that occur frequently. This resulted in a typology including eight types, ranging from parcel lockers to global agricultural auctions. Additionally, the types are categorised based on size from XXS to XXL, which can support the societal discussion on which type DCs cause visual intrusion.

For *research question 2* the relevant literature on factors driving DSD is reviewed. The literature review allows to identify main factors and sub factors. An overview of the relevant research streams is presented including their main characteristics, research methods, strengths and limitations. Together these research streams provide a rich picture of the factors that influence distribution structure design. The importance of some factors, for example logistics costs and service level, has been known for a long time (e.g. McKinnon, 1984), but it is the combination of many factors that influences companies to apply a centralised or decentralised distribution channel layout and select logistics facility locations. Based on the factors, an initial conceptual framework is developed; this framework is detailed out and validated later with the studies related to research questions 3 and 4.

Research question 3 relates to the importance of factors that have been identified from the literature review (see research question 2). We study the importance of the factors by surveying two groups of respondents. Based on the survey data we calculate the importance of the factors, i.e. the factor weights. Multiple methods can be used to calculate factor weights such as discrete choice modelling, factor analysis, or multicriteria decision-making (MCDM) models. We use a novel MCDM method, i.e. Best-Worst Method (Rezaei, 2015), because we aim to consistently measure the importance of many (i.e. 33) factors. Discrete choice modelling is less appropriate as respondents cannot choose from alternatives that include 33 factors. The data for this study are collected from two populations – decision-makers on DSD and experts - using an online survey.

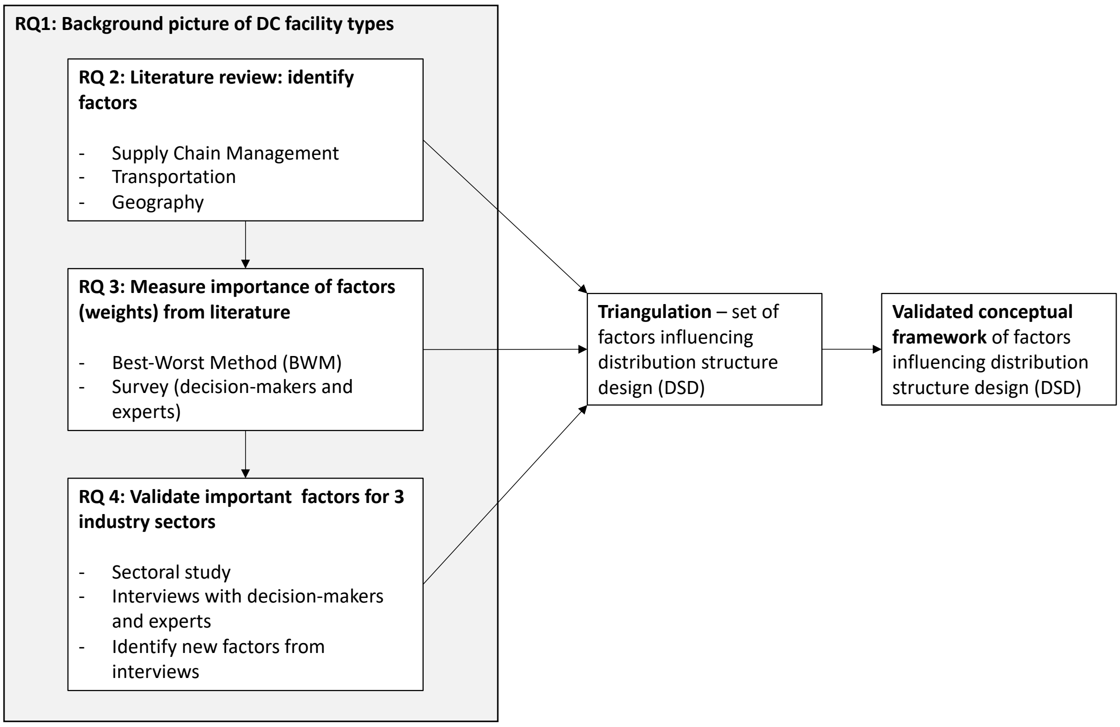


Figure 1.3 Research approach

Research question 4 is answered by conducting case study based empirical research into the factors that drive distribution structure design in three industry sectors – Fashion, Consumer electronics, and Online retail. Based on the sectoral results a detailed conceptual framework is developed. The framework is empirically validated by interviews with decision-makers on DSD - affiliated to shippers and Logistics Service Providers (LSPs) - and logistics experts. This study uses the important factors from the studies of research question 2 and 3 as input for the case interviews. Triangulation is established as we used multiple research methods to collect data on DSD. The empirical data for research questions 1 and 4 are collected in the Netherlands, i.e. the typology involves Dutch DCs and the interviewed decision-makers are affiliated to companies that have distribution structures organised via the Netherlands.

1.4 Relevance

1.4.1 Scientific relevance

The scientific contribution of this thesis rests on five pillars.

First, a broad range of logistics facilities has emerged to supply customers, ranging from small parcel lockers to mega distribution centres. Scholars use diverse terms to denote these facilities – e.g. city hub, freight hub, logistics depot, or fulfilment centre – but a typology is lacking in the literature (Higgins et al., 2012; Notteboom et al., 2017). Previous work proposes typologies based either on size or on functionality, but a typology based on both characteristics that is supported by empirical data is lacking. This thesis contributes to the literature by exploring a large empirical dataset of DC facilities in the Netherlands and proposing a typology based on size and other functional characteristics of these facilities. The typology can support public policy makers to develop spatial policies for each type.

Second, despite the frequent discussion of DSD factors in supply chain handbooks (e.g. Christopher, 2011; Chopra and Meindl, 2013) and academic papers (reviewed by Mangiaracina et al., 2015), there is little descriptive research into the factors that influence DSD (Mangiaracina et al., 2015; Heitz and Beziat, 2016; Onstein et al., 2019a and 2019b). Chopra (2003), for example, explains many factors - e.g. logistics costs factors, service level factors, product characteristics – and trade-offs between factors, but a systematic empirical analyses of influencing factors is lacking in the literature. The main contribution of this thesis is that it identifies the factors influencing DSD design. Our results show that many factors have been widely discussed already (e.g. logistics costs factors, service level, product characteristics) - but there are also new factors that are seldom mentioned. These could be included in SCM textbooks as they can be important in particular industries (e.g. factors such as personal preferences are found to also play a role in DSD).

As a third contribution, this thesis measures the weights of the factors that are of general importance to companies from diverse industry sectors. Calculating factor weights has not yet been performed for DSD. This thesis is the first contribution that calculates these weights for two groups of respondents, i.e. experts and decision-makers on DSD.

Fourth, most work on DSD includes quantitative research that models optimal distribution structure design - Reese (2006), Mangiaracina et al. (2015) and Olhager et al. (2015) provide valuable literature reviews. These studies prescribe a company's optimal DSD - i.e. with lowest logistics costs given a desired customer service level – but do not consider which factors should be modelled in diverse industry settings (Mangiaracina et al., 2015; Onstein et al., 2019a). Previous work focuses on a single industry sector or single company, while this thesis compares the importance of factors for multiple industry sectors. For example, one of the first studies by Geoffrion and Graves (1974) models optimal distribution centre locations for a food company. Other examples of previous work include the case of a telecom company (Ashayeri and Rongen, 1997), automotive company (Nozick and Turnquist, 2001), global electronics company (Lovell et al., 2005) and DIY company (Pedersen et al., 2012). McKinnon (1984) studied 29 food manufacturers in the UK but does not compare food companies with other industry sectors. A contribution of this thesis is that knowledge on the important factors in three studied industry sectors can support scholars to build quantitative DC location models for companies from these sectors.

In sum, an empirically validated conceptual framework of factors influencing DSD is missing. To the best of our knowledge, there are only two studies that have developed relevant conceptual frameworks, i.e. Lovell et al. (2005) and Song and Sun (2017), but their focus differs from our research. Lovell et al. (2005) investigate the factors that influence supply chain segmentation, while Song and Sun (2017) focus on supply chain decisions including not only distribution locations, but also sourcing and production locations. More descriptive literature exists on the part of DSD that includes DC location selection. Notable examples are Warffemius (2007), McKinnon (2009), Dablanc and Ross (2012), Klauenberg et al. (2016), and Verhetsel et al. (2018). However, none of these studies includes conceptual frameworks of factors influencing DC locations in diverse industry settings (Heitz and Beziat, 2016; Onstein et al., 2019a). We study the important factors in three industry sectors, i.e. Fashion, Consumer electronics and Online retail, and propose an empirically validated conceptual framework of the influencing factors. It is - to the best of our knowledge - the first PhD thesis since Warffemius (2007) that studies DSD in the Netherlands, although the scope of our research is somewhat different – i.e. Warffemius (2007) studied the localisation of distribution centres surrounding Amsterdam Airport Schiphol (AAS), while the geographical focus of this thesis includes the whole country of the Netherlands.

Finally, a topic that has recently received a lot of attention from scholars and spatial planners is logistics sprawl, i.e. the spatial deconcentration of logistics facilities (Dablanc and Ross, 2012; Klauenberg et al., 2016; Heitz et al., 2018; Kang, 2020). Research into the factors that cause sprawl is often lacking or mentioned on the side (Heitz and Beziat, 2016). Although this thesis does not investigate the factors that cause sprawl, it does study DC location factors and these factors might help to explain why companies increasingly select peripheral DC locations.

1.4.2 Societal relevance

The societal relevance of the thesis is explained in this section.

First, designing distribution structures is a complex issue in which many factors play a role (Chopra and Meindl, 2013). According to interviews with companies, experts and logistics consultants, many companies lack an overview of the relevant factors or elements that are important in distribution structure design. This thesis can support companies to select their optimal distribution structure design by indicating the important factors for three industry sectors. Companies from these sectors can use the factors that are important to them (Chapter 5). Apart from these three industry sectors, this thesis also investigates which factors are of general importance to all companies when designing their DSD – i.e. in Chapter 4 we calculated main factors as well as subfactors weights. Logistics consultants can use the factor weights (Chapter 4) and sectoral results (Chapter 5) in future DSD advice.

Second, public policy makers and land use planners affiliated to government departments (municipalities, provinces) generally lack knowledge of companies' preferences for DC locations and industrial land – as was confirmed by the sectoral company interviews. Government officials are also in need for arguments to attract distribution centres. They can now use the important factors from each sectoral case to plan industrial terrains that will attract companies from one or more of the researched sectors.
At the national level there is a public debate on the visual intrusion of DC facilities (CRa, 2019). Growing demand of online orders (Aljohani and Thompson, 2016; Heitz et al., 2018) will increase the construction of large DC facilities within the coming years. Knowledge of the factors that drive DSD can help policy makers understand where to expect construction of large-

scale facilities and thus where visual intrusion may appear. Results of this thesis are used by the Dutch ‘College of National Advisors’ (CRa, 2019) as input for their advice to the House of Representatives to mitigate the visual intrusion caused by distribution centres.

Third, infrastructure policy makers need to decide what are the most needed infrastructure investments. This thesis provides knowledge of what companies consider important in DSD. Infrastructure policy makers may use this knowledge to build better models to predict future construction of DC facilities and also to predict where new infrastructure investments are needed for freight transport (Tavasszy, 2020).

1.5 Outline of the thesis

The chapters of this thesis follow the research steps introduced above. The chapters are based on journal papers, which all have been published. The text of the chapters is identical to these articles - however, in chapter 2 we added few logistics terms and in chapter 3 we added explanation of underlying mechanism of inventory centralisation. The author of this thesis has been in the lead for the research and is also lead author. Table 1.1 shows an overview of the papers concerned.

Table 1.1 Publication status

	Publication status
Chapter 2	Onstein, A.T.C., Bharadwaj, I., Tavasszy, L.A., van Damme, D.A., and el Makhloufi, A. (2021). From XXS to XXL: Towards a typology of distribution centre facilities, *Journal of Transport Geography*, Vol. 94 (June 2021).
Chapter 3	Onstein, A.T.C., Tavasszy, L.A., and van Damme, D.A. (2019). Factors determining distribution structure decisions in logistics: a literature review and research agenda, *Transport Reviews*, Vol. 39 No. 2, pp. 243-260.
Chapter 4	Onstein, A.T.C., Ektesaby, M., Rezaei, J., Tavasszy, L.A. and van Damme, D.A. (2020). Importance of factors driving firms’ decisions on spatial distribution structures, *International Journal of Logistics Research and Applications*, Vol. 23 No. 1, pp. 24-43. DOI: 10.1080/13675567.2019.1574729.
Chapter 5	Onstein, A.T.C., Tavasszy, L.A., Rezaei, J., van Damme, D.A., and Heitz, A. (2020). A sectoral perspective on distribution structure design. *International Journal of Logistics Research and Applications*, 1-29. DOI: 10.1080/13675567.2020.1849074.

References

Agatz, N.A.H., Fleischmann, M., and van Nunen, J.A.E.E. (2008). E-fulfilment and multi-channel distribution – A review, *European Journal of Operational Research*, Vol. 187 No. 2, pp. 339-356.

Aljohani, K., and Thompson, R.G. (2016). Impacts of logistics sprawl on the urban environment and logistics: Taxonomy and review of literature, *Journal of Transport Geography*, Vol. 57, pp. 255-263.

Ashayeri, J., and Rongen, J.M.J. (1997). Central Distribution in Europe: A Multi-Criteria Approach to Location Selection, *The International Journal of Logistics Management*, Vol. 8 No. 1, pp. 97-109.

Bak, R. (2019). *Logistiek vastgoed in cijfers 2018 [Logistics real estate data 2018]*. Nieuwegein: NVM Business.

Chopra, S. (2003). Designing the Distribution Network in a Supply Chain, *Transportation Research Part E*, Vol. 39 No. 2, pp. 123-140.

Chopra, S. and Meindl, P. (2013). *Supply Chain Management. Strategy, Planning, and Operation*. Fifth Edition. Harlow: Pierson Education Limited.

Christopher, M. (2011). *Logistics and Supply Chain Management (4th Edition)*. Harlow, UK: Pierson Education Limited, 2011.

CRa (2019). (X)XL-verdozing. Minder, compacter, geconcentreerder, multifunctioneler. *College van Rijksadviseurs (CRa)*. The Hague, October 2019.

Dablanc, L. and Ross, C. (2012). Atlanta: a mega logistics center in the Piedmont Atlantic Megaregion (PAM), *Journal of Transport Geography*, Vol. 24 (2012), pp. 432-442.

Davydenko, I.Y. (2015). *Logistics Chains in Freight Transport Modelling*. Doctoral dissertation. Delft: Delft University of Technology.

EcommerceNews. (2017). Amazon is looking for 1,300 warehouses across Europe. https://ecommercenews.eu/amazon-looking-1300-warehouses-across-europe/.

Geoffrion, A.M., and Graves, G.W. (1974). Multicommodity distribution system design by benders decomposition, *Management Science*, Vol. 20 No. 5, pp. 822-844.

Hall, P.V. and Jacobs, W. (2012). Why are maritime ports (still) urban, and why should policy makers care? *Maritime Policy & Management*, Vol. 39 No. 2, pp. 189–206.

Heitz, A., and Beziat, A. (2016). The parcel industry in the spatial organization of logistics activities in the Paris Region: inherited spatial patterns and innovations in urban logistics systems, *Transportation Research Procedia*, Vol. 12 (2016), pp. 812-824.

Heitz, A., Dablanc, L., Olsson, J., Sanchez-Diaz, I., and Woxenius, J. (2018). Spatial patterns of logistics facilities in Gothenburg, Sweden. *Journal of Transport Geography* (2018), Available online, https://doi.org/10.1016/j.jtrangeo.2018.03.005.

Higgins, C.D., Ferguson, M., and Kanaroglou, P.S. (2012). Varieties of logistics centres: Developing a standardized typology and hierarchy. *Transportation Research Record*, Vol. 2288 No. 1, pp. 9-18.

Holland International Distribution Council (2018). *Dutch Logistics Sector. Holland is a key logistics hub that connects global markets*. Zoetermeer: HIDC.

Kang, S. (2020). Relative logistics sprawl: Measuring changes in the relative distribution from warehouses to logistics businesses and the general population, *Transport Geography*, Vol. 83 (2020).

Klauenberg, J., Elsner, L.-A., and Knischewski, C. (2016). Dynamics in the spatial distribution of hubs in groupage networks - the case of Berlin. Paper presented at World Conference on Transport Research (WCTR), Shanghai, July 10-15, 2016.

Lovell, A., Saw, R., and Stimson, J. (2005). Product value-density: managing diversity through supply chain segmentation, *The International Journal of Logistics Management*, Vol. 16 No. 1, pp. 142-158.

Mangiaracina, R., Song, G. and Perego, A. (2015). Distribution network design: a literature review and a research agenda, *International Journal of Physical Distribution & Logistics Management*, Vol. 45 No. 5, pp. 506-531.

McKinnon, A.C. (1984). *The spatial organization of physical distribution in the food industry*. Doctoral dissertation. London: University College London.

McKinnon, A.C. (2009). The present and future land requirements of logistical activities, *Land Use Policy*, Vol. 26, pp. S293–S301.

North, D.C. (1990). *Institutions, institutional change and economic performance*. Cambridge, UK: Cambridge University Press.

Notteboom, T., Parola, F., Satta, G., and Risitano, M. (2017). A taxonomy of logistics centres: overcoming conceptual ambiguity. *Transport Reviews*, Vol. 37 No. 3, pp. 276-299.

Nozick, L.K. and Turnquist, M.A. (2001). Inventory, transportation, service quality and the location of distribution centers, *European Journal of Operational Research*, Vol. 129 No. 2, pp. 362-371.

NVM (2021). Logistiek vastgoed in cijfers 2021. Retrieved from: https://www.nvm.nl/media/qkvlr155/logistiek-vastgoed-in-cijfers-2021.pdf. Accessed: 17 August 2021.

Olhager, J., Pashaei, S. and Sternberg, H. (2015). Design of global production and distribution networks: A literature review and research agenda, *International Journal of Physical Distribution & Logistics Management*, Vol. 45 No. 1/2, pp. 138-158.

Onstein, A.T.C., Tavasszy, L.A., and van Damme, D.A. (2019a). Factors determining distribution structure decisions in logistics: a literature review and research agenda, *Transport Reviews*, Vol. 39 No. 2, pp. 243-260.

Onstein, A.T.C., Ektesaby, M., Rezaei, J., Tavasszy, L.A. and van Damme, D.A. (2019b). Importance of factors driving firms' decisions on spatial distribution structures, *International Journal of Logistics: Research and Applications*, DOI: 10.1080/13675567.2019.1574729.

Pedersen, S.G., Zachariassen, F., and Arlbjørn, J.S. (2012). Centralisation vs de-centralisation of warehousing, *Journal of Small Business and Enterprise Development*, Vol. 19 No. 2, pp. 352-369.

Prologis (2017). Customer Growth Strategies: Europe's Most Desirable Logistics Locations. Retrieved from: https://www.prologis.com/logistics-industry-research/customer-growth-strategies-europes-most-desirable-logistics-locations. Accessed: 11 January 2021.

Reese, J. (2006). Solution methods for the p-median problem: An annotated bibliography. *Networks*, Vol. 48 No. 3, pp. 125–142.

Rezaei, J. (2015). Best-Worst Multi-Criteria Decision-Making Method, *Omega*, 53 (2015), pp. 49-57.

Rodrigue, J.-P. (2006). Transportation and the geographical and functional integration of global production networks, *Growth and Change*, Vol. 37 No. 4, pp. 510-525.

Rodrigue, J.-P., Comtois, C. and Slack, B. (2017). *The Geography of Transport Systems*. Fourth edition. Routledge, New York, USA.

Sheffi, Y. (2012). *Logistics clusters. Delivering value and driving growth*. The MIT Press, Cambridge, Massachusetts.

Tavasszy, L.A. (2020). Predicting the effects of logistics innovations on freight systems: Directions for research. *Transport Policy*, Vol. 86 (February 2020), pp. A1-A6.

Verhetsel, A., Kessels, R., Goos, P., Zijlstra, T., Blomme, N., and Cant, J. (2015). Location of logistics companies: a stated preference study to disentangle the impact of accessibility, *Journal of Transport Geography*, Vol. 42 (2015), pp. 110-121.

Warffemius, P.M.J. (2007). Modeling the Clustering of Distribution Centers around Amsterdam Airport Schiphol: location endowments, economies of agglomeration, locked- in logistics and policy implications. PhD diss., Erasmus University Rotterdam, The Netherlands.

2 From XXS to XXL: Towards a typology of distribution centre facilities

Onstein, A.T.C., Bharadwaj, I., Tavasszy, L.A., van Damme, D.A., and el Makhloufi, A. (2021). From XXS to XXL: Towards a typology of distribution centre facilities. Journal of Transport Geography, Vol. 94 (June 2021).

Abstract
Distribution centres are becoming more and more relevant for spatial planning, due to their rapidly increasing size and number. There is little literature, however, that provides a generalized analysis of the size and functional attributes of distribution centres, and none that discusses the relationships between these attributes. Our aim is to fill this gap by providing new evidence and analysis to understand this relationship. We make use of an extensive database of 2,888 DCs in the Netherlands to develop a new typology of DCs based on the geographical location of DCs, their functional attributes and client sector characteristics. The analysis shows that the context in which medium sized DCs are operating is more heterogeneous than in the case of very large and small size DCs. This study is a first attempt to analyse this relationship between facility size and functions based on a rich and extensive dataset of large population of DCs. The results can serve as input for further quantitative statistical analysis and international comparison.

2.1 Introduction

In the context of increasing globalisation of production networks, the increased complexity of supply chains and change in consumer behaviour, a broad range of logistics facilities has emerged during the past decades to support the distribution of products from producers to consumers. These facilities serve to consolidate and deconsolidate goods flows. Their size varies from small parcel lockers and city hubs to mega distribution centres.

Different terms are used in the literature to denote logistics facilities, e.g. distribution centre, warehouse, freight hub, e-fulfilment centre, logistics depot, or city hub. A standard typology for these, however, is lacking (Higgins et al., 2012; Notteboom et al., 2017). Our aim with this paper is to make a step towards such a typology, based on size and functional characteristics, where types are collectively exhaustive and mutually exclusive. We base the typology on the literature about logistics facilities and a large database about such facilities in the Netherlands. A typology can be helpful to support communication and debate between scholars and practitioners, as there is a great heterogeneity of logistics facilities that can be observed in the field – e.g. wholesale facilities, retail facilities, or logistics service provider facilities (Heitz et al., 2019). A typology is also a necessary starting point to study specific logistics facility types (ibid) – for example, research on logistics sprawl (Cidell, 2010; Heitz et al., 2020) could differentiate between small and large facility types. As such, the typology can support scholars to differentiate between types when studying their impact on urban areas in terms of land use, freight traffic, emissions, and employment. The proposed typology is based on size and other functional characteristics (such as activity type), as these characteristics influence the impact (of a facility) on the urban area. Currently, there is a dearth of knowledge on the impact of logistics facilities at the metropolitan level (Kang, 2020; Sakai et al., 2019). Spatial planners could use the characteristics of each type to discuss what are suitable locations for different facility types and accordingly design spatial plans.

Our approach has been to study the characteristics of various DCs present in a large database of DC real estate in the Netherlands. The database used contains information about both size and function of the DC, which allows us to study these characteristics together and leads to the combined typology. We derived a general framework of relevant functional characteristics based on the scientific literature. Next, we arrive at a typology which is based on size and function.

The remainder of this paper is organised as follows. Section 2.2 reviews the literature on previous typologies and provides perspectives on the impact of logistics facilities on urban areas. Section 2.3 explains the research method and database used, while Section 2.4 describes the population of DCs in the Netherlands. Section 2.5 includes the framework of criteria of the typology. Section 2.6 presents the typology and discusses the results, and Section 2.7 includes conclusions and recommendations for research and practice.

2.2 Literature review

2.2.1 Impacts of logistics facilities on urban areas

Over the last decade there is increased research on how logistics facilities impact urban areas in terms of land use, employment, and negative externalities such as freight traffic, emissions, and congestion (Kang, 2020; Sakai et al., 2017; Sakai et al., 2019). There is, however, still a lack of knowledge on the impact of logistics locations at the metropolitan level.

Most research in this area studies the impact of logistics sprawl, i.e. the spatial deconcentration of logistics facilities in metropolitan areas, and concludes that there is a positive relation between spatial deconcentration and negative externalities of logistics facilities (e.g. Dablanc and Ross, 2012; Woudsma et al., 2016). Operational shifts of the logistics industry towards large-scale regional distribution centres resulted in an increase in the distance between the distribution centre and the final customer, which in turn has resulted into an increase in negative environmental impacts such as greenhouse gas emissions, pollutions, noise nuisance, congestion, and fuel consumption (Aljohani and Thompson, 2016). A scenario study by Wagner (2010) confirms that in a scenario with dispersed logistics land use there are indeed more externalities compared to concentrated logistics land use. Freight trucks have to travel longer distances into urban areas and total distance travelled increases as shipments are moved from large trucks into smaller delivery vehicles (Crainic et al., 2004). Dablanc and Rakotonarivo (2010) calculated that sprawl of parcel and express transport companies in Paris cause increased truck kilometres and approximately 15,000 tonnes of additional CO_2 emissions per year. According to Sakai et al. (2017) the externality of increased freight traffic is not only caused by sprawling warehouses, but also by sprawling freight demand. Although DCs generally spread outwards into the periphery because of lower land costs and increased efficiency, there are also externalities if located within urban zones. Urban areas that host large facilities face more congestion and wear and tear of the local road network (Cidell, 2015), especially as local roads might not be suited for heavy trucks (Allen et al., 2012).

A typology can support to differentiate between types of logistics facilities when studying their impact on urban areas (e.g. freight traffic, emissions). Typologies of logistics facilities are important in understanding the underlying differences between the type of facilities that are more efficient and sustainable than others in terms of increasing productivity and employment, and/or attracting more or less freight traffic and logistics activities. Spatial planners can use a typology to examine the characteristics of logistics facility types. As some facilities require huge spaces, a typology can support spatial planning discussion on which facility types should be allowed in urban areas and which types are preferably located in peripheral areas.

2.2.2 Typologies of logistics facilities

Although the concepts of a warehouse and a distribution centre are well known in the Supply Chain Management (SCM) literature (Bowersox et al., 1968), a standard typology of logistics facility types is lacking (Notteboom et al., 2017). Four studies propose typologies - i.e. Desmet et al. (2010), Higgins et al. (2012), Notteboom et al. (2017) and Heitz et al. (2019). Desmet et al. (2010) developed a typology including four types of large-scale European Distribution Centres (EDCs). Higgins et al. (2012) propose a typology of logistics terminals consisting of five types. The smallest type S involves an individual warehouse, while the largest type XXL contains a large terminal including multiple logistics facilities, such as an airport or seaport. Their typology, however, does not differentiate at the level of individual logistics facility types as is the goal of our paper. Heitz et al. (2019) propose a systematic classification of 20 facility types based on four criteria - i.e. function (storage, cross-docking), operator (shipper, wholesale, retail, LSP), goods type, and goods destination (example types are generalist LSP facility, or express parcel terminal) – combined with a case study of logistics facilities in France. This analysis does not reflect on the relationship with magnitude of the DCs, however. Notteboom et al. (2017) propose a taxonomy of facility types based on activity type, i.e. warehousing and storage, transit and value-added services. Also here, the relationship with size is not discussed. Reviews of different, but possibly related types of logistics facilities include port-based logistics parks (Kuipers and Eenhuizen, 2004), intermodal terminals (Notteboom and Rodrigue, 2009), and mixed logistics nodes (Grundey and Rimienė, 2007). None of these explore a large empirical real-estate dataset and discuss the combined features of function and size of distribution centres. In summary, the literature review shows that existing typologies focus either on size or on functionality, but a typology based on both characteristics is lacking.

2.3 Method and Data

2.3.1 Method

Based on the scientific literature we derived a framework of relevant criteria to differentiate between logistics facilities. These criteria include surface size (m^2) as well as six other characteristics, i.e. 1) activity type, 2) product type, 3) product range and speed, 4) network structure, 5) market service area (geographical market scope), and 6) service days - explained in Section 2.5.1. Each criterion contains multiple categories that are based on literature - for example, market service area includes categories ranging from local to international. The framework of criteria was used to study the characteristics of logistics facilities present in a large database of DCs in the Netherlands. This revealed types that occur frequently in the data and are based on diverse combinations of criteria (Figure 2.1). For example, one of the types includes facilities that are used for regional (market service area) food (product type) distribution to retail stores.

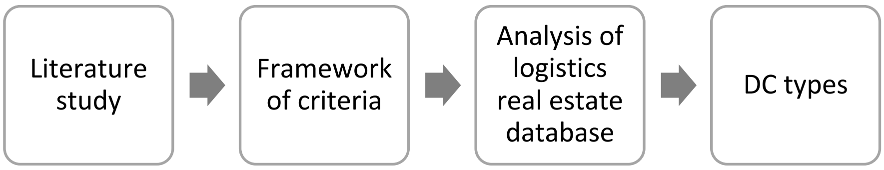


Figure 2.1 Research method

2.3.2 Data

The Netherlands is well-suited as study area for DCs as the country is a preferred logistics location that hosts many different types of logistics facilities. The logistics facility database used here includes two merged data sets: a first data set with 1,737 facilities with a surface area between 2,000m^2 and 122,000m^2 (Bak, 2017), and a second data set of 1,686 facilities with surface areas ranging from 5,000m^2 to over 300,000m^2 (Rijkswaterstaat, 2017). Both datasets have a national geographic focus. The first dataset was purchased from Bak real estate consultancy office. This dataset is used for the yearly statistics of logistics real estate in the Netherlands (NVM, 2020). The second dataset was obtained from Rijkswaterstaat, which is the executive agency of the Dutch Ministry of Infrastructure and Water Management. The datasets of Bak and Rijkswaterstaat are updated on a yearly basis, i.e. by adding new facilities or new users and deleting facilities that are demolished or no longer used as warehouse. At any point in time, all DCs in the database have been in use, functioning in the supply chain of that time. Both datasets were merged because both are based on the same geographical decomposition (zip code level), and together they provide a more complete overview of the total number of DCs in the Netherlands.

The Bak dataset includes data on the street address of facilities, zip code (6 digit), surface, year of construction, owner, and user, but not the industry sector. The Rijkswaterstaat dataset includes the street address, zip code (6 digit), surface, year of construction, user (but not the owner), and also the industry sector - i.e. 1,200 records include the industry sector code (Dutch SBI code, based on the EU NACE and UN ISIC classifications). We merged the datasets based

on zip code (6 digit) and street address. We deleted 535 duplicate facilities from the Bak dataset since the Rijkswaterstaat dataset is more elaborate - i.e. it includes data on the industry sector (SBI codes) of the company operating the facility. We also deleted two facilities for which there are no data on surface size available.
The combined database has 2,888 unique facilities that started operations between the year 1890 and 2016. Official counts of the total number of DCs in the Netherlands are lacking, but interviews with Dutch logistics experts indicate that the total number of DCs in the Netherlands is around 3,500 – 4,000. This means that our database represents approximately 75 to 80% of the total number of DCs in the Netherlands.
However, the database has a limitation as it does not include data of small logistics facilities (i.e. < 2,000m^2). Based on the research of Piepers (2018), these facilities were estimated to at least 8,680, based on the total number of small parcel pickup points in the Netherlands. As there are limited data on the smallest logistics facilities, there are two types based on definitions from literature - i.e. parcel locker and city hub. Another limitation is that there is one large facility, i.e. the flower auction in Aalsmeer, that consists of multiple individual facilities in the database because the flower auction expanded multiple times throughout the years.

2.4 The population of DCs in the Netherlands

Figure 2.2 shows the share of the total facility surface area (m^2) per size range as this gives a better picture than the number of large scale DCs - the number of large facilities >20,000m^2 is relatively small (i.e. only 19% of the total number), but they represent almost half (47%) of the total of 42 million m^2 logistics facility space in the Netherlands in 2016 (Figure 2.2).
The share of the total constructed surface of mega DCs - i.e. with a total surface area larger than 40,000m^2 - has increased significantly in the Netherlands, from 11% of the floor space constructed in the 1980s to 38% in the 2010s. The first DCs with surface size of more than 100,000m^2 floorspace were constructed in the 1970s. In the period 1980-2016, the construction of small facilities (between 5,001–10,000m^2) decreased, while the surface share of midsize facilities (15,001 – 20,000m^2) remained more or less the same over the same period.

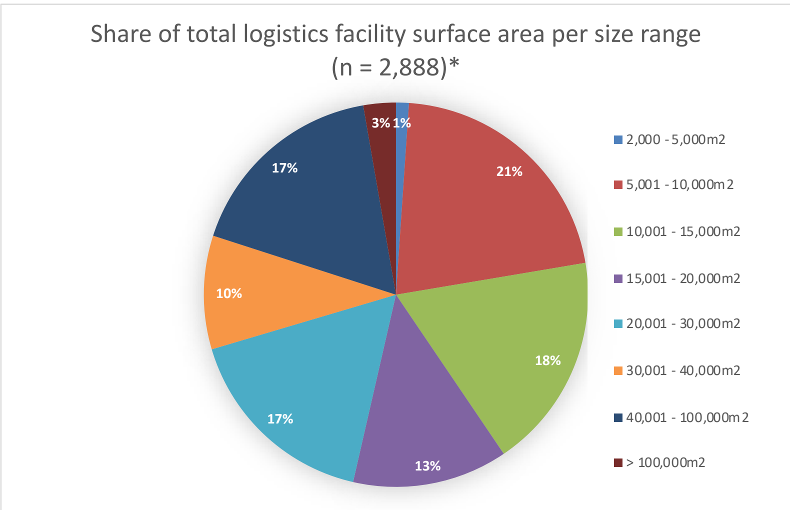


Figure 2.2 Share of logistics facility surface area per size range in 2016 (n=2,888)[1]

[1] Note that there are no data including surface areas of the smallest facilities (0 - 2,000m^2). There are, however, at least 8,680 pickup points in the Netherlands (Piepers, 2018). If we assume a pickup point has an average surface of 30 m^2 these facilities would represent 0,62% (260,400m^2) of the total logistics facility surface area in the Netherlands.

Further analysis at industry sector level shows that the companies operating the facilities are classified into 10 broad sectors (SBI chapters): i.e. seven Wholesale trade sectors (SBI 461-467); Freight transport by road (4941); Warehousing and storage (521), and Support activities for transport (522). In each sector (except SBI 461) the highest share of logistics facilities has a size between 5,001-7,500m^2, implying that middle-sized logistics facilities are very popular to companies of diverse industry sectors. Figure 2.3 shows the shares of different size ranges in the total surface area (m^2) of logistics facilities per industry sector.

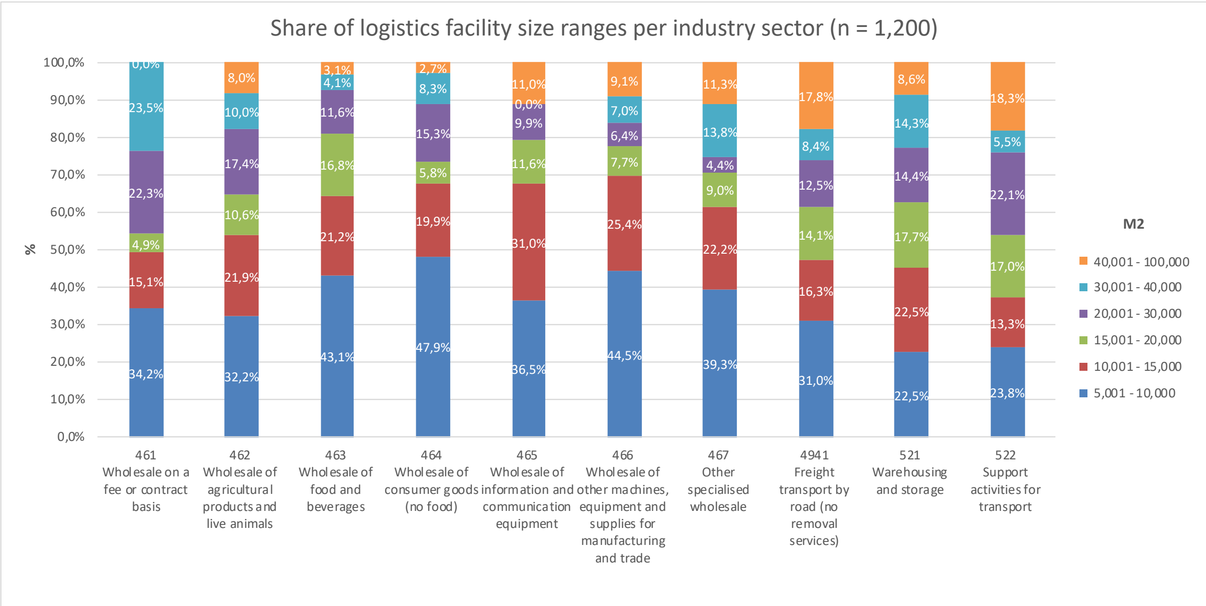


Figure 2.3 Share of logistics facility size ranges per industry sector in 2016 (n=1,200) (source: Rijkswaterstaat, 2017)

In industry sectors 464 (Wholesale consumer goods) and 466 (Wholesale of machines and equipment) the small facilities (5,001 – 10,000m^2) represent a relatively large share of the total existing surface area, while in industry sectors 4941 (Freight transport by road) and 522 (Support activities for transport) the large facilities (>40,000m^2) represent a relatively large share of the total existing sectoral surface area. In sectors 4941 (Freight transport by road) and 522 (Support activities for transport) the large share of large facilities (>40,000m^2) can be explained by the domination of large LSPs that need very large facilities to store and distribute products for multiple shippers - e.g. CEVA and GVT in sector 4941, and CEVA, Docdata and DHL in sector 522. In the same 4941 sector (Freight transport by road), there is also a significant share (31%) of small facilities (5,001-10,000m^2) in the total sectoral surface area for which there are three possible explanations, i.e. first, freight transport is a sector in which there are many start-up companies, second, the average year of construction of the corresponding facilities is 1990, which was a time at which there were less consumers to serve per facility, and third, DCs were smaller because they more often served national customer markets before the start of free trade in the European Union in 1993. The wholesale Food sector (SBI 463) is represented by a large share of small and medium-sized facilities in the total surface area (5,000-15,000m^2) (Figure 2.3). This is because Food wholesalers often serve a regional market. The wholesale Agriculture sector (SBI 462) shows a higher share of larger DC surface (>20,000m^2) than in the wholesale Food sector, which can be explained as wholesale Agriculture (SBI 462) is one step before wholesale Food (SBI 463) in the food supply chain.

Overall, the analysis of the data indicates there are multiple facility sizes and facility types per industry sector (Figure 2.3) – as was also concluded for facilities in France (Heitz et al. 2019). Therefore, it is difficult to assign industry sectors to individual facility types in our typology. It is, however, possible to explain individual facility types based on various functional criteria. For example, the size of a mega flower distribution facility (112,000m^2) in the sector wholesale Agriculture (SBI 462) can be explained by the worldwide market service area of the facility in combination with flowers being a space extensive product to store and distribute. To understand how sizes can be related to function, however, we need to define the functional characteristics first. This is the subject of the next section.

2.5 Functional characteristics and their relation to size

According to Notteboom et al. (2017), logistics facilities can be categorized by their main activity in a supply chain - i.e. warehousing and storage, transit, or value-added services. Other possible criteria to capture the variety of logistics facilities are, e.g. size, geographical market scope, product type, product range, operator of the facility, or position in the transport chain (Higgins et al., 2012; Notteboom et al., 2017; Heitz et al., 2019).
In this paper, the typology of logistics facilities is based on six functional criteria extracted from literature: 1) activity type, 2) product type, 3) product range and speed, 4) network structure, 5) market service area (geographical market scope), and 6) service days – related to size (i.e. the seventh criterion). The operator, which can be represented by e.g. shipper, LSP, or retail company (Heitz et al., 2019), is not considered as a criterion in this typology because of the existence of multiple possible operators for different types. The position in the transport chain criterion (by Notteboom et al., 2017) is incorporated in the network structure criterion. We discuss these criteria in the next subsection. Together, the criteria result in what we call 'size logic', or interaction between functional criteria and size. We introduce this in the second subsection.

2.5.1 Functional criteria

Activity type
This criterion is important to differentiate logistics facilities based on the main activity performed at the facility. The criterion includes six possible activities, i.e. storage (S), consolidation (C), warehousing (W), distribution (D), cross-docking (CD), and Value Added Logistics (VAL) (Higginson and Bookbinder, 2005) – comparable to the categories in Notteboom et al. (2017). A logistics facility often performs multiple of these activities at the same time. Logistics facilities that have Storage (S) as main activity, are dedicated to the storage of goods, i.e. finished goods, semi-finished goods, or raw materials. They can be used for short-term storage or long-term storage. The Consolidation (C) activity means that goods are merged for outbound distribution to a specific customer or geographic area (Higginson and Bookbinder, 2005). Small logistics facilities – e.g. a parcel locker or parcel pickup point - are too small to consolidate goods, the goods are delivered consolidated to the facility for further distribution to address locations and neighbourhoods in the city. Small facilities can, however, be used as consolidation points for goods returns. In opposition, large logistics facilities are often used to deconsolidate large goods flows into smaller goods flows (disaggregation of loads / breaking of bulk) for specific regions or customers. Warehousing (W) includes the receiving, put away, and order picking of goods for distribution towards the final customer, or towards a subsequent node in the supply chain (Higginson and Bookbinder, 2005). Large facilities can accommodate many warehousing activities - for example online company DCs in which employees pick many

small orders. At the smallest facilities there are usually no order picking activities, here the main activity is to distribute parcels into a specific geographic area. The Distribution (D) activity implies that the facility is used to reduce transit times and increase the speed at which goods move through the supply chain (Notteboom et al., 2017). Today, most facility types are used to increase distribution speed towards the customer. At large facilities it is possible to apply cross docking to reduce transit times. Small facilities such as city hubs can contribute to high delivery speed because of their location near consumer areas. Cross-docking (CD) means that a product is received at a facility and then shipped at the earliest opportunity. Goods only pass through from one dock to another dock, they are already consolidated at another facility (Higginson and Bookbinder, 2005). Value Added Logistics (VAL) contain activities that maximise the goods value in the supply chain, including repacking, pricing, or labelling of goods (Notteboom et al., 2017).

Product type
The type product handled at the facility can be generic (parcels, pallets, bulk) or specific (e.g. industrial goods, equipment, or fresh food) (Heitz et al., 2019). The product type criterion is important because specific products may require a specific type storage facility, for example a cold storage. Products can be unitised (into pallets or cases) or non-unitised, which influences the handling characteristics of the products. Unitised products require less handling operations.

Product range and speed
This criterion includes the range of products that are distributed from a facility as well as the distribution speed of the products, i.e. the speed at which inventories 'move through a warehouse' - a high inventory turnover usually means good business performance. Both elements are characterised along a single dimension, the product range can be small / large while distribution speed can be low (slow movers) / high (fast movers).

Network structure
Network structure refers to the layout of the transport system between production and consumption locations, including a number of logistics facilities. Examples are the direct, centralised, decentralised, and hub and spoke structure (Onstein et al., 2020).
The direct structure implies that products are distributed directly from production to the end customer, there are no other intermediate hubs. In case of direct network structure, goods are (temporarily) stored in a facility located at or near the production location. The direct structure is not often used, there are often intermediate facilities to save transport costs. In a centralised structure there is a single facility at which goods are consolidated - usually a large DC - and from there they are distributed to the customer. The decentralised structure includes multiple facilities in multiple echelons, for example a national DC combined with three smaller regional facilities. The hub and spoke system is a transport system in which a central hub is used for transport to multiple smaller facilities ("the spokes").

Market service area
Market service area refers to the geographic market focus of the facility (Grundey and Rimienė, 2007), of which there are five categories, i.e. neighbourhood, town/city, regional, national, international. The market service area criterion is important because different facility types serve different geographical areas.

Service days
The service days criterion includes the delivery time (in days) between the facility and its customer. Customer service is a very important aspect in today's businesses as customers expect

high service levels for goods distribution, i.e. deliveries within single or few days (Christopher, 2011). Small facilities located within urban agglomerations - such as parcel pick up points or Urban Consolidation Centres - can offer faster delivery times than large facilities located outside urban areas.

All characteristics that are presented above determine what we call the ‘size logic’. A facility located in an urban area is often small (because of high land prices) and difficult to access by large freight vehicles. Because of the small size the facility is inefficient (automation of parcel handling is not possible), it can only handle parcels or small city deliveries (e.g. fresh food orders for restaurants) and serve a small geographic area. However, because of their small size they can be located in close proximity to the customer, which allows quick deliveries and convenient return options, especially for parcels ordered online.

2.5.2 Relation of functional criteria to size

In this subsection we explain the interaction between the six functional criteria and size. Size (measured as the surface area in m^2) is an important criterion to include in a typology for two reasons. First, size determines which logistics activities are possible to organise from the facility, and second, a typology based on size can support the spatial planning authorities in their decision-making process about the suitability of facility types and their locations at different geographical level.

The first criterion includes the *activities* performed at the facility, which influence its size, i.e. a facility used for long term storage requires a larger space compared to a facility that is used for cross-docking (of the same goods). In case there are VAL activities performed at the facility these activities will require additional space. *Product type* (space extensive or space intensive) also affects the facility size, for example, a sand company requires a large semi-open storage space, whereas a company selling smartphones needs a small hub to deconsolidate goods for rapid transport to the retail or online customer. *Product range* affects the size of a facility in such a way that a broad product range generally requires more storage space - and therefore a larger facility - compared to a small product range. *Distribution speed* influences the size of the facility in another way, i.e. in case there are many slow moving goods handled at the facility, there is more space needed to store products (e.g. pallets racks) compared to a facility that cross-docks fast moving goods.
The *network structure* of the transport system may include single (centralised) or multiple (decentralised) facilities. In case of a centralised structure all inventories are stored at a single location, which influences the surface size of the facility. *Market service area* and the size of a logistics facility are positively related - a large facility generally serves are large geographic area. The *service days* criterion is also positively related to facility size, i.e. in case the customer demands a low number of service days (e.g. same day delivery) the goods are often sent to the customer from a small (local) hub. Large hubs are often located further from consumer areas, from where it takes multiple days to transport goods to the customer.

The *size* criterion includes seven categories, i.e. XXS to XXL. The XXS size is based on the size of a parcel locker or small store or pickup point where customers can collect or return their parcel, i.e. up to $200m^2$. The XS size is based on the size of a city hub (up to $2{,}000m^2$) (Browne et al., 2005). The sizes S, M and L are arbitrary; determining these facility types is complex because multiple types and industry sectors are represented in multiple size ranges (Table 2.1). It is, however, necessary to propose a typology to support our research and discussion. The XL ($20{,}001 – 40{,}000m^2$) and XXL ($>40{,}000m^2$) sizes are based on business literature (NVM, 2020) as well as the database which shows an increased construction of XXL facilities (i.e. >40,000m^2).

2.6 Proposed typology

This section presents the proposed typology including 8 logistics facility types. Each facility type is illustrated based on the criteria explained above. The 8 types are, in order of average size:

1. Parcel lockers and pick-up points
2. City hubs
3. Parcel and postal sorting facilities
4. Regional food wholesale and retail facilities
5. National retail and e-commerce facilities
6. Manufacturer DC facilities
7. Bulk facilities
8. Global agricultural auctions

In this typology the sectoral dimension is leading. Other functional criteria help to explain the underlying variation in DCs and, as we will see below, their sizes. We present these types below, discuss the variations in terms of size within each category and summarize the typology.

2.6.1 DC Types

Type 1: Parcel lockers and pick-up points

Parcel lockers are self-service lockers at which consumers can collect and return goods purchased online (Vakulenko et al., 2018), they are often situated in places that attract many visitors, e.g. public buildings (libraries, universities), supermarkets or gas stations. Parcel lockers enable high speed distribution, customers can pick-up their parcel the same day. Parcel locker facilities have become increasingly popular because they aggregate individual customer demand and therefore reduce delivery costs towards the customer (Janjevic and Winkenbach, 2020).

Parcel pick-up points are generally small, behind the counter areas, having a small size of e.g. 5m^2 – 30m^2 (Figure 2.4). This type facility is used to store small parcel volumes for a short period of time (e.g. 2 – 3 days) during which customers can collect their product. The number of service days is low, it is often possible to collect products the same day or next day. The parcel pick-up point can also function as consolidation point for goods returns (Higginson and Bookbinder, 2005). Parcel pick-up points have a local (neighbourhood) market service area, they are often located in stores (supermarkets), post offices, public buildings (libraries, schools), gas stations, or other areas that generate consumer trips (Weltevreden, 2008). In the Netherlands, there are at least 8,680 parcel pick-up points (Piepers, 2018). Grocery retailer Albert Heijn, for example, offers parcel pick-up points for Bol.com (webshop) customers. In case the parcel pickup point is located in a store there is the advantage of upselling opportunities.

Type 2: City hubs

City hubs are logistics facilities from where consolidated deliveries take place within urban areas, they are located in the vicinity of their market service area and are mostly used for fast city deliveries. A city hub is usually owned by single company. Possible city hub activities are storage, warehousing or consolidation of returned goods. Warehousing could include order

picking for a large organisation, for example a university (Browne et al., 2005). A special type in this category is the Urban Consolidation Centre (UCC) in which goods from multiple companies are consolidated for last mile distribution. Logistics companies deliver their loads at the UCC, and the UCC operator delivers the loads, often with environmentally friendly transport modes (Browne et al., 2005). UCCs are often operated by last-mile specialists. A sub type of the city hub is the mobile depot from which goods are delivered by cargo bike to the final customer. Because of rapid growth in online retail and stricter city delivery regulations, city hubs have been a major trend over the last years to organise last-mile distribution (Janjevic and Winkenbach, 2020).
Since city hubs and UCCs are used to serve a local area (city deliveries), they have a small size between 200 < 2,000m^2. Their location close to the customer enables next day or even same day deliveries. There are no data on the total number of city hubs and UCCs in The Netherlands, but there are at least 14 UCCs included in the Dutch national network of Binnenstadservice.nl.

Type 3: Parcel and postal sorting facilities
This facility type is used by parcel and post companies - such as Sandd, DPD, UPS and DHL – for rapid last mile distribution to the customer – but also for consolidation and warehousing. Dutch parcel and postal sorting facilities are situated at the outskirts or outside urban areas, at locations that are highly accessible by truck. During night times, parcels are distributed between a decentralised network of facilities, from where regional deliveries take place the next day. Because of the regional focus, next day deliveries are possible. Parcel and postal sorting facilities have an S – M – L – XL or XXL size (between 2,500 – 66,000 m^2 according to our database) depending on the number of residents in the focus region. The largest number of facilities owned by the six largest post- and parcel companies in the Netherlands have a size S (i.e. 39 facilities) or M (i.e. 29 facilities). The largest facilities in this category (i.e. 45,000 – 66,000m^2) are owned by DHL. Note that a recent trend are e-retailers such as Amazon that open their own parcel sorting facilities (Janjevic and Winkenbach, 2020) - these facilities are not yet included in our data.

Type 4: Regional food wholesale and retail facilities
This category includes logistics facilities that are used for regional food distribution towards retail stores or online customer’s homes. Other types of activities of these facilities include storage, consolidation, warehousing, cross-docking and VAL. These type facilities are operated by large grocery retail companies or their LSPs. Wholesale grocery facilities are also included in this category because these companies also typically apply a regional distribution system. The main reason to apply regional facilities is to reduce outbound transport costs. Companies that use these facilities often sell a broad range of high demand products.
The facility is ideally located in the transport centre of gravity of its regional focus area. The size of the facility can range from L – XL to XXL (examples from our database include 15,000m^2 (Albert Heijn: AH) - 19,000 (Deen, AH) – 27,000 (AH in Rotterdam) – 35,000 (AH in Tilburg) – 41,000 (AH in Nieuwegein) – 55,000 (AH in Delfgauw) - 62,000m^2 (AH in Zaandam), depending on regional product demand. The largest number of facilities from food wholesalers and retailers in the Netherlands have a size M (i.e. 40 facilities) or XL (i.e. 30 facilities). There is also a subcategory of Medium-sized facilities of online grocery retailers such as Picnic and Hello Fresh that also apply regional facilities to supply city hubs – their Medium size is influenced by the small product range and small market service area compared to offline grocery retailers. Goods are typically transported in boxes, roll containers, or pallets towards the retail. Some fresh products require temperature-controlled storage and distribution. The distribution speed depends on the product, i.e. high (next day) for fast movers or low

(>week) for slow movers. The network structure consists of two echelons, i.e. regional facilities that are supplied by a central (national) facility (see Type 5).

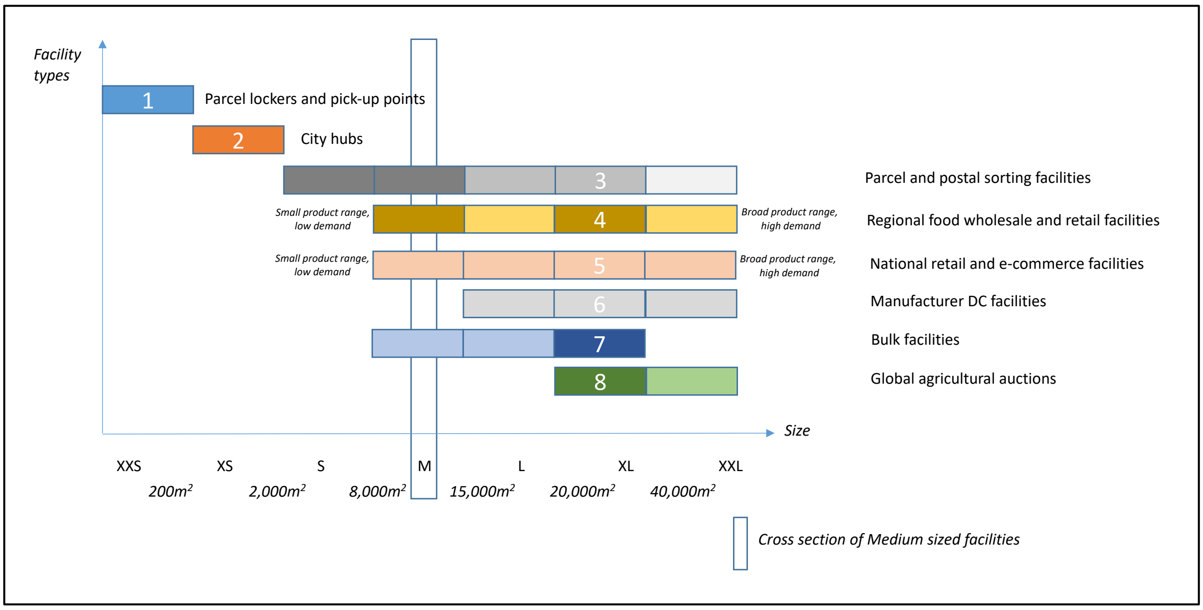


Figure 2.4 Logistics facility typology

Type 5: National retail and e-commerce facilities
This type facility is used for storage, consolidation, warehousing, cross-docking, and Value-Added Logistics. The main goal is national distribution towards retail chains or online customers. Ecommerce facilities are also included in this category because ecommerce facilities often have the same functionalities, for example the same national market service area. National retail / e-commerce facilities are operated by offline or online retailers, or outsourced to LSPs. This type consists of a single (centralised) facility from where goods distribution takes place towards multiple sorts of customers, i.e. regional facilities, retail stores, pick-up points, or online customers' homes. Companies that use this facility type can specialise on a single goods type (e.g. online sale of photo cameras) or sell a broad product range. The delivery speed can be high (next day) for fast movers such as t-shirts or low (>week) for slow movers such as a leather belt. The goods are delivered in parcels (to online customers), boxes or pallets (to regional facilities or retail locations). The size of the facility ranges from M – L – XL – to XXL (examples from our database include 17,600m^2 (Hema) – 18,000 (WE) – 19,000 (Bart Smit) – 34,000 (Xenos) – 36,000 (Foot Locker) – 44,000 (Leen Bakker) – 45,000 (Zeeman) – 50,000 (Bol.com) – 55,000 (Wehkamp) - 116,000 (Ikea)), depending on product range and demand. Hema, for example has a large customer base, but their facility is relatively small because the company sells a small product range and stocks many items in their retail stores. Bol.com, however, sells a broad range of products and their facility supplies a national geographic area resulting in a mega distribution centre. To reduce outbound transport costs, the facility is preferably located in the transport centre of gravity of its national market service area. It must be noted that some retail companies, e.g. Hema, have started international operations, implying this facility type may evolve towards an international distribution type. As a second note, there are many small (S) retail stores (e.g. a DIY store), but these are not included in this standard type since the main activity of these stores is commerce instead of logistics.

Type 6: Manufacturer DC facilities
This type logistics facility is used for storage, consolidation, warehousing, VAL, and national or international distribution. These facilities are operated by manufacturers or outsourced to their LSPs. Distribution can take place from 1) Manufacturer to retail stores owned by the manufacturer (e.g. Nike), 2) Manufacturer to retail chain not owned by the manufacturer (e.g. to MediaMarkt), 3) Manufacturer to wholesale (e.g. to food wholesalers such as Hanos and Sligro). The network structure is centralised, i.e. it includes a single facility.
The product range can be small or broad, many manufacturers focus on a broad product range (e.g. different sorts of apparel), but there are also manufacturers that focus on a single product (e.g. photo camera's, printers) of which they sell different types. The preferred location is in the transport centre of gravity of the (inter)national consumer market – although some consumer electronics manufacturers locate outside the centre of gravity to gain tax advantages. Because of the national or international geographic market focus, this facility type is characterised by a large size ranging from L – XL to XXL (e.g. 24,000 (Forever21) - 28,000 (Samsung) – 31,000 (Grolsch) – 39,000 (Timberland) – 52,000 (Ricoh) - 70,000 (Canon) - 122,000m^2 (Michael Kors)). High delivery speed (e.g. next day) is possible for national deliveries, but international deliveries often take multiple days.

Type 7: Bulk facilities
Important activities of this facility type include storage and distribution of bulk goods. The main goal is regional (e.g. sand, soil) or national (e.g. oil) distribution to customers such as construction companies, industry or gas stations. Bulk facilities can be operated by manufacturers or wholesalers. Because of the high costs to transport bulk goods, these type facilities are often located near the location of the raw materials or near a port of entry. In case of regional wholesale, the facility can also have a central location within the regional market service area that is highly accessible by truck or barge. The network structure is centralised, a single facility is used to serve the customer target market.
The facilities have a size M – L or XL, of which XL size is the most frequent. Examples include 8,200m^2 (Kroon Oil), 13,700 (Aluminium Verkoop Zuid), 16,900 (Konings Staal), 21,400 (Kroger Staal), 31,700 (Douma Staal) and 33,500m^2 (Vogten Staal), depending on the market service area as well as the space required to store the goods. The product range is small, most facilities are used to distribute single or few products - examples of bulk products are sand, soil, oil, grain, gas, salt, iron ore, coal, bauxite, aluminium. The delivery speed depends on the market service area, i.e. single day for regional deliveries or multiple days for national deliveries. Most facilities have a regional service area as it is costly to truck bulk goods over large distances. In case of national service area, barge transport can be used to save transport costs.

Type 8: Global agricultural auctions
Auctions are a special type since these facilities are not only used for logistics activities – i.e. storage, consolidation, warehousing, VAL and distribution - but also to auction and trade goods. Agricultural auctions are located near production areas to save transport costs of large inbound goods flows, i.e. between production sites and the auction. An auction is a cooperation that is owned by its members, e.g. flower producers. The product range handled at the facility is small, it only includes agricultural products such as vegetables or flowers. There is a centralised network structure, the auction is the only logistics facility between production and retail locations.
Most auctions have a size XL or XXL, there are six fruit and/or vegetables auctions in the database that have sizes of 11,200m^2 (Geldermalsen), 17,000m^2 (Venlo), 20,000m^2 (Breda), 23,000m^2 (Venlo), 23,600m^2 (Zwaagdijk), 29,500m^2 (Barendrecht), and four Dutch flower

auctions which have the following sizes, 20,000m^2 (Naaldwijk), 25,800m^2 (Eelde), 316,000m^2 (Rijnsburg) and 500,000m^2 (Aalsmeer). The auctions serve national as well as international customers. The delivery speed depends on the market service area, national retail deliveries often take a single day, while delivery times of international deliveries take up multiple days.

2.6.2 Relationship between function and size

The contexts in which very large (type 8) and small size DCs (types 1 and 2) operate are relatively easy to identify, while the context for medium sized DCs (type 3 – 5) is more heterogeneous (Figure 2.4). Type 8 are agricultural auctions that have a very large size because of their European or worldwide market service area in combination with agricultural products being space extensive products to store. Types 1 and 2 are parcel lockers, parcel pick-up points and city hubs. These facilities have a small size because they handle small volumes and serve a minor geographic area such as a neighbourhood. Types 1 are often located in urban areas (e.g. city centres, suburban shopping centres) that are too expensive to construct large logistics facilities.

Types 3 – 7 have facilities in similar size ranges, but the diversity in sizes within each type can be explained by the functional criteria. Type 3 are Parcel and postal sorting facilities of which the largest number of facilities has a size S or M, followed by L, XL and XXL. Sizes S and M are somewhat older facilities or facilities that serve a small geographic area, for example PostNL has constructed a network of decentralised S and M facilities - each facility serves its own city or region. The larger facilities are especially popular to parcel companies (i.e. UPS, TNT, and particularly DHL) because of two reasons. First, larger regional facilities are needed because of the rapid e-commerce growth, and second, because parcel companies apply a network structure that includes large national hubs - used to supply regional hubs.

Type 4 are Regional food wholesale and retail facilities, the largest number of these facilities have a size M or XL (Figure 2.4). The Medium facilities are older facilities, while the XL facilities are recent facilities that include new constructions (e.g. Lidl) or facility expansions (e.g. Albert Heijn, Jumbo) by food wholesale or retail companies in order to centralise operations that were previously executed from multiple facilities. Type 5 (National retail and e-commerce facilities) have a size ranging from M to XXL, while type 6 (Manufacturer DC facilities) have a size between L and XXL. The variety in sizes can be explained by their functional characteristics such as product range, customer demand and market service area. Bulk facilities (Type 7) have a size between M and XL, but most bulk facilities have a size XL as bulk products are space extensive products that require large storage space.

Table 2.1 presents a summary of the above facility types categorised into diverse size ranges.

Table 2.1. Cross section of facility types into size ranges

Name	Building size	Function *	Product type	Product range and speed	Market service area	Service days	Number of facilities in NL	Types represented in each size range
XXS	< 200 m^2	S / D / (and C only for online goods returns)	Parcels	Broad range High speed	Local: Neigh-bourhood	Same day Next day	> 8,680 pick up points and parcel lockers	Parcel locker Pick up points

XS	200 - < 2,000 m^2	S / C / W / D	Parcels Fresh food delivery	Broad range High speed	Local: Town / City	Same day Next day	Un-known	City hub
S	2,000 - < 8,000 m^2	S / C / W / D	Parcels	Small / broad range Fast-movers / slow-movers	Regional	Next day	995	Parcel and postal sorting facility
M	8,000 - < 15,000 m^2	S / C / W / D / CD / VAL	Parcels Pallets Bulk	Small / broad range Fast-movers / slow-movers	Regional National	Next day Multi-ple days	1,024	Parcel and postal sorting facility Regional food wholesale and retail National retail or e-commerce facility Bulk facility
L	15,000 – < 20,000 m^2	S / C / W / D / CD / VAL	Parcels Pallets Bulk	Small / broad range Fast-movers / slow-movers	Mostly National and Inter-national (although there are large regional Post and Food retail DCs)	Next day Multi-ple days	319	Parcel and postal sorting facility Regional food wholesale and retail National retail or e-commerce facility Manufacturer DC facility Bulk facility
XL	20,000 - < 40,000 m^2	S / C / W / D / CD / VAL	Parcels Pallets Bulk	Small / broad range Fast-movers /	Mostly National and Inter-national	Next day Multi-ple days	411	Parcel and postal sorting facility Regional food wholesale and retail

				slow-movers	(although there are very large regional Post and Food retail DCs)			National retail or e-commerce facility Manufacturer DC facility Bulk facility Global agricultural auction
XXL	> 40,000 m^2	S / C / W / D / CD / VAL	Parcels Pallets	Small / broad range Fast-movers / slow-movers	National Inter-national (although there are very large regional Post and Food retail DCs)	Multi-ple days (online possi-bly faster)	146	Parcel and postal sorting facility Regional food wholesale and retail National retail or e-commerce facility Manufacturer DC facility Global agricultural auction

* Storage (S), consolidation (C), warehousing (W), distribution (D), cross-docking (CD), Value Added Logistics (VAL).

2.6.3 Discussion

This section compares the proposed typology of logistics facilities with previous typologies and analyses the geographical locations of the logistics facility types.

The proposed typology consists of two layers, a first layer in which there is distinction between sectors (e.g. parcel, food, wholesale, retail, bulk, agriculture), and second layer including functional criteria which explain the variation within the first layer – for example, functional criteria such as market service area can explain whether a parcel facility has a small or large size. The typology is unique as it combines the aspects of size with other functional characteristics of logistics facilities. Our results show that the relation between size and facility type is ambiguous since size ranges M – XXL include multiple facility types (Figure 2.4). Size ranges of facility types can, however, be explained by the functional criteria - as we did above.

2.6.3.1 Comparison with previous typologies

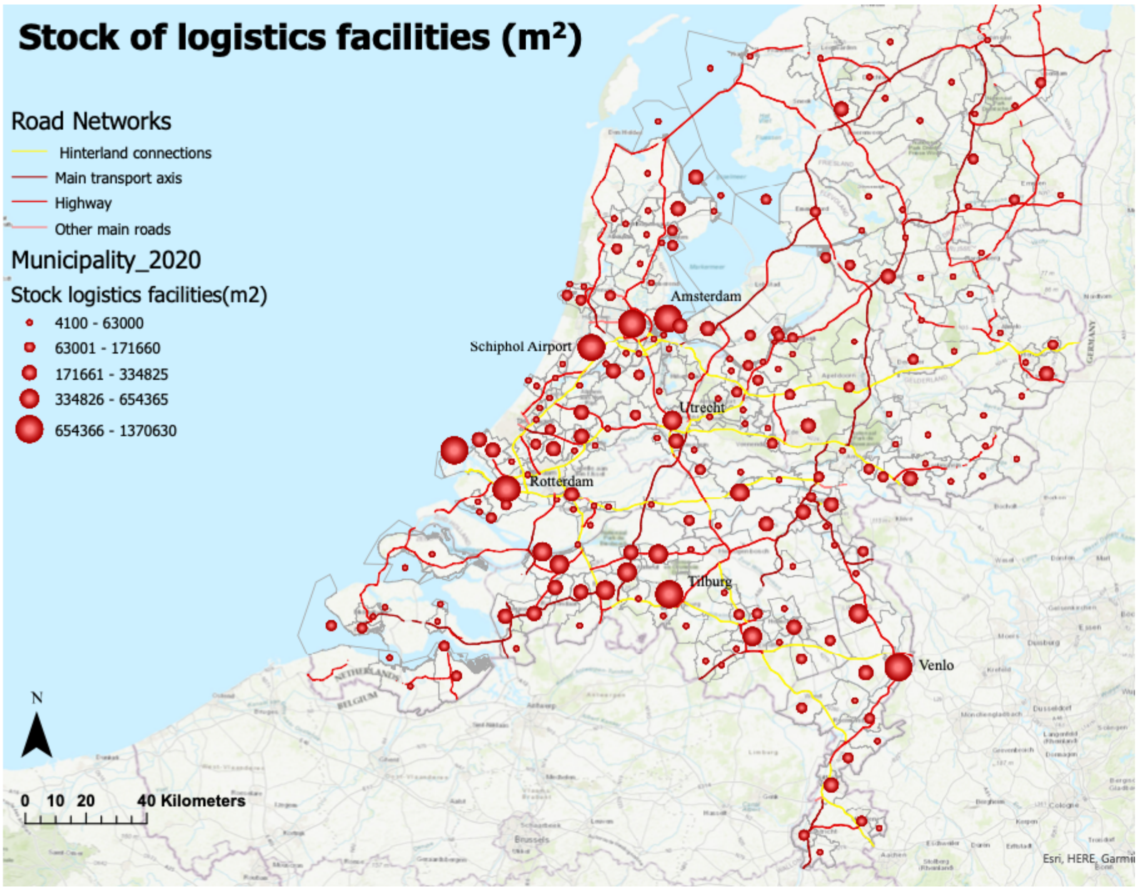
To discuss the results, we compare our proposed typology with previous typologies. Compared to Heitz et al. (2019), our study contains less facility types (i.e. 8 versus 20), which can be explained as we do not subdivide the types into possible users / operators, e.g. shipper versus

LSP. It is, however, possible to disaggregate types by adding possible operators. A second distinction is the geographical base of the typology, i.e. Heitz et al. (2019) base their typology on logistics facilities in France. The Netherlands are, however, a very urbanised country compared to other popular logistics countries such as France and Germany. As there are larger rural areas in these countries, other facility types could be observed to supply these areas. As a third distinction, our typology combines e-commerce facilities with national retail facilities. We argue that e-commerce facilities can be considered retail facilities that often have the same national market service area - note that operations may be different in e-commerce facilities, e.g. smaller order sizes (pick by item instead of pick by case / pallet load), larger number of vehicles compared to national retail facilities.
Notteboom et al. (2017) provide a detailed overview of the reasons behind the ambiguity around the concept of a logistics facility – i.e. two main causes for the conceptual ambiguity are temporal dimensions (e.g. technological changes) and spatial dimensions (e.g. institutional and political contexts in which companies operate). The authors also provide a comprehensive taxonomy of logistics centres based on seven criteria – including size and functionality as in our typology. The main difference is that our analysis starts by examining logistics facilities in the Netherlands, whereas Notteboom et al. (2017) start with a taxonomy and position existing facility types (including their definitions) within the taxonomy. Another difference is that the taxonomy by Notteboom et al. (2017) contains conceptualisations including multiple logistics facilities (e.g. Distripark, Freight village), whereas our typology focuses on individual logistics facility types.
Higgins et al. (2012) use a method and scope comparable to the approach by Notteboom et al. (2017). The authors distinguish between an individual warehouse or distribution centre, but also between concepts including multiple facilities such as an inland port, or freight village. Our typology is different as it includes a sectoral layer, which is important as there are multiple types of (sectoral) distribution centres that have different functional characteristics.

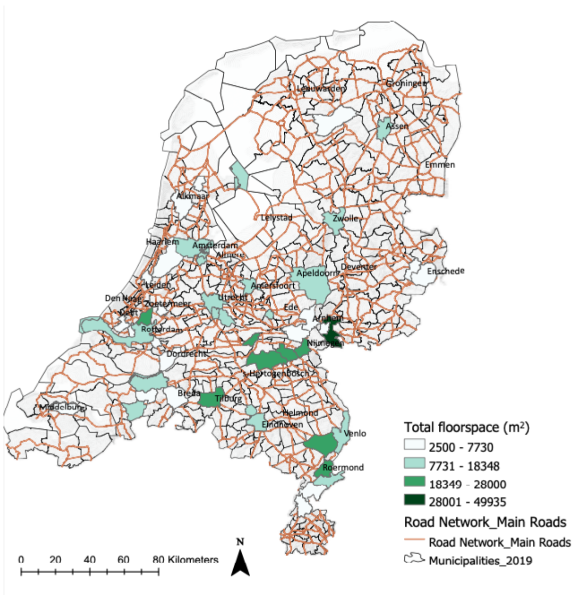
One of the aims of this paper is to develop a typology that can be of use to policy makers to design spatial policies on where to locate specific types of DCs. A cross section of our typology (Table 2.1, Figure 2.4) shows there are multiple facility types included in size ranges M – L – XL and XXL. As there are multiple facility types represented in these sizes, it is not possible to design a single spatial policy per size range. Therefore, each of the eight types in the proposed typology deserves own spatial policy, and within each standard type a differentiation of spatial measures based on size – e.g. Medium (M) retail facility versus Large (L) retail facility – is needed.

2.6.3.2 Locations of the logistics facility types

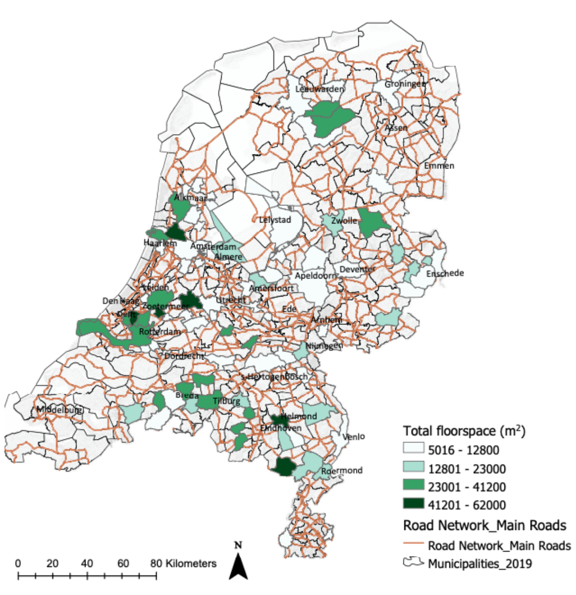
Analysis of the total logistics floorspace (m^2) per municipality (Figure 2.5) indicates there are concentrations of warehouses in municipalities near the ports of Rotterdam and Amsterdam, near Schiphol Airport (Amsterdam), and along the main hinterland corridors (indicated by yellow lines) - these locations are in line with findings from Bowen (2008) suggesting that air and highway transportation strongly influence warehouse locations. Rotterdam and Amsterdam not only have the largest seaports and airport, but they are also the largest urban agglomerations of the country. The northern part of the Netherlands hosts less logistics facilities as there are less and smaller urban areas, and less consumer areas in the hinterland.



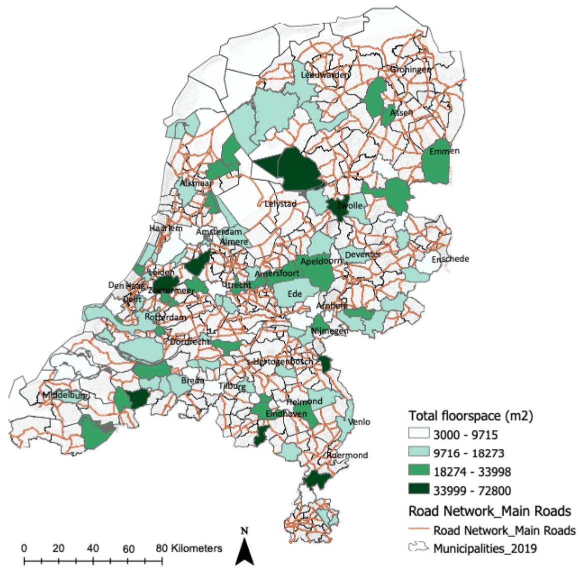
Total logistics floorspace (m²) per municipality.



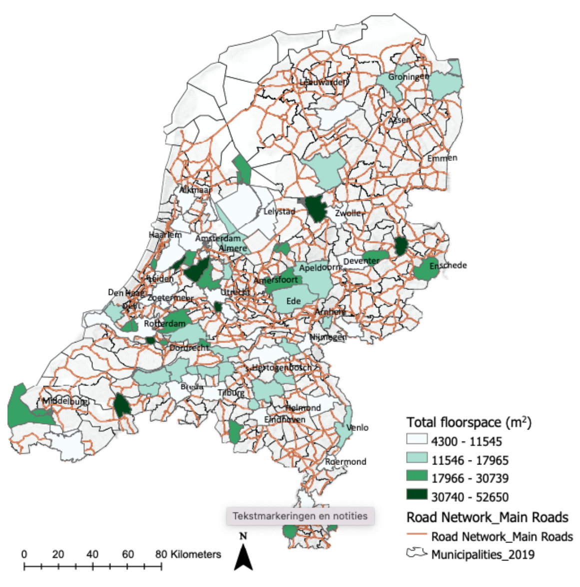
Type 3 Parcel and postal sorting facilities.



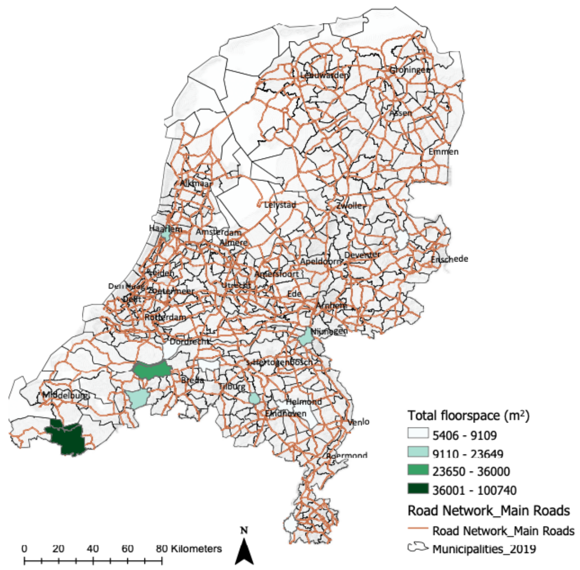
Type 4 Regional food wholesale and retail.



Type 5 National retail and e-commerce.



Type 6 Manufacturer DCs.



Type 7 Bulk facilities.

Figure 2.5 Logistics facility locations in the Netherlands: total logistics floorspace (m^2) per municipality

As mentioned there are no data on the total number and locations of parcel lockers & pick-up points (Type 1) and city hubs (Type 2) in the Netherlands. However, examples suggest that city hubs are found at strategic locations at the edge of the city - often near major roads for goods distribution into the city. Companies prefer these locations because they are easily accessible for large freight trucks (incoming goods) (Browne et al., 2005). Parcel lockers and pick-up points can be found in stores, post offices, public buildings, and gas stations, as explained in section 2.6.1.

The locations of parcel and postal sorting facilities (Type 3) shows an overlay of two spatial patterns. First, facilities are located near Dutch cities (large consumer areas) for regional and national distribution. Secondly, there are concentrations of facilities located along the German border for international distribution. The older medium-sized parcel sorting facilities of the national postal company are located at industrial terrains near medium sized cities and within 500 meters of a motorway entrance. These facilities are used as a network for regional distribution. Newer facilities are located further away from the central city, probably because of their large size (45,000 - 66,000 m^2) and (inter)national market service area.
Regional food wholesale and retail facilities (Type 4) show a network of regional facilities throughout the country. These facilities are used for regional distribution to wholesale and retail locations (e.g. supermarkets) and/or for e-commerce deliveries. Large grocery companies often use regional facilities that are supplied by a national facility, but there are also grocery companies that use a single (national) facility to supply all their retail locations. Large food DCs - of large grocery chains - are often located at an industrial terrain at the edge of a large city, having its own highway access - which corresponds to a case study of supermarket DCs in Paris (Heitz et al., 2019). Older, medium sized food company facilities (e.g. 8,000 - 13,000m^2) can be found at older industrial terrains that are nowadays located within the city. Sometimes these facilities are not only used for distribution but also for production. Type 5 "National retail and e-commerce" facilities do not show an immediately identifiable spatial pattern. Type 5 facilities can be found in central as well as peripheral areas, supplying the whole country. Large companies may decide to move their DC to the centre of the country to reduce transport distances to their consumers, while medium-sized (e.g. online) companies may decide to stay in their peripheral 'home' area and distribute via the network of a Logistics Service Provider. Type 6 (Manufacturer DC) facilities can be found near the port of entry (Rotterdam, Amsterdam) and along the main hinterland corridors. Note that Type 5 and Type 6 often use LSPs, however, the logistics facilities of these LSPs are not included as the type of customer of each LSP is unknown. Including these LSP facilities would probably mean that Type 5 and 6 facilities are in many Dutch municipalities. Bulk facilities (Type 7) are located at industrial terrains that are accessible by barge or train for inbound transport. For example, the largest facility (100,000m^2), which is used by a company that supplies raw materials for the construction sector, is located in the port of Terneuzen. Global agricultural auctions (Type 8) - i.e. only 10 facilities - are located near production areas to reduce inbound transport costs between production locations and the auction.

2.7 Conclusion

Many concepts related to logistics facilities can be found in the literature – e.g. distribution centre, warehouse, freight hub, e-fulfilment centre, Urban Consolidation Centre (UCC), logistics depot - but a standard typology of logistics facilities is lacking (Higgins et al., 2012; Notteboom et al., 2017). Researchers often use one of these concepts to study a logistics problem, but a standard typology used by scholars to distinguish between concepts was not found in the literature. This paper proposes a typology of logistics facilities based on size as well as six other functional criteria – i.e. activity type, product type, product range and speed, network structure, market service area, and service days - that can be used by the scientific community and also by public and private actors for mutual understanding when discussing research, public policies, and public or private investments related to logistics facilities. To the best of our knowledge, there is no typology based on size as well as functionality of the facility. A typology based on size is important for scholars to differentiate between types of facilities when studying their impact on urban areas, for example in terms of land use, freight traffic and local emissions. Spatial planners can use the typology to discuss what are suitable locations for diverse facility types and develop spatial plans accordingly. The proposed typology could also support the public debate on the visual intrusion of logistics facilities - i.e. the visual pollution of the landscape because of the low architectural quality of logistics facilities - as it is now possible to differentiate between types in the discussion.

The typology is based on literature combined with data on 2,888 logistics facilities in the Netherlands. The types are defined based on the seven criteria mentioned above. The data are used to exemplify the types, and also to analyse what are common size ranges of each type. The proposed typology includes eight facility types, e.g. parcel and postal sorting facility, and bulk facility.

Results show that the importance of large facilities has increased over the years, not only in absolute numbers, but especially in their contribution to the total constructed surface area. The share of facilities > 20,000m^2 is relatively small (19%), but they represent almost half (47%) of the total 42.1 million m^2 logistics facility surface in the Netherlands. Large facilities are therefore important in the development of spatial planning policies. These spatial policies could focus on suitable locations, but also on spatial measures to mitigate accessibility problems, or sustainability questions related to e.g. visual intrusion. Another aspect is that it is not possible to design a single spatial policy per size range, because a cross section of the size ranges M – L – XL and XXL (Table 2.1) shows there are multiple facility types represented in each size range. Therefore, each of the eight types in the proposed typology deserves own spatial policy.

We derive several opportunities for future research. First, as the evolution of logistics facilities proceeds, the typology will need to be updated on a regular basis. Future research could therefore address new types of logistics facilities (e.g. mega city hubs). Secondly, new work could focus on collecting examples of spatial measures that can be used to design policies that mitigate visual intrusion or other sources of external effects. Thirdly, dynamics in warehouse types over time did not fall inside the scope of this research but could be presented in follow-up work. Fourthly, we find that very large facilities are mostly found outside urban areas. Future research could study the relation between facility size and proximity to urban areas. Finally, in other countries there will be different sorts and volumes of data about logistics real estate. Future research could develop typologies based on other countries and make comparisons with our proposed typology.

References

Aljohani, K, Thompson, R.G., 2016. Impacts of logistics sprawl on the urban environment and logistics: Taxonomy and review of literature. J. Transp. Geogr. 57, 255–263.

Allen, J., Browne, M., Cherrett, T., 2012. Investigating relationships between road freight transport, facility location, logistics management and urban form. J. Transp. Geogr. 24, 45–57.

Bak, R., 2017. Dataset of 1737 distribution centres located in the Netherlands.

Bowen, J.T., 2008. Moving places: the geography of warehousing in the US. J. Transp. Geogr. 16, 379-387.

Bowersox, D., Smykay, E., LaLonde, B., 1968. Physical distribution management. Logistics problems of the firm. New York: MacMillan.

Browne, M., Sweet, M., Woodburn, A., Allen, J., 2005. Urban freight consolidation centres. Final report. London: University of Westminster.

Christopher, M., 2011. Logistics and Supply Chain Management. Harlow: Pierson Education Limited.

Cidell, J., 2010. Concentration and decentralization: the new geography of freight distribution in US metropolitan areas. J. Transp. Geogr. 18, 363–371.

Cidell, J., 2015. Distribution centers as distributed places: mobility, infrastructure and truck traffic. In: Birtchnell, T., Savitzky, S., Urry, J. (Eds.), Cargomobilities: Moving Materials in a Global Age. Routledge, New York, NY.

CRa, 2019. (X)XL-verdozing. Minder, compacter, geconcentreerder, multifunctioneler [XXL-boxes. Less, more compact, concentrated, multifunctional]. The Hague: College van Rijksadviseurs (CRa).

Crainic, T.G., Ricciardi, N., Storchi, G., 2004. Advanced freight transportation systems for congested urban areas. Transp. Res. Part C Emerg. Technol. 12(2), 119–137.

Dablanc, L., Rakotonarivo, D., 2010. The impacts of logistics sprawl: How does the location of parcel transport terminals affect the energy efficiency of goods' movements in Paris and what can we do about it? Procedia Soc. Behav. Sci. 2(3), 6087-6096.

Dablanc, L., Ross, C., 2012. Atlanta: a mega logistics center in the Piedmont Atlantic Megaregion (PAM). J. Transp. Geogr. 24, 432–442.

Desmet, D., Boute, R., Vereecke, A., 2010. A typology of European distribution centres. Gent: Vlerick Leuven Gent Management School.

Grundey, D., Rimienė, K., 2007. Logistics centre concept through evolution and definition. Eng. Econ. 4(54), 87-95.

Heitz, A., Beziat, A., 2016. The parcel industry in the spatial organization of logistics activities in the Paris Region: inherited spatial patterns and innovations in urban logistics systems. Transp. Res. Proc. 12, 812-824.

Heitz, A., Dablanc, L., Olsson, J., Sanchez-Diaz, I., Woxenius, J., 2020. Spatial patterns of logistics facilities in Gothenburg, Sweden. J. Transp. Geogr. 88.

Heitz, A., Launay, P., Beziat, A., 2019. Heterogeneity of logistics facilities: an issue for a better understanding and planning of the location of logistics facilities. Eur. Transp. Res. Rev. 11(5).

Higgins, C.D., Ferguson, M., Kanaroglou, P.S., 2012. Varieties of logistics centres: Developing a standardized typology and hierarchy. Transp. Res. Rec. 2288(1), 9-18.

Higginson, J.K., Bookbinder, J.H., 2005. Chapter 3: Distribution centres in supply chain operations. In: Langevin, A.L., Riopel, D., (Eds), Logistics Systems: Design and Optimization. New York: Springer, pp. 67-91.

Janjevic, M., Winkenbach, M., 2020. Characterizing urban last-mile distribution strategies in mature and emerging e-commerce markets. Transp. Res. Part A: Policy and Pract. 133, 164-196.

Kang, S., 2020. Relative logistics sprawl: Measuring changes in the relative distribution from warehouses to logistics businesses and the general population. J. Transp. Geogr. 83(2020).

Kuipers, B., Eenhuizen, J., 2004. A framework for the analysis of seaport-based logistics parks. In: Licheng, S., Notteboom, T. (Eds), Proceedings of the 1st international conference on logistics strategies for ports. Dalian: Dalian University Press, 151–171.

Notteboom, T., Parola, F., Satta, G., Risitano, M., 2017. A taxonomy of logistics centres: overcoming conceptual ambiguity. Transp. Rev. 37(3), 276-299.

Notteboom, T., Rodrigue, J.-P., 2009. Inland Terminals within North American and European Supply Chains. Transp. and Commun. Bull. for Asia and the Pac. 78(1), 1-39.

NVM, 2020. Logistiek vastgoed in cijfers 2020. Retrieved from: https://www.nvm.nl/media/qfgb0u5i/logistiek-vastgoed-in-cijfers-2020.pdf, Accessed date: 28 May 2021.

Onstein, A.T.C., Ektesaby, M., Rezaei, J., Tavasszy, L.A., van Damme, D.A., 2020. Importance of factors driving firms' decisions on spatial distribution structures. Int. J. of Logist.: Res. and Appl. 23(1), 24-43.

Piepers, A., 2018. The definitive guide to pick-up points in Europe, Press Release, 2018. Retrieved from: https://www.paazl.com/blog/definitive-guide-pick-up-points-in-europe/, Accessed date: 13 September 2019.

Rijkswaterstaat, 2017. Database of 1686 distribution centres located in the Netherlands.

Sakai, T., Kawamura, K., Hyodo, T., 2017. Spatial reorganization of urban logistics system and its impacts: case of Tokyo. J. Transp. Geogr. 60, 110-118.

Sakai, T., Kawamura, K., Hyodo, T., 2019. Evaluation of the spatial pattern of logistics facilities using urban logistics land-use and traffic simulator. J. Transp. Geogr. 74, 145-160.

Vakulenko, Y., Hellström, D., Hjort, K., 2018. What's in the parcel locker? Exploring customer value in e-commerce last delivery. J. of Bus. Res. 88, 421-427.

Wagner, T., 2010. Regional traffic impacts of logistics-related land use. Transp. Policy 17(4), 224-229.

Weltevreden, J. W., 2008. B2c e-commerce logistics: the rise of collection-and-delivery points in The Netherlands. Int. J. of Retail & Distrib. Manag. 36(8), 638-660.

Woudsma, C., Jakubicek, P., Dablanc, L., 2016. Logistics sprawl in North America: methodological issues and a case study in Toronto. Transp. Res. Procedia 12, 474–488.

3 Factors determining distribution structure decisions in logistics: A literature review and research agenda

Onstein, A.T.C., Tavasszy, L.A., and van Damme, D.A. (2019). Factors determining distribution structure decisions in logistics: a literature review and research agenda, Transport Reviews, Vol. 39 No. 2, pp. 243-260.

Abstract
Distribution structures, as studied in this chapter, involve the spatial layout of the freight transport and storage system used to move goods between production and consumption locations. Decisions on this layout are important to companies as they allow them to balance customer service levels and logistics costs. Until now there has been very little research into the factors that drive decisions about these structures. Moreover, the literature on the topic is scattered across various research streams. In this chapter we review and consolidate this literature, with the aim to arrive at a comprehensive list of factors. Three relevant research streams were identified: Supply Chain Management (SCM), Transportation and Geography. The SCM and Transportation literature mostly focus on distribution structure including distribution centre (DC) location selection from a viewpoint of service level and logistics costs factors. The Geography literature focuses on spatial DC location decisions and resulting patterns, mostly explained by location factors such as labour and land availability. Our review indicates that the main factors that drive decision making are “demand level”, “service level”, “product characteristics”, “logistics costs”, “labour and land”, “accessibility” and “contextual factors”. The main trade-off influencing distribution structure selection is “service level” versus “logistics costs”. Together, the research streams provide a rich picture of the factors that drive distribution structure including distribution centre location selection. We conclude with a framework that shows the relative position of these factors. Future work can focus on completing the framework by detailing out the sub factors and empirically testing the direction and strength of relationships. Cooperation between the three research streams will be useful to further extend and operationalize the framework.

3.1 Introduction

In the context of globalization, many new international trade and transport flows have emerged during the past decades, introducing major logistics challenges to organize movements across large distances (Rodrigue, 2006). Products need to be transported to the right location, at the right time, in the right condition and for the right price. To meet these challenges, it is essential for companies – such as shippers and Logistics Service Providers (LSPs) - to create effective distribution structures, using transport and distribution centres in an optimal configuration. Distribution structures involve the spatial layout of the freight transport and storage system used to move goods between production and consumption locations. Goods can be distributed to the customer using direct transport or via one or more intermediate storage points. “Centralised” structures may include a single distribution centre location (Figure 3.1: Layout 2 and 3) or, sometimes, direct shipment is used (Figure 3.1: Layout 1). PC manufacturer Dell uses direct shipment to transport products to their private customers (Chopra, 2003). Furniture reseller IKEA uses a single distribution centre in The Netherlands to supply Dutch and Belgian stores.

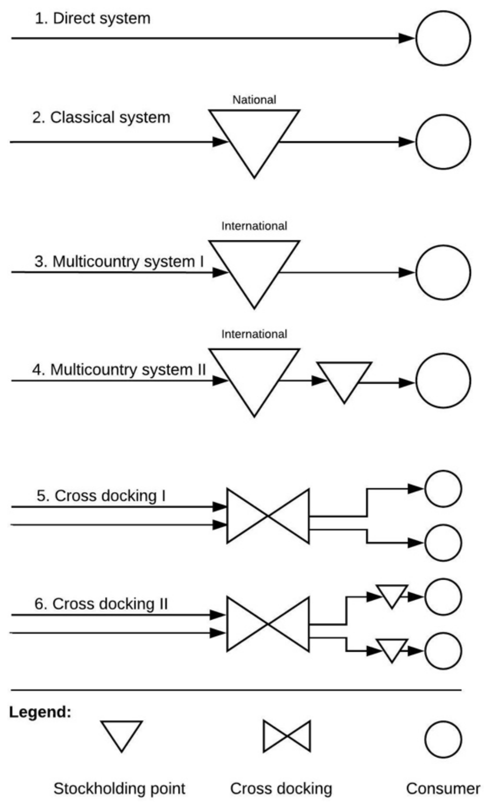


Figure 3.1 Alternative distribution structures. Triangles indicate the intermediate storage points (based on Kuipers & Eenhuizen, 2004)

“Decentralised” distribution structures include multiple distribution centre locations in a so-called multi-echelon system (Figure 3.1: Layout 4 and 6). A “multi-country system” includes an international distribution centre (DC) and a number of regional or local DCs. This distribution structure is used for example by the Dutch fashion retailer G-Star. The central DC is located in Amsterdam and is complemented by remote regional DCs located in e.g. USA, Asia, and Australia (Dohmen, 2017). Fashion shipper Zara recently decided to further decentralise distribution by adding a new DC in the Netherlands (op de Woerd, 2017). Online shipper Amazon aims at a heavily decentral structure with 1300 local distribution centres near European cities (EcommerceNews, 2017). Our chapter deals with the factors behind these decisions.

Knowing the important decision making factors enables companies to select their optimal distribution structure including DC location(s). This is important for several reasons. First, a good structure is essential to meet customer service levels, for example, by delivering the right product on time (Lambert & Stock, 1993; Van Thai & Grewal, 2005; Christopherson & Belzer, 2009). Second, good decisions can reduce logistics costs by bundling goods or reducing inventory (Korpela & Tuominen, 1996). Third, it helps companies to adapt to rapid changes in consumer preferences. Fourth, distribution structure selection is a strategic decision that asks for substantial investments. From a public policy perspective, knowledge on decision making factors can help policy makers to better predict DC location patterns, which facilitates the design of sustainable transport policies (Klauenberg, Elsner, & Knischewski, 2016). Knowing the important factors can also improve the quality of DC location optimization models – which are criticised for omitting relevant location factors or having incorrect factor weights (Mangiaracina, Song, & Perego, 2015).

It is surprising that despite this obvious need, knowledge on the factors of importance actually used by companies is scarce. It has been known for some time from the logistics literature that many factors may drive decision making on distribution structures, e.g. logistics costs factors, including transport costs, inventory costs and handling costs; service level factors including delivery lead time and delivery reliability; and local attractiveness factors for warehouse settlements (McKinnon, 1984). Also, trade-offs between some of these factors have been documented. High inventory costs influence companies to select centralised distribution structures because this minimises the number of storage locations. High transport costs influence companies to select decentralised distribution structures – including regional DC locations - as this minimises transport distances. Beyond these broad notions, however, the literature on the topic is limited. A comprehensive list of factors rooted in empirical or theoretical research is lacking. The existing literature on the topic is mainly normative, directed at optimization (Mangiaracina et al., 2015). Little descriptive research, i.e. on how companies actually make their decisions, has been performed (Verhetsel et al., 2015). Notable exceptions are McKinnon, 1984; Jakubicek & Woudsma, 2011; Van den Heuvel et al., 2013; Verhetsel et al., 2015. This descriptive work is, however, mostly confined to specific aspects or a single industry sector. We have not found any work that differentiates between types of companies, e.g. shippers and LSPs. Descriptive literature on the processes – and process related factors - that companies follow to arrive at these decisions is scarce as well.

This chapter reviews the literature about factors that drive decision making on distribution structures, i.e. including distribution centre locations. A literature review can add value to academic discussion in several ways: it can identify gaps in literature, reflect on dominant methodologies or theories, or outline knowledge available for practical applications (van Wee & Banister, 2015). We compare the research methods and findings of three relevant research streams that were identified in the literature - Supply Chain Management (SCM; here including the broad Operations Research literature), Transportation (Freight transport modelling) and Geography (including Economic geography) – and accordingly identify research gaps. The main research question for the literature review is: *Which factors determine companies' decisions on distribution structures?*

The chapter is organised into five sections. Section 3.2 describes the review approach. In section 3.3 we present and discuss the results of the review by research stream. Section 3.4 synthesises the results across research streams and proposes a framework that includes findings from all three directions. Section 3.5 includes conclusions and recommendations for further research.

3.2 Review approach

We used the Systematic Literature Review (SLR) method to identify, select and analyse relevant literature. The SLR method aims to be transparent and complete in selecting and analysing literature (Colicchia & Strozzi, 2012). Following the SLR methodology, a brainstorm with transport scholars resulted in several keywords to search for relevant literature, e.g. distribution structures and distribution centre locations. The brainstorm consisted of two rounds, a first round with five PhD students in the area of transportation & logistics and a second round with an assistant professor and professor of logistics. After the brainstorm rounds we constructed several strings to search for relevant literature, e.g. distribution structure, distribution structure, distribution centre location, logistics facilities location, warehouse location, storage location, depot location and firm location. To also identify literature on process related factors, we included strings combined with the terms “decision making” and “process”.

The literature has been selected by using Boolean logic. We evaluated literature references and “cited by” references – known as backward and forward snowballing (van Wee & Banister, 2015) - for relevance. Search engines of Web of Science, Google Scholar and Transportation Research International Documentation (TRID) were used, complemented by literature obtained via our academic network. Most literature was published in scientific journals. We minimised usage of conference proceedings. Selected articles stem from the 1980s until 2017. The literature identified originated from all geographic areas since distribution structure and DC location selection are highly international affairs. No reasons were found to exclude geographical areas. In total, over 100 articles were reviewed. Eventually, we identified three distinct streams of literature related to our subject - Supply Chain Management, Transportation and Geography. These streams have natural differences in focus; we describe these foci and classify papers further according to the relevant research topics within each research stream. Cross-research stream comparisons are made according to the following classification criteria:

- Emphasis on level of centralisation or on distribution centre location selection;
- Descriptive versus prescriptive research approach;
- Comparison of the research methods used.

3.3 Review results

Three relevant research streams were identified during the literature review: Supply Chain Management, Transportation and Geography. As expected, the SCM research field provides the earliest and most extensive coverage of the topic. The other streams have adopted insights from SCM for mostly descriptive purposes. We discuss the findings, research methods, strengths and limitations of each research stream, followed by a synthesis of relevant factors and discussion of commonalities and differences between them.

3.3.1 Supply Chain Management

Decision-making on distribution structures including DC locations is an important research topic in the SCM research stream, as decisions influence logistics costs and service levels along the supply chain. Frequently recurring factors include demand characteristics (temporal and spatial patterns), logistics service level, logistics costs (transport, inventory, warehousing) and product characteristics.

- In cases of high volume and spatially dispersed product demands, multiple distribution centres can be used because economies of scale reduce transport costs; also this allows fast deliveries (high service). Here, companies will choose a decentralised distribution structure (McKinnon, 1984).
- In the context of distribution structures, the main service level dimension is lead time or delivery time. In general, decentralised distribution structures with multiple distribution centre locations shorten delivery times but increase logistics costs, i.e. a trade-off exists between the required service level and logistics costs (Christopher, 2011). Depending on the product, customers are willing to accept shorter or longer delivery times (Chopra, 2003).
- Logistics costs include transport costs, inventory costs and warehousing costs (handling, storage). The trade-off between logistics cost categories will indicate the optimal number of distribution centres (Figure 3.2).

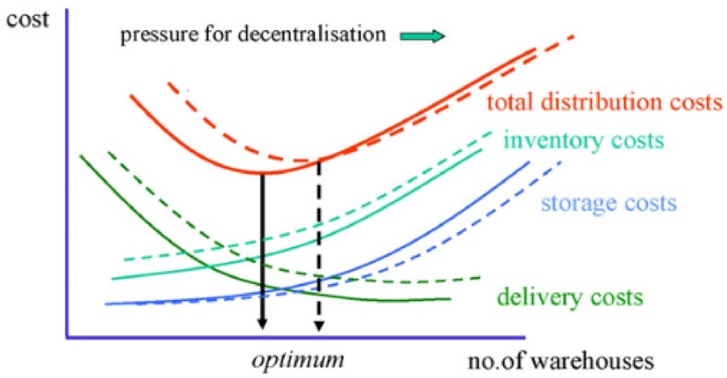


Figure 3.2 Distribution structure optimisation (McKinnon, 2009, p. S297)

- High outbound transport costs will drive companies to decentralised distribution structures, and high inventory costs towards the opposite. Changes in, amongst others, interest rates and unit transport costs will influence this trade-off (Ashayeri & Rongen, 1997; Christopher, 2011; Chuang, 2002).
  - o A closer look at the trade-off between inventory costs and transport costs shows that companies can reduce inventory costs by centralising their distribution operations. An important concept in the spatial concentration of inventory is the 'square root law of inventory' (SRL) which is a quick approximation for inventory savings. The square root law states that the change ratio in safety stock of a product is proportional to the square root of the change ratio in number of stock locations, mainly due to risk pooling (Maister, 1976). For example, centralisation from 10 stock locations to one stock location would reduce inventories by 68%. The trade-off is that outbound transport costs will be higher because transport distances are larger and faster transportation is needed to

achieve customer service levels. Note that this law has not remained undisputed (see e.g. Das, 1978; Zinn et al., 1989) and that cost savings resulting from inventory centralisation may also exist for cycle stocks due to economies of scale (see e.g. Baumgartner et al., 2012).
    - Another mechanism is that the degree of centralisation (the number of warehouses) of a company's distribution system influences the locations of the warehouses. For example, a distribution design including single national DC will result in another warehouse geography than a design including five regional DCs. Arguments for centralisation are higher product availability, fewer inventories needed to ensure a customer service level, and less warehousing operations (McKinnon, 1984).
- The fourth major factor involves the product characteristics value density and packaging density. Products with high value and packaging density are typically stored centrally to minimise inventory and handling costs (Christopher, 2011). In another direction, Fisher (1997) distinguishes between functional and innovative products. Functional products are standardised, low-value products that satisfy basic needs, requiring fast and frequent delivery. These products are often distributed using decentralised distribution. Innovative products have opposite characteristics and are often stored centrally, possibly in combination with cross-dock DCs - in which goods are directly reconsolidated for fast transport to customers.

The SCM literature perceives the choice of distribution structure as an isolated decision of an individual shipper. Chopra (2003) developed a distribution network design framework based on product characteristics, but also on network requirements such as response time and returnability. Key decision choices are 1) direct customer delivery versus customer pick up, and 2) usage of intermediaries or intermediate locations. (Dis)advantages of different distribution network designs are discussed. Earlier, Picard (1982) identified the pros and cons of distribution structures used by multinationals. Both studies analyse traditional distribution structures, for example the "Direct system" from manufacturer to the customer. In the current e-commerce era, companies also use combinations of distribution structures to deliver retail stores as well as customer's homes. Therefore, it would be interesting to expand the current frameworks by analysing the strengths and limitations of combinations of traditional distribution structures. Meixell and Gargeya (2005) reviewed global supply chain design models and their relation with supply chain globalisation issues. The authors conclude that few supply chain models have a comprehensive approach that includes outsourcing and supply chain integration. Today, shippers often (partly) outsource distribution activities to LSPs, which implies other factor weights to model to support distribution structure decisions. For example, a shipper that partly outsources distribution to an LSP will stronger value factors such as service level and logistics costs in their distribution structure decisions, but gives less value to the exact locations of LSPs' distribution centres being part of their distribution structure. Korpela, Lehmusvaara and Tuominen (2001) designed a framework to incorporate companies' strategy and service objectives in supply chain design or supply chain optimisation.

The SCM research stream mainly focuses on prescriptive DC location models that have a quantitative nature. Most applied research uses methods from Operations Research (OR) that identify optimal DC locations from a cost perspective under service quality restrictions. Reese (2006) presents an overview. Two types of facility location models exist: discrete and continuous facility location models (also see Ballou, 1992). Continuous facility location models start with macroeconomic variables. There are no restrictions on the number of potential locations. Discrete facility location models assume a finite set of potential locations, for p facilities optimal locations according to minimal total logistics costs are calculated. Continuous facility location models can be used in case a company aims to redesign their total distribution structure. Discrete facility location models can be used in case a company already has selected a set of potential DC locations. Extensions of these basic approaches are manifold. Dynamic and stochastic models exist, taking into account future uncertainties such as relocation possibilities. Modelling relocation possibilities gained importance since the number of large land plots decreased. Besides network optimization models to find the best location, selection methods have been proposed based on Multi-Criteria Decision Analysis (Demirel, Demirel, & Kahraman, 2010).

Concerning decision making processes and process related factors, we identified only seven SCM studies (Table 3.1), mainly with a normative view towards the distribution structure design process. The studies can be characterized by the scope of the process, its structure, and its methods.

- The scope of the decision making process influences the companies' distribution structure decision. Differences in scope mostly relate to the start of the process to arrive at a design. McKinnon's (1984) model starts with marketing channel selection. Ashayeri and Rongen's (1997) model starts with an analysis of expected goods flows. Christopher W. Steel (CWS) Consulting Group et al. (2011) start decision making with the business strategy (see also Treacy & Wiersema, 1993). Various terms are used for the distribution structure analysis – e.g. "modelling DC network scenarios" (CWS Consulting Group et al., 2011) or 'determine the number of DCs' (Gill & Ishaq Bhatti, 2007).

Table 3.1 Decision making process steps in the literature

Author(s)	Process steps
McKinnon (1984)	1) Marketing channel selection 2) Logistics channel analysis (nodes, areas, routes) 3) Logistics channel choice
Ashayeri & Rongen (1997)	1) Goods flow analysis 2) Goods flow scenarios 3) Physical distribution costs analysis 4) Minimal transport costs per mode and country 5) Determination potential DC locations based on goods flow scenarios 6) Optimisation DC location choice 7) Evaluation (sensitivity analysis)
Chuang (2002)	1) Community location requirements survey 2) Confrontation requirements and location characteristics 3) Quality Function Deployment (QFD)
Gill & Ishaq Bhatti (2007)	1) Determine the number of DCs 2) Determine DC locations 3) Capacity allocation per DC
CWS Consulting Group et al. (2011)	1) Business strategy 2) Modelling DC network scenarios 3) Location screening (weighted ranking)

	4) Field validation (on-site) 5) Discussion and negotiation
Korpela & Tuominen (1996)	Analytic Hierarchy Process decision aid: 1) Problem definition 2) Possible warehouse locations 3) Qualitative criteria and logistics cost analysis 4) Best alternative (cost benefit ratio)
van Thai & Grewal (2005)	Three step prescriptive DC location decision making model: 1) Selection geographic area 2) Potential locations 3) Determine location choice by distribution costs optimisation

- Concerning the structure, Ashayeri and Rongen (1997) propose a cyclical and iterative process, whereas others, for example Chuang (2002), propose a linear process. In practice, such strategic decisions usually take multiple decision making and negotiation rounds. Each round influences the decision outcome (Koppenjan & Klijn, 2004).
- The reviewed models are found to include combinations of quantitative and qualitative methods. For example, in the CWS Consulting Group et al. (2011) model, different distribution structure scenarios are modelled (quantitative). After deciding on the distribution structure, site selection criteria are discussed, followed by location screening and negotiations on potential locations (qualitative). Chuang's process step model (2002) is a prescriptive model including company community participation, i.e. customers, suppliers and employees are surveyed on DC location requirements. In this model, community participation is an influencing process-related factor.
- The two studies by Korpela and Tuominen (1996) and Van Thai and Grewal (2005) include prescriptive models to select DC locations, but do not include the broader distribution structure choice (centralised/decentralised). In contrast to the other studies, both studies do agree on the process sequence.

In summary, important strengths of the SCM research stream include its focus on decision support and the consideration of a broad set of factors including logistics costs, service level and their trade-offs. There are, however, also several limitations. The applicability of OR location models in DC location decision making has been under debate for some time (Melo, Nickel, & Saldanha-da-Gama, 2009). First, in order to best support DC location decisions knowledge is needed on the factors that matter for DC locations. Little knowledge is available and this has not been used in normative models. Second, not all factors in location decisions can be modelled. There is a lack of modelling qualitative location factors – which also drive DC location decisions (Bowen, 2008; Dablanc & Ross, 2012). Third, assumptions on cost factors in these models are often unrealistically simple (e.g. setup costs are assumed equal in urban and rural areas) to make calculation possible. Friedrich (2010), to our knowledge, is the only model, based on many factors, that is able to reproduce rather accurately the settlement pattern of DCs of four major retail chains in Germany. Fourth, models often focus on a single product although often an extensive product variety has to be serviced by a single distribution structure (Melo et al., 2009). Fifth, the validation of prescriptive models is most often lacking, in terms of the predicted versus the realised performance of a model solution.

3.3.2 Transportation

The transportation research stream mainly focuses on descriptive, quantitative models that predict freight flows from the tradition of transportation engineering. With this aim in mind it has an interest to understand future spatial distribution patterns including the underlying mechanisms, from a descriptive viewpoint. Limited in the 90's to a "pick-up" factor to calculate additional trip kilometres driven in indirect movements, since recently, modelling efforts have moved towards describing the formation of spatial distribution structures. Transportation models build on the behavioural assumption that companies minimise generalized logistics costs (inventory, transport, and handling). Factors assumed to be important match well with the factors from the SCM research stream. At the same time, certain logistics variables that are endogenous in SCM models, such as shipment size, are fixed in these models or not modelled explicitly. The implication of this is that these transportation research based models will have a limited representation of companies' actual behaviour responses to policies.

Transportation models exist at two levels: disaggregate (micro) and aggregate (macro). Disaggregate models focus on explaining decisions at the company level. Aggregate models describe flows for aggregate agents such as cities, regions and countries. A disadvantage of disaggregate models is that they are relatively data hungry, while aggregate models have a challenge in modelling the large heterogeneity in companies and their characteristics. Friedrich, Tavasszy and Davydenko (2014) give the latest state of the art review of distribution structures in freight transport models. The work of Friedrich (2010) is the most detailed in the description of factors for distribution structures at the company (micro) level. He includes a large number of factors for service level and logistics costs. Kim, Park, Kim and Lee (2010) present a discrete choice model for distribution channel choice in South Korea, however without a spatial dimension and not based on logistics costs. The SMILE model (Tavasszy, Smeenk, & Ruijgrok, 1998) uses an aggregate two stage choice process including enumeration of alternative channel choices conditional on actual locations. Jin, Williams and Shahkarami (2005) developed an aggregate model for DC location choice and freight predictions within the UK. Maurer (2008) also proposes a model for the UK, but from a normative perspective. Davydenko (2015) estimates a model for the Netherlands based on observations of use of DCs.

The transportation modelling discipline shows strengths and limitations. A strength is that the models are able to predict freight flows by modelling DC locations. This provides insights to policy makers in the evaluation of infrastructure investments and transport policies. A weakness is that until now the focus has been on simplified logistics models based on costs alone, disregarding the trade-off with service levels or connected decisions such as the choice of mode or shipment size. A second weakness is that models, especially those at larger spatial scale, lack the data needed to represent all freight flows, and therefore have to make many simplifying assumptions. Third, transportation models build on neoclassical behavioural assumptions, assuming rational behaviour, without explicitly modelling individual subjective and emotional factors.

3.3.3 Geography

The geography research stream – including economic geography – focuses on the analysis of spatial DC location patterns, as opposed to understanding the distribution structure selection processes. Leading works in this respect include McKinnon, 1984; Bowen, 2008; Dablanc, 2013; and Dablanc, Ogilvie, & Goodchild, 2014. The main factors that are studied in relation to DC location decisions focus on accessibility factors, labour and land conditions, and a wide array of contextual factors.

- Air accessibility and motorway network accessibility strongly influence the importance of USA metropolitan counties as distribution centre locations. Accessibility reduces logistics costs (Melachrinoudis & Min, 2000; Woudsma, Jensen, Kanaroglou, & Maoh, 2008). Rail accessibility has a minor influence on distribution centre location decisions in the USA (Bowen, 2008). Research in Greater Los Angeles shows that air transport access and motorway accessibility positively influence DC rents (Sivitadinou, 1996). In Belgium and the Netherlands, port accessibility was found to be an important factor (Kuipers & Eenhuizen, 2004; Verhetsel et al., 2015).
- A second important factor is labour and land availability (Hesse, 2004). Land availability influences distribution centres to disperse further from central areas. Peripheral areas are attractive because of lower land and labour costs (and thus lower warehousing costs), less traffic congestion, easier planning requirements (zoning) and future expansion capabilities (Hesse, 2004). DC operations require many warehouse employees which are not always available (as in some European regions).
- Contextual factors include taxes, labour union power, costs of doing business, cost of living, local economic incentives (Cidell, 2011, 2015; Hesse, 2004), international trade conditions (Van Thai & Grewal, 2005), presence of a business park (Warffemius, 2007), and costs of insurance policies (Melachrinoudis & Min, 2000). Companies, for example, locate a distribution centre near the border of a country, because recurring tax advantages are higher than additional transport costs. Contextual factors influence logistics costs as well as accessibility and labour & land availability. Customs, for example, can hinder DC accessibility (thereby increasing logistics costs). Zoning policies positively or negatively influence land availability (Cidell, 2011). Although Geography research stream provides detailed insights in location factors, it was found that logistics costs factors receive little attention.

Models used are descriptive and quantitative and focus on spatial areas as units of analysis, rather than on relations between DC locations and freight patterns as in the transportation literature. Woudsma et al. (2008) use spatial-autoregressive modelling (SAR) to investigate how transport system performance (T) influences logistics land use (LU). The TLU model tests the influence of several variables on logistics land use. An empirical model to explore location characteristics of warehouse and distribution (W&D) facilities in Greater Los Angeles has been developed by Sivitadinou (1996). Particularly, the relation between location characteristics and land rent has been modelled. Further research can investigate what are the spatial patterns of different DC types, for example international DCs versus urban DCs. Verhetsel et al. (2015) used a stated preference study to examine Flemish (Belgian) companies' "willingness to pay" for location characteristics. The authors included four accessibility variables - road, rail, inland navigation and port – but did not incorporate air accessibility, which is also known to influences DC location attractiveness (Warffemius, 2007). Cidell (2010) researched suburbanisation of warehousing in US metropolitan areas by analysing Economic Census data (1986 – 2005). Results show warehouse concentrations in few core counties. Currently, a major research topic

is logistics sprawl, or *"the spatial deconcentration of logistics facilities and distribution centers in metropolitan areas"* (Dablanc & Ross, 2012, p. 432). Recently, several works have appeared that calculate changes in DC barycentres (weighted geometric centre) in the megaregions of Paris "Ile-de-France" (Dablanc & Rakotonarivo, 2010), Los Angeles (Dablanc, 2014) and Seattle (Dablanc, 2014; Dablanc et al., 2014). Results show that the main tendency of DC locations is to sprawl outwards to peripheral (urban) zones.
The geography research reviewed does not provide process related literature on distribution structure including DC location selection. Dablanc and Rakotonarivo (2010) did, however, study influential decision-makers. Logistics location decisions are not only influenced by companies - such as shippers and LSPs - but also by developers, investors, government departments and local communities who supply logistics land. The role of investors cannot be neglected since investors own most DCs. Local communities can have a positive or negative opinion towards DC localisation (Cidell, 2011).

Economic geography focuses on business location decisions - e.g. office locations, production locations and retail locations – from a trade and location choice perspective. A vast literature exists on location theories – for an overview of classical, neoclassical and behavioural location theories we refer to Atzema, Lambooy, Van Rietbergen and Wever (2002). Few studies address the location(s) of distribution centres (Hesse & Rodrigue, 2004). Accessibility is one of the key drivers in DC location selection. Surprisingly, European Distribution Centres (EDCs) near Amsterdam Airport Schiphol rely more on road accessibility than on air accessibility (Warffemius, 2007). Agglomeration economies, however, influence EDCs to cluster around the airport. Agglomeration economies originate from e.g. a rich labour market, nearness of suppliers and information exchange (Idem, 2007). According to Rivera et al. (2016) there are many benefits of logistics clustering, these include a high availability of transportation services (e.g. more direct destinations) in the cluster, opportunities to collaborate on transportation and value added logistics services, and many career opportunities for logistics staff. Disadvantages of clustering are higher land prices, congestion, and negative externalities such as pollution. McCann (1998) studied industrial firm locations from a transaction cost and logistics cost approach and concludes that the influence of logistics costs in location decisions is underestimated.

In summary, the geography research stream is strong in analysing spatial location patterns, for which multiple research methods can be used. The geography research stream does not take into account the logistics decisions on distribution structures, including the related factors that lead to spatial settlements. Agglomeration as an important topic in economic geography has been studied qualitatively and with quantitative models. Economic geographic theories are criticised for not taking transaction costs into account (McCann & Mudambi, 2005). For example, the transaction costs of severance can influence companies to relocate within their current region.

3.4 Synthesis

This section presents a synthesis of the reviewed research streams. The research streams are compared on their main focus, research methods used, as well as the strengths and limitations of the research streams. The research streams differ in focus and diverse research methods are used (Table 3.2). SCM and Transportation focus on distribution structure selection, i.e. including DC locations. Geography focuses on spatial patterns of DC locations and Economic Geography studies location factors to explain DC locations. Supply Chain Management research stream includes the most literature; therefore most literature is normative (prescriptive).

Table 3.2 Main characteristics of the three research streams

	Main characteristics	Modelling methods	Strengths & limitations
Supply Chain Management	Prescriptive quantitative models Focus on distribution structures (level of centralisation) including DC locations	Facility location and network design models MCDA as decision support method	+ Detail on logistics costs and logistics trade-offs - Little reflection on descriptive validity - Little attention for descriptive DC location models
Transportation	Mainly descriptive and predictive quantitative models for larger areas Focus on distribution structures (level of centralisation) including DC locations	Disaggregate and aggregate freight transport models Discrete choice models Network design models	+ Describes large population of companies + Theory on transport decision making - Still few empirical models - Creating representative data for an entire area is a challenge
Geography	Descriptive research on spatial DC patterns Descriptive and predictive economic models Focus on DC locations	Spatial-economic descriptive analysis (SAR, centre of gravity) Applied NEG (spatial equilibrium) models	+ Spatial mapping of DC locations + Economic theories on industry behaviour and location choice - Hardly any empirical models on DC locations - No research on the influence of distribution structures (centralised / decentralised) on DC location selection

A clear gap in the academic literature is that it insufficiently links the decisive factors to the wide variety of distribution structures possible. The research streams do not use or provide an integrated framework of all factors that drive distribution structure including distribution centre location selection. Therefore, future cooperation between the research streams may be useful to explain companies' decision making. SCM and Transportation can support the framework with detailed insights in logistics costs factors, service level factors and the influence of product characteristics. Geography can provide knowledge on location related factors, e.g. labour costs and land costs, and contextual factors such as taxes. Our review indicates that the important factors that drive decision making can be consolidated into the following main categories: 1) demand level, 2) service level, 3) product characteristics, 4) logistics costs 5) labour and land availability 6) accessibility and 7) contextual factors. Factors 1-3 denote the demand side of companies – such as shippers - for distribution services, while factors 5-7 lie on the supply side to fulfil distribution structure demand. Table 3.3 provides a summary of the underlying factors.

Table 3.3 Main factors in the literature on decision making about distribution structures

Main factor	
1) Demand level factors	Demand volatility Spatial demand pattern
2) Service level factors	Lead time Flexibility Responsiveness Frequency of delivery Reliability of delivery
3) Product characteristics	Product value density Packaging density Inventory policy Production and sourcing locations
4) Logistics costs factors	Transport costs (inbound and outbound) Inventory costs Warehousing costs (incl. handling and storage) Interest (capital costs)
5) Labour and land availability	Labour costs Land costs Expansion capability
6) Accessibility	Distance to transport network by mode (road, air, sea, rail) Congestion
7) Contextual factors	Zoning laws, regulations and policies Presence of a business park Cost of living Cost of doing business Logistics real estate availability Local taxes and subsidies (incentives) International trade conditions Costs of insurance policies Customs performance Labour conditions

The factors in Table 3.3 influence each other in many different ways. From our literature analysis, we could derive the following basic framework with the main groups of factors and their interrelationships (Figure 3.3). The framework shows the factors and their interrelationships that appeared in the literature. New relationships and other factors might (and will) exist, but identifying these lies beyond the scope of this review.

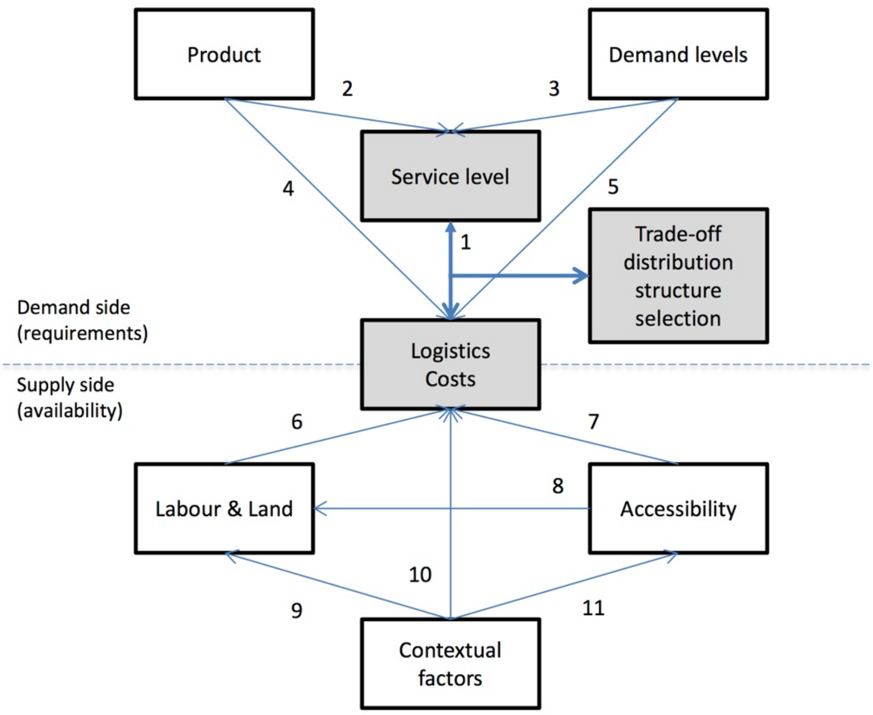


Figure 3.3 Framework of factors influencing distribution structure selection

Service level versus logistics costs is the main trade-off influencing distribution structure selection (arrow 1). Service requirements are influenced by the product characteristics (arrow 2, e.g. high value density will imply a preference for high speed) and the level of demand (arrow 3, e.g. high volatility will require flexibility and responsiveness). Logistics costs are influenced in different ways by the product type, the service level and demand levels. Inventory costs are sensitive to packaging and value density (arrow 4); transport costs respond to absolute demand levels and spatial patterns of customers (arrow 5). Naturally, the higher the required service levels, the higher transport costs will be (arrow 1). On the supply side of the services market, logistics costs are determined by available capacity of labour and land (arrow 6) and transport options (arrow 7). Accessibility influences labour availability by reducing interregional friction within the labour market (arrow 8). As explained before, the contextual factors identified have relations with accessibility, labour & land, and will also influence logistics costs directly (arrows 9-11). Future research could focus on:

- Other relationships than those already identified, for example bi-directionality in relationships 3 and 5, denoting elastic demand for services or costs, respectively.
- A more detailed and perhaps quantified framework including the underlying factors within these groups; this would need to be based on new material at a more detailed level.
- An extension of the framework by linking factors to a model of the decision process; noting, at the same time, that additional research is needed to develop a framework for process steps.

3.5 Conclusions and future research

This chapter provides a literature review on company decision making on distribution structures (i.e. the spatial layout of the freight transport and storage system used to move goods between production and consumption locations) including distribution centre locations by investigating three research streams: Supply Chain Management, Transportation and Geography. The main question of the literature review is: *Which factors determine companies' decisions on distribution structures?*

The main contribution of this review is that the decision making factors of distribution structure selection and DC location selection are reviewed simultaneously – a novel but imperative approach since distribution structure (centralised/decentralised) influences DC location selection. We have identified seven groups of factors and have drawn a framework that shows their interrelationships. These groups of factors are 1) demand level, 2) service level, 3) product characteristics, 4) logistics costs (transport costs, inventory costs and warehousing costs), 5) labour and land availability, 6) accessibility and 7) contextual factors.

Comparison of the research streams shows differences in focus and research methods. SCM and Transportation focus on distribution structure including DC location selection, whereas Geography only focuses on DC location selection. SCM mainly applies Operations Research (OR) techniques to calculate DC locations. The applicability of SCM models is debated because it is impossible to model all decision making factors and it is unknown whether companies take rational location decisions based on SCM models. Transportation models show similar limitations as SCM models. The geography research stream is strong in analysing spatial patterns of DC locations (barycentre analysis). Logistics sprawl – i.e. the spatial deconcentration of logistics activities – has recently become an important research area because of the negative externalities caused by sprawl, e.g. noise, congestion and emissions. Economic geography studies focus on cluster theory, i.e. economic activities cluster because of agglomeration economies, for example a thick labour market. In conclusion, little overlap exists in the research methods used by the three research streams.

Literature on the process steps and process related factors influencing distribution structure selection is an unexplored research field, mainly studied by SCM. Our main conclusion is that there is no consensus in the literature on the process steps followed by companies (descriptive) or should optimally be followed (prescriptive) in distribution structure decision-making. Process start and process sequence are contested as well. Process step models encompass quantitative as well as qualitative elements. Quantitative elements, such as Centre of Gravity (CoG) models, are often used to support DC location selection. Qualitative elements include e.g. discussions and negotiations on potential locations. Differences in the scope of these processes and the methods used are factors that influence the distribution structure outcome. The influence of community participation in decision making is another process related factor. The reviewed process models have linear sequence. In practice, however, strategic decision making is an iterative process. Therefore, we argue that the proposed process models can be improved by including more feedback loops.

The review may help practitioners with an end-to-end perspective on the factors that drive distribution structure including DC location selection and help them to make better, i.e. cost-efficient, decisions. We derive several opportunities for future research:

- Frameworks of influence relationships are mostly rooted in SCM, and were adopted by the transportation and geography literature, without questioning, however, their validity in a descriptive setting. Research into actual choice behaviour of companies may shed light on their empirical validity. Different types of companies may need to be distinguished. The current literature provides no lead as to differences in factors among different types of companies.
- Together, the research streams do not provide an integrated framework of all factors that drive distribution structure including distribution centre location selection. To build this framework, future cooperation between the three research streams is needed. SCM and Transportation can support the framework with detailed insights in logistics costs factors, service level factors and the influence of product characteristics. Geography and Economic Geography can contribute by providing knowledge on location related factors (e.g. labour costs and land costs) and contextual factors (e.g. taxes).
- We discuss the influencing relations between the major groups of factors as they appear in the literature. Further work can focus on completing the framework by detailing out the sub factors and empirically testing the direction and strength of relationships.
- Logistics sprawl is an upcoming research topic for Geography scholars. Future Geography research should, however, give more attention to the factors that drive DC location decisions, since this will help to better understand why logistics activities are sprawling. Geography traditionally has a focus on location factors. Thus, to explain sprawl, more research into logistics costs factors and logistics trade-offs is needed. It would also be useful to investigate whether different types of distribution centres are sprawling. Urban distribution centres, for example, can be expected to demonstrate sprawl within the city agglomeration, while crossdock facilities are expected to sprawl from the city region to highly accessible locations in the periphery.
- Although this chapter reviewed decision making from company (e.g. shippers and LSPs) perspective, other actors also influence logistics location decisions, e.g. real estate developers, investors, government departments and local communities. Future research should therefore investigate to what extent these actors influence decision making.

References

Ashayeri, J., & Rongen, J. M. J. (1997). "Central Distribution in Europe: A Multi-Criteria Approach to Location Selection". *The International Journal of Logistics Management, 8*(1), 97 – 109.

Atzema, O. A. L. C., Lambooy, J. G., van Rietbergen, A., & Wever, E. (2002). *Ruimtelijke Economische Dynamiek: kijk op bedrijfslocatie en regionale ontwikkeling*. [Spatial Economic Dynamics: view on firm location and regional development]. Bussum: Coutinho.

Ballou, R. H. (1992). *Logistics Management*. Schoonhoven: Academic Service.

Baumgartner, K., Fuetterer, A., & Thoneman, U. W. (2012). Supply chain design considering economies of scale and transport frequencies. *European Journal of Operational Research, 218*(2012), 789-800.

Bowen, J. (2008). Moving places: the geography of warehousing in the US. *Journal of Transport Geography, 16*(6), 379–387.

Chopra, S. (2003). Designing the distribution network in a supply chain. *Transportation Research Part E: Logistics and Transportation Review*, *39*(2), 123–140.

Christopher, M. (2011). *Logistics and Supply Chain Management (4th Edition)*. Harlow: Pierson Education Limited 2011.

Christopher W. Steel (CWS) Consulting Group, HDR Engineering, Fitzgerald, & Halliday, Halcrow, Resource Systems Group (2011). *Background Research Material for Freight Facility Location Selection: A Guide for Public Officials* (Report No. 13). National Cooperative Freight Research Program. Washington: Transportation Research Board.

Christopherson, S., & Belzer, M. (2009). The next Move: Metropolitan Regions and the Transformation of the Freight Transport and Distribution System. In N. Pindus, H. Wial & H. Wolman (Eds.), *Urban and Regional Policy and its Effects* (pp. 194–222). Washington: Brookings.

Chuang, P. T. (2002). "A QFD approach for distribution's location model". *International Journal of Quality & Reliability, 19*(8/9), 1037–1054.

Cidell, J. (2010). Concentration and decentralization: the new geography of freight distribution in US metropolitan areas. *Journal of Transport Geography*, *18*(3), 363–371.

Cidell, J. (2011). Distribution Centers among the Rooftops: The Global Logistics Network Meets the Suburban Spatial Imaginary. *International Journal of Urban and Regional Research, 35*(4), 832–851.

Cidell, J. (2015). Distribution centers as distributed places: Mobility, infrastructure and truck traffic. In T. Birtchnell, S. Savitzky & J. Urry (Eds.), *Cargomobilities: Moving Materials in a Global Age* (pp. 17–34). New York, NY: Routledge.

Colicchia, C., & Strozzi, F. (2012). Supply chain risk management: a new methodology for a systematic literature review. *Supply Chain Management: An International Journal*, *17*(4), 403–418.

Dablanc, L. (2013, October). "Logistics sprawl:" the growth and decentralization of warehouses in the L.A. area. Paper presented at the meeting of 5th International Urban Freight Conference, Long Beach.

Dablanc, L. (2014). Logistics Sprawl and Urban Freight Planning Issues in a Major Gateway City: The Case of Los Angeles. In J. Gonzalez-Feliu, F. Semet & J.-L. Routhier (Eds.), *Sustainable Urban Logistics: Concepts, Methods and Information Systems* (pp. 49–69). Berlin Heidelberg: Springer-Verlag.

Dablanc, L., Ogilvie, S., & Goodchild, A. (2014). Logistics Sprawl: Differential Warehousing Development Patterns in Los Angeles and Seattle. *Transportation Research Record: Journal of the Transportation Research Board*. Washington (2410), 105–112.

Dablanc, L., & Rakotonarivo, D. (2010). The impacts of logistic sprawl: How does the location of parcel transport terminals affect the energy efficiency of goods' movements in Paris and what can we do about it? *Procedia Social and Behavioral Sciences, 2*, 6087–6096.

Dablanc, L., & Ross, C. (2012). Atlanta: a mega logistics center in the Piedmont Atlantic Megaregion (PAM). *Journal of Transport Geography, 24*(2012), 432–442.

Das, C. (1978). A Reappraisal of the Square Root Law. *International Journal of Physical Distribution & Logistics Management, 8*(6), 331-336.

Davydenko, I. Y. (2015). *Logistics Chains in Freight Transport Modelling* (Doctoral dissertation). Retrieved from https://repository.tudelft.nl.

Demirel, T., Demirel, N.Ç., & Kahraman, C. (2010). Multi-criteria warehouse location selection using Choquet integral. *Expert Systems with Applications, 37*, 3943–3952.

Dohmen, P. (2017, March 28). *Interview P. Dohmen, Logistics Director Worldwide*, G-Star.

EcommerceNews. (2017). Amazon is looking for 1,300 warehouses across Europe. *EcommerceNews*. Retrieved from https://ecommercenews.eu.

Fisher, M. L. (1997). What is the Right Supply Chain for Your Product? *Harvard Business Review, 75*(March April), 105–116.

Friedrich, H. (2010). *Simulation of logistics in food retailing for freight transportation analysis* (Doctoral dissertation). Retrieved from https://publikationen.bibliothek.kit.edu

Friedrich, H., Tavasszy, L. A., & Davydenko, I. Y. (2014). Distribution structures. In L. A. Tavasszy & G. de Jong (Eds.), *Modelling Freight Transport* (pp. 65–88). London: Elsevier.

Gill, A., & Ishaq Bhatti, M. (2007). Optimal model for warehouse location and retailer allocation. *Applied Stochastic Models in Business and Industry, 23*(3), 213–221.

Hesse, M. (2004). Land for logistics: locational dynamics, real estate markets and political regulation of regional distribution complexes. *Tijdschrift voor economische en sociale geografie*, *95*(2), 162–173.

Hesse, M., & Rodrigue, J.-P. (2004). The transport geography of logistics and freight distribution. *Journal of Transport Geography, 12*(2004), 171 - 184.

van den Heuvel, F. P., de Langen, P. W., van Donselaar, K. H., & Fransoo, J. C. (2013). Spatial concentration and location dynamics in logistics: the case of a Dutch province. *Journal of Transport Geography, 28*(2013), 39–48.

Jakubicek, P., & Woudsma, C. G. (2011). Proximity, Land, Labor and Planning? Logistics industry perspectives on facility location. *Transportation Letters: The International Journal of Transportation Research, 2*, 161–173.

Jin, Y., Williams, I., & Shahkarami, M. (2005, October). Integrated regional economic and freight logistics modelling: Results from a model for the Trans-Pennine Corridor, UK, Paper presented at the European Transport Conference, Strasbourg, France.

Kim, E., Park, D., Kim, C., & Lee J.-Y. (2010). A New Paradigm for Freight Demand Modeling: The Physical Distribution Channel Choice Approach. *International Journal of Urban Sciences. 14*(3), 240–253.

Klauenberg, J., Elsner, L.-A., & Knischewski, C. (2016). Dynamics in the spatial distribution of hubs in groupage networks - the case of Berlin. Paper presented at the World Conference on Transport Research, Shanghai, China.

Koppenjan, J. F. M., & Klijn, E. H. (2004). *Managing uncertainty in networks; a network approach to problem solving and decision making.* London: Routledge.

Korpela, J., Lehmusvaara, A., & Tuominen, M. (2001). Customer service based design of the supply chain. *International Journal of Production Economics, 69*(2), 193–204.

Korpela, J., & Tuominen, M. (1996). A decision aid in warehouse site selection. *International Journal of Production Economics*, *45*(1), 169–180.

Kuipers, B., & Eenhuizen, J. (2004, September). A framework for the analysis of seaport-based logistics parks. In S. Licheng & T. Notteboom (Eds.), *Proceedings of the 1st International Conference on Logistics Strategies for Ports* (pp. 151–171). Dalian, Dalian University Press.

Lambert, D. M., & Stock, J. R. (1993). *Strategic Logistics Management*. Boston: Irwin Homewood.

Maister, D. H. (1976). Centralisation of Inventories and the "Square Root Law". *International Journal of Physical Distribution, 6*(3), 124-134.

Mangiaracina, R., Song, G., & Perego, A. (2015). Distribution network design: a literature review and a research agenda. *International Journal of Physical Distribution & Logistics Management, 45*(5), 506–531.

Maurer, H. (2008). *Development of an Integrated Model for Estimating Emissions from Freight Transport* (Doctoral dissertation), The University of Leeds, Institute for Transport Studies. Retrieved from http://www.its.leeds.ac.uk

McCann, P. (1998). *The Economics of Industrial Location. A Logistics-Costs Approach*. Berlin Heidelberg: Springer-Verlag.

McCann, P., & Mudambi, R. (2005). Analytical differences in the economics of geography: the case of the multinational firm. *Environment and Planning A, 2005*(37), 1857–1876.

McKinnon, A. C. (1984). *The Spatial Organization of Physical Distribution in the Food Industry* (Doctoral dissertation). University College London, London. Retrieved from http://discovery.ucl.ac.uk/view/theses/

McKinnon, A. C. (2009). The present and future land requirements of logistical activities. *Land Use Policy, 26S*(2009), S293–S301.

Meixell, M. J., & Gargeya, V. B. (2005). Global supply chain design: A literature review and critique. *Transportation Research Part E: Logistics and Transportation Review*, *41*(6), 531–550.

Melachrinoudis, E., & Min, H. (2000). The dynamic relocation and phase-out of a hybrid, two-echelon plant/warehousing facility: A multiple objective approach. *European Journal of Operational Research, 123*(1), 1–15.

Melo, M. T., Nickel, S., & Saldanha-da-Gama, F. (2009). Facility location and supply chain management – A review. *European Journal of Operational Research*, *196*(2009), 401–412.

op de Woerd, M. (2017, July 3). Hoe Flevoland modereus Zara als eerste uit Spanje lokte [How Flevoland Drove Fashion Giant Zara out of Spain first]. *Trouw*. Retrieved from https://www.trouw.nl/

Picard, J. (1982). Typology of Physical Distribution Systems in Multi-national Corporations. *International Journal of Physical Distribution & Materials Management, Vol. 12*(6), 26–39.

Reese, J. (2006). Solution Methods for the p-Median Problem: An Annotated Bibliography. *Networks, 48*(3), 125–142.

Rivera, L., Gligor, D., & Sheffi, Y. (2016). The benefits of logistics clustering. *International Journal of Physical Distribution & Logistics Management, 46*(3), 242-268.

Rodrigue, J.-P. (2006). Transportation and the Geographical and Functional Integration of Global Production Networks. *Growth and Change*, *37*(4), 510–525.

Sivitadinou, R. (1996). Warehouse and distribution facilities and community attributes: an empirical study. *Environment and Planning A, 1996*(28), 1261–1278.

Tavasszy, L. A., Smeenk, B., & Ruijgrok, C. J. (1998). A DSS For Modelling Logistics Chains in Freight Transport Policy Analysis. *International Transactions in Operational Research 5*(6), 447–459.

van Thai, V., & Grewal, D. (2005). Selecting the location of distribution centre in logistics operations: A conceptual framework and case study. *Asia Pacific Journal of Marketing and Logistics*, *17*(3), 3–24.

Treacy, M., & Wiersema, F. (1993). Customer intimacy and other value disciplines. *Harvard Business Review*, *71*(1), 84–93.

Verhetsel, A., Kessels, R., Goos, P., Zijlstra, T., Blomme, N., & Cant, J. (2015). Location of logistics companies: a stated preference study to disentangle the impact of accessibility. *Journal of Transport Geography, 42*(2015), 110–121.

Warffemius, P. M. J. (2007). *Modeling the Clustering of Distribution Centers around Amsterdam Airport Schiphol: location endowments, economies of agglomeration, locked-in logistics and policy implications* (Doctoral Dissertation), Erasmus University Rotterdam, Rotterdam. Retrieved from https://repub.eur.nl

van Wee, B., & Banister, D. (2015). How to Write a Literature Review Paper? *Transport Reviews, 36*(2), 278–288.

Woudsma, C., Jensen, J. F., Kanaroglou, P., & Maoh, H. (2008). Logistics land use and the city: A spatial–temporal modeling approach. *Transportation Research Part E, 44*(2), 277–297.

Zinn, W., Levy, M., & Bowersox, D. J. (1989). Measuring the Effect of Inventory Centralization / Decentralization on Aggregate Safety Stock: The “Square Root Law” Revisited. *Journal of Business Logistics, 10*(1), 1-14.

4 Importance of factors driving firms’ decisions on spatial distribution structures

Onstein, A.T.C., Ektesaby, M., Rezaei, J., Tavasszy, L.A. and van Damme, D.A. (2020). Importance of factors driving firms’ decisions on spatial distribution structures, International Journal of Logistics Research and Applications, Vol. 23 No. 1, pp. 24-43. DOI: 10.1080/13675567.2019.1574729.

Abstract
The design of a spatial distribution structure is of strategic importance for companies, to meet required customer service levels and to keep logistics costs as low as possible. Spatial distribution structure decisions concern distribution channel layout - i.e. the spatial layout of the transport and storage system - as well as distribution centre location(s). This chapter examines the importance of seven main factors and 33 sub-factors that determine these decisions. The Best-Worst Method (BWM) was used to identify the factor weights, with pairwise comparison data being collected through a survey. The results indicate that the main factor is logistics costs. Logistics experts and decision-makers respectively identify customer demand and service level as second most important factor. Important sub-factors are demand volatility, delivery time and perishability. This is the first study that quantifies the weights of the factors behind spatial distribution structure decisions. The factors and weights facilitate managerial decision-making with regard to spatial distribution structures for companies that ship a broad range of products with different characteristics. Public policy-makers can use the results to support the development of land use plans that provide facilities and services for a mix of industries.

4.1 Introduction

Distribution refers to the steps involved in the transportation and storage of goods, from supplier to customer in a supply chain (Chopra 2003). To meet the required service levels, it is of strategic importance for companies (e.g. shippers and logistics service providers - LSPs) to select the optimal distribution channel layout - i.e. the spatial layout of the transport and storage system - to serve customer needs and keep logistics costs low (Ashayeri and Rongen 1997; Baker 2006; Verhetsel et al. 2015). Together, the distribution channel layout and choice of distribution centre (DC) location(s) are known as the decision on spatial distribution structures. Figure 4.1 shows typical layouts. Products can be transported directly from the manufacturer (layout 1 in Figure 4.1), from central DC locations (layouts 2 and 3 in Figure 4.1), from cross-dock DCs (layout 5), or from multiple (regional or local) DC locations to the customer (layout 4 and 6). These configurations and DC locations will produce very different results in terms of customer order lead-time and various logistics cost components, including inventory costs and transport costs.

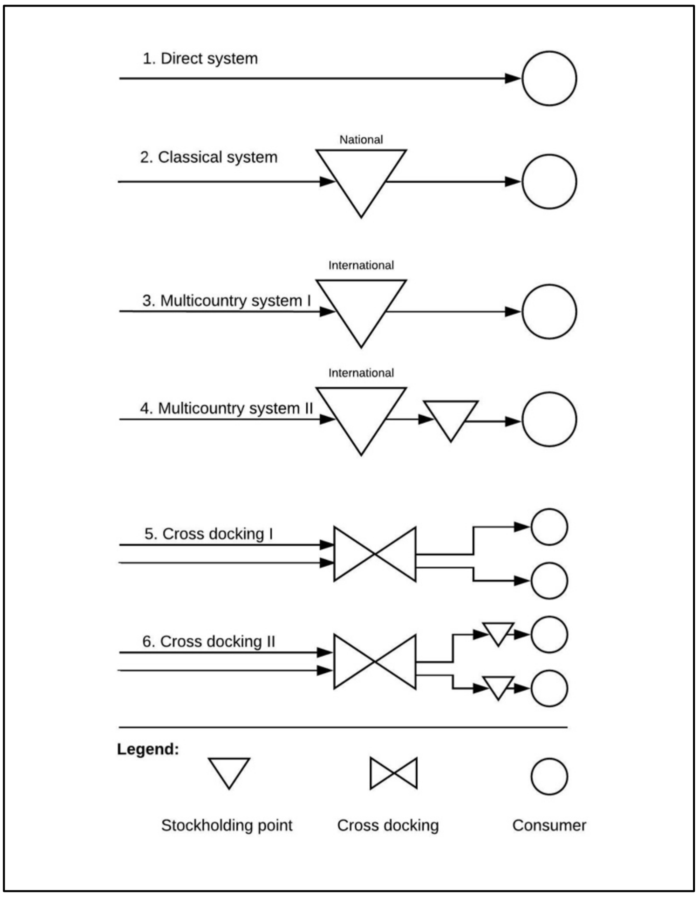


Figure 4.1 Distribution channel layouts (based on Kuipers and Eenhuizen 2004)

Spatial distribution structures are affected by a wide array of factors, ranging from customer requirements concerning service levels and delivery costs, to specific location attributes and the broader institutional environment in which the company has to operate (Picard 1982; Cooper 1984; McKinnon 1984; Korpela et al. 2001; Chopra 2003; Wanke and Zinn 2004). These factors affect decisions in a variety of ways. Volatile demand, for example, drives companies towards a central DC layout, allowing them to pool inventory risks, while high service level requirements, for example including same-day deliveries, drive companies towards a decentralized layout that allows them to cut delivery times. The aim of this chapter is to provide insight into the importance of the various factors involved in choosing the optimal spatial distribution structure. We examine whether there are factors of general importance to decision-makers - i.e. decision-makers affiliated to companies in diverse industries - and experts. Knowing these factors is particularly relevant when it comes to designing spatial distribution structures for companies shipping multiple products with diverse characteristics, for example low value and high value products. Our research can also help policy-makers develop land use plans designed to attract companies from diverse industries. Furthermore, our research should help scientists and consultants to improve DC location models, which often use incomplete factor sets or incorrect factor weights (Mangiaracina, Song, and Perego 2015). Despite a clear need for this type of knowledge, there is a lack of empirical research into the factors that drive companies' spatial distribution structure decision (Onstein et al. 2019). Traditional distribution network design models are prescriptive, often using optimisation methods to calculate the optimal distribution layout (Meixell and Gargeya 2005; Olhager, Pashaei and Sternberg 2015). Mangiaracina, Song, and Perego (2015), for example, found that only five out of 126 reviewed studies include empirical research. To the best of our knowledge, Song and Sun (2017) are the only authors to have developed and tested a descriptive framework (including 15 factors) on supply chain network design, looking at the factors behind combined supply chain functions, including sourcing, production and distribution locations, although not identifying the unique contribution these factors have on the distribution-related decisions. As such, our study is the first to address the importance of factors that exclusively determine the selection of a spatial distribution structure. Although the location choice for DCs has attracted more empirical research (e.g. Hesse 2004; McKinnon 2009; Dablanc 2013; van den Heuvel et al. 2013; Verhetsel et al. 2015), none of the studies involved includes all the relevant factors. Our study contributes to existing literature by identifying a holistic set of factors and by empirically testing their importance.

Our main research questions are: (1) *what are the main factors that determine companies' spatial distribution structure decision?* and (2) *how important are these factors, relative to each other?* To answer these questions, first, a descriptive framework was developed based on existing literature, after which the relative importance of the factors involved was measured, using the Best-Worst Method (BWM) to determine the factor weights. BWM is a suitable method to quantify factor weights, because it requires fewer pairwise comparison data than matrix-based multi-criteria decision-making methods (Rezaei 2015). An online survey was used to collect the data from two populations: 1) Decision-makers on spatial distribution structures and 2) Experts.

The remainder of the chapter is organised as follows. Section 4.2 reviews relevant literature and presents a set of factors that drive the selection of spatial distribution structures. In Section 4.3, the Best-Worst Method and the survey data collection procedure are addressed, while the results are discussed in Section 4.4, and the conclusions, practical implications, research limitations and suggestions for future research are presented in Section 4.5.

4.2 Decision factors

This section discusses the main factors and the underlying factors (sub-factors) on the basis of a systematic literature review. A summary of all the factors is presented in Table 4.2 at the end of this section.

We set up a systematic literature review panel (Tranfield, Denyer and Smart 2003), including a PhD student and two Logistics professors. The context of the literature review was spatial distribution structure selection. The selection criteria focus on spatial distribution structures, i.e. factors that drive distribution channel layout and distribution centre location selection. Studies that do not deal with factors driving the spatial distribution structure decision were excluded. Furthermore, only studies are included that aim to identify the factors or explain their influence. Studies that only list factors, for example, as a preparation for quantitative modeling, were not included. Several databases (i.e. ScienceDirect, Google Scholar, Emerald and Scopus) were used to search for specific keywords (i.e. spatial distribution structure, distribution channel layout, distribution network design, DC location, warehouse location, etc.) and strings – for example, 'factors distribution channel layout'. Backward snowballing and forward snowballing resulted in more relevant publications. 52 academic publications were selected for in-depth examination (40 papers, three PhD theses, three conference proceedings, four academic book chapters, one working paper and one Master thesis). The studies in question involve supply chain management, (economic) geography and transportation disciplines. The use of academic literature increases the validity of the factor selection, i.e. indicating that the factors being included are indeed important factors. The factors were selected from the publications either because they were listed in a table containing the influencing factors, or because they were mentioned in the text of the publication. Selecting factors from 52 studies can be problematic when there are differences in population or study context. However, when the importance of a factor is confirmed by multiple studies with different contexts and research methods (e.g. quantitative models, surveys, interview-based), it may be assumed that it is indeed an important factor (Rousseau, Manning and Denyer 2008).

We reduced the original literature-based list of 48 factors to a smaller set of 33 factors (Table 4.2), taking into account the time constraints related to filling out a survey. We selected 32 factors based on the number of literature references, i.e. factors with only one or two references (for example cost of living) were excluded. To validate the importance of the factors that were identified, nine experts were asked for their opinion on the 20 most important factors, 19 of which were already included in the set of 32 factors. Although the factor 'perishability' receives relatively little attention in relevant literature, it is added because six (of nine) experts argue that it is an important factor. All nine experts are decision-makers on spatial distribution structures or researchers with over five years of experience on spatial distribution structure selection in diverse industry sectors. The experts were selected from our own network and approached by email. Twenty experts were approached. Nine experts agreed to give their opinion. Seven out of nine experts are from academia and two out of nine experts from industry. Table 4.1 presents an overview of the experts' expertise.

Table 4.1 Expertise of logistics experts for factor validation

Expert	Expertise
1	Full professor Freight and Logistics and principal scientist with over 20 years of experience on research projects within diverse industries, e.g. automotive, fashion, food and aviation
2	Assistant professor Transport and Logistics, applied researcher and consultant with 18 years of experience in diverse industries, e.g. office retail sector, humanitarian supply chains and oil&gas
3	Assistant professor Transport and Logistics, experience with supervising MSc thesis in several industry sectors

4	Assistant professor Transport and Logistics, experience with research on location selection for city distribution centres
5	Assistant professor Operations and Supply Chain Management with over 10 years of experience on research projects in several industries, e.g. aviation, high-tech, tourism, oil&gas as well as research on facility location selection
6	Professor of Logistics and Operations Management with over 20 years of research on warehousing as well as consultancy on DC location selection
7	Senior researcher on (sea)freight transport and spatial logistics processes. Research project (2014) that analyses spatial logistics and economic development in two European regions
8	Logistics director of supermarket chain – decision-maker with 25 years of experience in the food sector
9	Director of Port Innovation – decision-maker with experience in development of industrial clusters

4.2.1 Demand factors

Three demand-related factors are distinguished from literature: 1) demand level, 2) demand dispersion - geographical dispersion of customers over the company's target market – and 3) demand volatility (Vos 1993; Christopher 2011). Customer demand level influences the number of DCs needed to deliver customer orders in time. A high demand level involves daily customer orders, while a low demand level involves customer orders less than once a month. High demand volatility implies that customer demand levels fluctuate on a monthly basis. Low demand volatility implies that demand levels are stable over a period of at least six months. In the case of geographically dispersed customer demand, mixed layouts have two advantages: 1) reduced inventory risks and 2) the possibility of quick deliveries using regional DCs. In the case of high demand volatility, it is better to use a layout with few DC locations, to reduce inventory costs (Chopra 2003; Mangiaracina, Song, and Perego 2015).

4.2.2 Service level factors

Five important service level factors are: 1) supplier lead-time, 2) delivery time, 3) delivery reliability, 4) responsiveness and 5) returnability. Delivery time is defined as *"time from [customer] order placement to customer delivery - in days"* (Wanke and Zinn 2004, 470). Delivery times are influenced by transport mode and delivery frequency (Mangiaracina, Song, and Perego 2015). The type of product determines the delivery times customers are willing to accept. They do not accept long delivery times for substitutable products, which motivates companies to choose decentralised layouts. Delivery reliability is imperative for companies distributing high-value goods. Responsiveness is the reaction speed and flexibility in meeting customer demand (Christopher 2011). A decentralized layout and fast transport modes increase a company's responsiveness (Chopra 2003). Returnability refers to *"the ease with which a customer can return unsatisfactory merchandise and the ability of the network to handle such returns"* (Chopra 2003, 124). Decentralized layouts (for example Layout 4, Figure 4.1) offer customers flexible return options. In the e-commerce era, returnability has become an important service element (Hjort and Lantz 2016).

4.2.3 Product characteristics factors

There are three product factors that influence the spatial distribution structure decision: 1) Product value density, 2) Package density and 3) Perishability. High value products are associated with high inventory costs, motivating companies to choose a centralised layout (Wanke and Zinn 2004, Christopher 2011). Products with a low value density are often easily substituted, which means they have to be available locally and motivates companies to choose a layout with local DCs (Ashayeri and Rongen 1997). Packaging density (number of products per m^3) influences handling and inventory costs. High perishability - i.e. shelf life length in months (Wanke and Zinn 2004, 470) - may motivate companies to choose a distribution channel layout without storage or with cross docking – for example layout 5 or 6 (Figure 4.1).

4.2.4 Logistics costs factors

Based on existing literature, four leading logistics costs factors can be identified: 1) inbound transport costs, 2) outbound transport costs, 3) inventory costs and 4) warehousing costs. Many authors emphasise the importance of logistics costs factors (see e.g. Ashayeri and Rongen 1997; Chopra 2003; Christopher 2011). Inbound transport costs refer to the transport between the supplier and the shipper's or LSP's DC - including the costs of transport mode, labour and capital. Outbound transport costs involve the transport costs between the shippers' or LSP's DC and their customers (Friedrich, Tavasszy, and Davydenko 2014). Inventory costs include cost of capital, obsolescence, damage and deterioration, pilferage, shrinkage, insurance and management cost (Christopher 2011). Warehousing costs include handling costs (in and out), labour costs and storage costs (Friedrich, Tavasszy, and Davydenko 2014). Innovations in information systems that match supply and demand can reduce inbound and outbound transport costs (Christopher 2011). In the case of high outbound transport costs, companies will tend to favour a decentralised layout. In the case of high inbound transport costs, they will prefer a centralised distribution channel layout, including DC(s) near the production location. Companies are willing to accept inventory costs because of production scale advantages, but also to guarantee lead-times and deliver under demand uncertainty (Pedersen, Zachariassen, and Arlbjørn 2012). High inventory costs can lead companies to favour a centralised distribution channel layout (Nozick and Turnquist 2001).

4.2.5 Proximity-related location factors

Proximity-related location factors include 1) distance from DC to production facilities (McKinnon 1984; Sivitadinou 1996; Davydenko 2015), 2) distance from DC to supplier locations (McKinnon 1984; Nozick and Turnquist 2001; Friedrich 2010; Jakubicek 2010) and 3) distance from DC to consumer markets (Warffemius 2007; Bowen 2008; Woudsma et al. 2008; Cidell 2011; Dablanc and Ross 2012). DCs have to be near production facilities when products are stored at production locations and the DCs are only used for cross docking (Chopra 2003). Because of high customer service requirements, being near consumers is more important than being near suppliers (Holl 2004).

4.2.6 Accessibility-related location factors

Accessibility is a major factor in choosing a spatial distribution structure. It is a term that is used to denote local access between DCs and connecting transport infrastructures. Sub-factors are 1) distance from DC to motorways (Bowen 2008; Cidell 2010; Dablanc and Ross 2012), 2) distance from DC to airports (Warffemius 2007), 3) distance from DC to seaports (Verhetsel et al. 2015), 4) distance from DC to inland ports and inland terminals (Warffemius 2007; Pedersen, Zachariassen, and Arlbjørn 2012), 5) distance from DC to rail terminals (Sivitadinou 1996), 6) available transport infrastructure for different transport modes - highways, railways and waterways (Melachrinoudis and Min 2000; Davydenko 2015), and 7) congestion between the DC location and customer locations (Tavasszy, Ruijgrok, and Davydenko 2012). Motorway accessibility and airport accessibility are important factors according to research conducted in the USA. In the Amsterdam Airport Schiphol (AAS) region, DC locations are primarily driven by road access (Warffemius 2007). Research in Flanders (Belgium) shows that, in that particular area, port access drives companies to select DC location(s) near large ports, with companies relying heavily on low-cost sea transport (Verhetsel et al. 2015). Some decision-makers at parcel companies, however, prefer locations near airports to minimise air cargo lead-times (Dablanc and Rakotonarivo 2010). Decision-makers rarely select a DC location based on rail accessibility (Bowen 2008).

4.2.7 Resources-related location factors

These factors are related to the local availability of resources required in DC activities, including 1) labour market availability, 2) labour costs, 3) land availability and 4) land costs (Sivitadinou 1996; Hesse 2004; Warffemius 2007; Verhetsel et al. 2015). Labour market availability has become a key factor (Verhetsel et al. 2015), especially in regions with a focus on logistics activities where labour has become scarce, for example European regions of Venlo, Antwerp and North Rhine-Westphalia. Land availability is also expected to be assigned a high factor weight, because of the limited availability of land in urban agglomerations (Klauenberg, Elsner, and Knischewski 2017). Land costs drive companies to design a spatial distribution structure that includes peripheral DC locations (Dablanc and Ross 2012), although they are willing to pay higher land prices for attractive locations near consumer markets (Sivitadinou 1996).

4.2.8 Institutional factors

Institutional factors relate to the legal and fiscal framework conditions that apply to DC locations and include: 1) taxes, 2) zoning, 3) laws, regulations and customs and 4) investment incentives (Warffemius 2007; Woudsma et al. 2008; Cidell 2010; Sheffi 2013; Chopra and Meindl 2013). Many logistics clusters around the world have created Free Trade Zones where transhipment and re-export of goods are exempt from import duties and taxes, which attracts companies to design spatial distribution structures with DCs in these clusters, for example Singapore and Panama (Sheffi 2013). Zoning rules for DCs are often less complex in peripheral areas than they are in urban areas (Hesse 2004). Zoning can be used to encourage or discourage warehouse localisation (Cidell 2011). Speedy customs procedures reduce delivery times, which has a positive influence on the attractiveness of a DC location for high value goods. Investment incentives receive modest attention in literature, and although investment incentives are a decisive factor according to project developers and government professionals, they are less important according to forwarding companies (Klauenberg, Elsner, and Knischewski 2017).

4.2.9 Firm characteristics

Finally, relevant firm characteristics identified in literature are: 1) company size and 2) business strategy. Small and Medium-sized Enterprises (SMEs) find the factor of inventory costs less important, because they benefit to a lesser extent from economies of scale than large companies when deciding on the spatial distribution structure (Pedersen, Zachariassen, and Arlbjørn 2012).

Differences in business strategy also affect decision-making. Three well-known business strategies are: a) customer intimacy, b) operational excellence and c) product leadership (Porter 1985; Treacy and Wiersema 1993). Customer intimacy focuses on high service levels, for which companies choose a decentralised layout or a centralised layout with a responsive transport system. Operational excellence focuses on large and competitively priced product volumes. Hybrid layouts - including central DCs and regional DCs - are used to keep logistics costs down and guarantee reasonable delivery times. Product leadership focuses on new and creative products. To commercialise ideas quickly, tiers are eliminated from the supply chain, resulting in centralised layout.

4.2.10 Factor classification

Table 4.2 presents the framework of 33 factors, classified into seven main factors. Because existing literature disagrees on what the important factors are, with SCM studies emphasizing logistics costs and service level factors, while (economic) geography studies favouring location-related and institutional factors, factors were included from both disciplines and divided among seven main factors, four of which are based on SCM literature: 1) Demand factors, 2) Service level factors, 3) Product characteristics factors (Mangiaracina, Song, and Perego 2015), and 4) Logistics costs factors (Chopra 2003). Because we were unable to find any comprehensive framework of (economic) geographical factors in relation to spatial distribution structures, the following classification is proposed: 5) Location-related factors, and 6) Institutional factors. To simplify comparisons between the large number of Location-related factors, three categories of sub-factors were developed: 5a) Proximity-related location factors, 5b) Accessibility-related location factors, and 5c) Resources-related location factors. Additionally, main factor 7) Firm characteristics is also included. The factors can also be categorised as internal or external to a company. Demand factors, location factors and institutional factors are external factors, the other factors are internal to the company. A table including all references for each factor is available upon request.

Table 4.2 Main factors and sub-factors that drive decision-making on spatial distribution structures

Main factors	Sub-factors	Definition	Number of literature references
1. DEMAND FACTORS			
	Demand level	Customer demand level	16
	Demand volatility	Rapid changes in customer demand	10
	Demand dispersion	Geographical dispersion of customer demand over the company's target market	5
2. SERVICE LEVEL FACTORS			
	Supplier lead time	Time from order placement at supplier to delivery at the DC	16
	Delivery time	Time from customer order placement to customer delivery - in days	7
	Delivery reliability	% of customer orders delivered On Time In Full	12
	Responsiveness	Reaction speed as well as flexibility to fulfill customer demand	16
	Returnability	The ease with which a customer can return unsatisfactory merchandise and the ability of the network to handle such returns	2

3. PRODUCT CHARACTERISTICS FACTORS			
	Product value density	(Cost of goods sold) / (weight in kilograms)	16
	Package density	The number of products per m^3	11
	Perishability	1 / (Shelf life length in months)	2
4. LOGISTICS COSTS FACTORS			
	Transport costs - Inbound	Transport costs between supplier and DC. Including costs for mode of transportation, labour and capital	27
	Transport costs - Outbound	Transport costs between DC and customer. Including costs for mode of transportation, labour and capital	27
	Inventory costs	Cost of capital, obsolescence, damage and deterioration, pilferage, shrinkage, insurance and management cost	22
	Warehousing costs	Warehousing costs include handling costs (in- and out), labour costs and storage costs. Storage costs exist of space, land and equipment	18
5a. PROXIMITY-RELATED LOCATION FACTORS			
	Distance DC to consumer markets	Distance from DC to target consumer markets	20
	Distance DC to production facilities	Distance from DC to a company's own production facilities	15
	Distance DC to suppliers	Distance from DC to facilities of suppliers (production and distribution facilities)	13
5b. ACCESSIBILITY-RELATED LOCATION FACTORS			
	Available transport infrastructure	Transport infrastructure availability for different transport modes	24
	Distance DC to motorway		18
	Distance DC to airport		13
	Distance DC to seaport		13
	Distance DC to inland port / terminal		9
	Distance DC to rail terminal		5
	Congestion	Traffic congestion near DC location as well as between DC location and consumer locations	8
5c. RESOURCES-RELATED LOCATION FACTORS			
	Labour market availability	Availability of labour in the region(s) of DC location(s)	23
	Labour costs per region	Differences in labour costs per region	15
	Land availability for DC	Land availability to locate a DC	2
	Land costs for DC	Price per acre for logistics land	19
6. INSTITUTIONAL FACTORS			
	Taxes	Tax level and tax policy consistency in the country of DC location	17
	Zoning	Possibility to locate DC according to local zoning plans	7
	Laws, regulations, customs	Ease to locate a DC according to national laws, regulations and customs	8
	Investment incentives	Investment incentives from authorities to locate a DC	5
7. FIRM CHARACTERISTICS			
	Company size, business strategy		2

4.3 Determining factor weights

In this section, the Best-Worst Method (BWM) used to identify the factor weights, and the associated survey data collection procedure are discussed.

4.3.1 Best-Worst Method

Decision-making involving spatial distribution structures is a complex process because decision-makers need to rationalise a combination of quantitative and qualitative factors, factor weights and trade-offs between factors. Multi-criteria decision-making (MCDM) can help reduce complex decision-making by weighing multiple decision-making factors. Keeney and Raiffa (1976) provide the initial extensive overview of MCDM. Examples of Multi-Criteria Decision-Making methods are the Weighted Sum Model (WSM), Analytic Hierarchy Process (AHP), ELECTRE (Triantaphyllou 2000) and hybrid methods like AHP-TOPSIS-2N (De Souza et al. 2018), BWM-TOPSIS (Gupta 2018) and scenario building-MCDA (Gomes, et al. 2017). MCDM can be used for selecting alternatives, sorting alternatives in a preference order, ranking alternatives, or describing the performance of alternatives (Roy 1996). A relatively new MCDM method is the Best-Worst Method (BWM), which calculates the weights of decision-making factors through a pairwise comparison of the best (i.e. the most important) and the worst (i.e. the least important) factor and the other factors (Rezaei 2015). The decision was made to use BWM in this study because it has advantages over other MCDM methods. Firstly, BWM is a vector-based method, which means that fewer comparisons are needed compared to AHP, for example: BWM requires 2(n-3) pairwise comparisons, whereas AHP requires n(n-1)/2 pairwise comparisons. As such, BWM reduces the respondent time needed to compare the factors, increasing the response rate (Galesic and Bosnjak 2009). Secondly, BWM produces more consistent comparisons (Rezaei 2015). Inconsistency in pairwise comparisons is a well-known criticism of MCDM caused by inconsistent judgements of factors and inaccurate human knowledge (Herman and Koczkodaj 1996). BWM leads to consistent conclusions (Rezaei 2015). Thirdly, BWM includes more structured comparisons, i.e. respondents first select the best and worst factor and then systematically compare the best factor over the other factors, and the other factors over the worst. For AHP, respondents may consider a factor to be very important, but later find even more important factors and start altering their initial pairwise comparisons. Fourthly, BWM only uses integers, which makes the method easy to use. BWM has already been applied in other research areas - e.g. supplier selection and segmentation (Rezaei et al. 2015; Rezaei et al. 2016; Rezaei and Fallah Lajimi 2018), measuring logistics performance indicators (Rezaei, van Roekel, and Tavasszy 2018), port performance measurement (Rezaei et al. 2018), measuring quality of transit nodes (Groenendijk et al. 2018), standard battels (van de Kaa et al. 2018) and water resource management (Chitsaz and Azarnivand 2017), to name a few.

BWM includes five steps to determine the factor weights (Rezaei 2015, 2016):

Step 1: Determine a set of decision factors $\{c_1, c_2, \ldots c_n\}$
The decision factors are identified on the basis of a literature review and expert validation (as explained in Section 4.2).

Step 2: Determine the best (i.e. most important) and worst (i.e. least important) factors
The decision-maker selects the most and least important factors from the set independently, which means that different decision-makers could make different choices.

Step 3: Conduct the pairwise comparison between the best factor (i.e. most important) and the other factors
In this step, the decision-makers express their preference for the best factor over the other factors, by using a number from 1 to 9 (1: equally important, 9: extremely more important). This results in the Best-to-Others vector:

$$A_B = (a_{B1},\, a_{B2}, \dots,\, a_{Bn})$$

Where a_{Bj} represents the preference of factor B over factor j, and $a_{BB} = 1$.

Step 4: Conduct the pairwise comparison between the other factors and the worst factor.
In this step, decision-makers express their preference of the other factors over the worst factor, by using a number from 1 to 9. This results in the Others-to-Worst vector:

$$A_W = (a_{1W}, a_{2W}, \dots, a_{nW})^T,$$

Where a_{jW} represents the preference of factor j over the worst factor W, and $a_{WW} = 1$.

Step 5: Determining the optimal factor weights $(w_{1,}^{*} w_2^{*}, \dots, w_n^{*})$
For each pair of $\mathrm{w_B/w_j}$ and $\mathrm{w_j/w_W}$, the optimal weight should meet $\mathrm{w_B/w_j = a_{Bj}}$ and $\mathrm{w_j/w_W = a_{jW}}$. To satisfy these conditions, the maximum absolute differences $\left|\frac{w_B}{w_j} - a_{Bj}\right|$ and $\left|\frac{w_j}{w_W} - a_{jW}\right|$ for all j should be minimised. Considering the non-negativity characteristic and the weights sum condition, this yields the following problem:

$$\min \max_j \left\{ \left|\frac{w_B}{w_j} - a_{Bj}\right|, \left|\frac{w_j}{w_W} - a_{jW}\right| \right\}$$
s.t.
$$\sum_j w_j = 1$$
$$w_j \geq 0, \text{ for all } j \qquad (1)$$

Problem (1) can be transferred into:

$$\min \xi$$
s.t.
$$\left|\frac{w_B}{w_j} - a_{Bj}\right| \leq \xi, \text{ for all } j$$
$$\left|\frac{w_j}{w_W} - a_{jW}\right| \leq \xi, \text{ for all } j$$
$$\sum_j w_j = 1$$
$$w_j \geq 0, \text{ for all } j \qquad (2)$$

Solving problem (2) will produce the optimal factor weights $(w_{1,}^{*} w_2^{*}, \dots, w_n^{*})$ and ξ^*. Because there may be more than one optimal solution for problems that are not fully consistent and that have more than three criteria (Rezaei 2016), the optimal objective values of problem (2) have been used to calculate the lower and upper bounds of the weight of factor j by using problems (3) and (4):

$$\begin{aligned}
&\min w_j \\
&\text{s.t.} \\
&\left|\frac{w_B}{w_j} - a_{Bj}\right| \leq \xi^* \text{, for all } j \\
&\left|\frac{w_j}{w_W} - a_{jW}\right| \leq \xi^* \text{, for all } j \\
&\sum_j w_j = 1 \\
&w_j \geq 0\text{, for all } j
\end{aligned} \qquad (3)$$

$$\begin{aligned}
&\max w_j \\
&\text{s.t.} \\
&\left|\frac{w_B}{w_j} - a_{Bj}\right| \leq \xi\text{, for all } j \\
&\left|\frac{w_j}{w_W} - a_{jW}\right| \leq \xi\text{, for all } j \\
&\sum_j w_j = 1 \\
&w_j \geq 0\text{, for all } j
\end{aligned} \qquad (4)$$

Now the optimal weight intervals for each factor have been calculated. The final factor weights are calculated using equation (5):

$$w_j^* = \left(\min w_j + \max w_j\right)/2 \qquad (5)$$

A comparison is fully consistent when $a_{Bj} \times a_{jW} = a_{BW}$ for all j. To verify the consistency of the comparisons, BWM includes a consistency ratio using ξ^* (Rezaei 2015):

$$\textit{Consistency Ratio} = \frac{\xi^*}{\textit{Consistency Index}} \qquad (6)$$

The consistency ratio (CR) has a value between 0 and 1. Although no threshold has yet been proposed for the BWM, in this study, the values below 0.20 are considered. Values closer to 0 show a high consistency and values closer to 1 show a low consistency in the pairwise comparisons of the respondents (Rezaei 2016). A consistency index (Rezaei 2015) is used to calculate the consistency ratio. Lower values of ξ^* result in a smaller consistency ratio, which means the vectors are more consistent:

$\boldsymbol{a_{BW}}$	1	2	3	4	5	6	7	8	9
CI (max ξ)	0.00	0.44	1.00	1.63	2.30	3.00	3.73	4.47	5.23

4.3.2 Survey data collection

An online survey with 41 questions was used to collect the pairwise comparison data. Online surveys are an efficient way to approach large groups of potential respondents, a potential drawback being a possible low response rate. Two professors of logistics – with expertise in spatial distribution structure selection - provided feedback on the survey, which resulted in several improvements. For example, factor definitions were added to increase the construct validity. The Three Step Test Interview Method (Hak, Van der Veer, and Jansen 2004) was used to test survey consistency and correct the understanding of the questions. Step 1 includes observing a potential respondent thinking aloud. Step 2 includes clarifying and completing the observations. Step 3 is a semi-structured interview based on the respondent's experiences and opinion about the survey. How many respondents are to be considered enough for this method (TSTI) is based on saturation, which is a number like 3-5 (please see Hak et al. 2004). Three test respondents were selected and interviewed, i.e. two experts and one decision-maker with experience in spatial distribution structures. The respondents provided useful feedback that allowed us to improve the survey questions and answers. For example, in the BWM questions, it is emphasised that respondents should indicate only *one* most important and *one* least important factor. Three selection criteria were used to compare online survey tools, such as SurveyMonkey, Google Forms, SurveyGizmo and TU Delft Collector: 1) ease with which to include respondents' answers in follow-up questions 2) unlimited number of respondents 3) costs. The TU Delft Collector tool scored best on all criteria.

To illustrate the BWM questions, an example of the survey structure is presented below – based on BWM's step 1 to step 4. In the first step, the decision–making factors are identified. In the second step, respondents are asked to indicate the most important and least important factors. In the third step, respondents indicate their preference of the most important factor over the other factors:

> Based on the MOST important factor you have selected, please determine your preference of this factor over the other factors using a 1 to 9 measurement scale *(1 shows about equal importance to the factor at hand and 9 means the factor is extremely more important. Please check below for detailed explanation of 1 to 9 scales[2]).*

Main factors	Demand	Service level	Product characteristics	Logistics Costs	Location factors	Institutional factors	Firm characteris-tics
Most important: Logistics costs				X			

In the fourth step, respondents indicate their preference among the other factors over the least important factor:

2 Definition of a 1 to 9 measurement scale:

1: Equal importance	*7: Very strongly more important*
3: Moderately more important	*9: Extremely more important*
5: Strongly more important	*2, 4, 6, 8: Intermediate values*

Based on the LEAST important factor you have selected, please determine your preference of the other factors over the least important factor using a 1 to 9 measurement scale.

Main factors	Least important factor: Institutional factors
Demand	
Service level	
Product characteristics	
Logistics costs	
Location factors	
Institutional factors	X
Firm characteristics	

Next, the respondents are asked to indicate the importance of the sub-factors, using the same questions, as illustrated in the example above.

The survey is completed by two groups of respondents: 1) decision-makers and 2) experts, allowing us to compare data from both groups. Decision-makers are defined as managers who take decisions on spatial distribution structures affiliated to shippers or LSPs. A control question is included to test whether the decision-makers are - or were recently - actively involved in decision-making. The experts are professors working in the area of logistics, or consultants who advise companies on spatial distribution structures. Experts were invited to respond because, based on their experience with multiple industry sectors, they have a broad knowledge on spatial distribution structure selection. Based on these selection criteria, 601 target respondents were selected from a LinkedIn database (consisting of 3,300 connections), 77 target respondents from the own network and 63 respondents from participant lists of logistics and transport conferences. Respondents were invited by e-mail and via online news items on the websites of Amsterdam Logistics, EVO – the Dutch Shippers' Branch Organisation - and Logistiek.nl magazine. The survey was opened 717 times and completed by 82 respondents. The answers from 75 respondents could be used for the analysis, resulting in a response rate of 10.5%. Of the respondents, 22 are decision-makers (29%), 45 are experts (60%) and 8 respondents (11%) are affiliated to other organisation types, e.g., retail or government. To strengthen the validity of the research, decision-makers identified the important factors based on the context of their company, while experts identified the important factors based on the industry sector about which they know most. The average factor weights are calculated on the basis of a sample of decision-makers and experts from various industry sectors, i.e. fashion, consumer electronics, agriculture, food and healthcare, and experts on fashion, high-tech, consumer electronics, FMCG, agriculture, food, flowers, oil & gas and aviation.

4.4 Results and discussion

This section contains the results and discussion of the main factor weights, sub-factor weights and global weights of the sub-factors, followed by a cluster analysis that was conducted to identify potential homogeneous subgroups of respondents.

4.4.1 Main factor weights

Table 4.3 shows the main factor weights, based on the final step of the BWM (Step 5). First, the optimal weights of the factor for each respondent is determined, after which the mean of the factor weights of all the respondents is calculated to determine a weight per main factor and per sub-factor.

Table 4.3 Main factor weights (n=75)

Main factors	Mean weight total sample	Median	Standard deviation (s)	Rank	CR	Mean weight subgroups	
						Decision-makers	Experts
Demand factors	0.161	0.144	0.089	3	0.126	0.165	0.162
Service level factors	0.163	0.132	0.101	2		0.189	0.155
Product characteristics	0.108	0.092	0.077	6		0.073	0.134
Logistics costs factors	**0.202**	0.190	0.115	1		**0.193**	**0.196**
Location factors	0.151	0.115	0.103	4		0.147	0.152
Institutional factors	0.091	0.071	0.068	7		0.122	0.076
Firm characteristics	0.120	0.087	0.088	5		0.107	0.122

The average consistency ratio (CR) of the main factors is 0.126, which indicates very consistent pairwise comparisons (Rezaei 2015). The sub-factor comparisons are also very consistent – with the highest CR being 0.199. Respondents identify logistics costs as the most important main factor, followed by service level and demand. Academic studies traditionally emphasise logistics costs as a major driver of spatial distribution structures (Chopra and Meindl 2013; Verhetsel et al. 2015). Both decision-makers and experts view logistics costs as the most important factor, while experts consider demand to be the second most important factor, as opposed to decision-makers, who place service level in second position, which is understandable, since decision-makers focus more on providing the best service level to their customers (Treacy and Wiersema 1993).

That fact that product characteristics are viewed as the second least important main factor is remarkable, since SCM literature emphasises the importance of product characteristics, like product value density, in the spatial distribution structure decision (Chopra 2003; Wanke and Zinn 2004). Song and Sun (2017), for example, found that product characteristics have a significant direct effect on supply chain network design. A possible explanation is that respondents see inventory costs as the outcome of high product value density and instead assign a high weight to sub-factor inventory costs. Global factor weights (Table 4.4), however, show that sub-factor inventory costs (0.043) is only valued slightly higher than sub-factor product value density (0.036). To test whether there are differences in the weights between the two respondent groups, a statistical analysis was conducted. Paired t-test shows that, for the main factors demand, service level, logistics costs, location factors and firm characteristics, there are no significant differences in the mean weights assigned by the decision-makers and experts, respectively. For the main factors product characteristics and institutional factors, there are significant differences. K-means cluster analysis (Section 4.4.3), however, does not find clusters that distinguish between decision-makers versus experts. "Institutional" is the least important main factor, which is in line with Song and Sun's (2017) conclusion that political-social characteristics do not have a significant effect. However, institutional sub-factors, such as zoning, can be a precondition for spatial distribution structure localisation.

4.4.2 Sub-factor weights

Our results show that the three demand related sub-factors – demand level, demand volatility and demand dispersion - are viewed as being almost equally important by the total sample of respondents (Table 4.4).

Table 4.4 Local and global sub-factor weights (and rank)

Main factors and sub-factors	Local weights	Global weights	Subgroup weights	
			Decision-makers	Experts
1. DEMAND FACTORS				
Demand level	0.313 (3)	0.051 (5)	0.373	0.280
Demand volatility	0.362 (1)	0.059 (2)	0.404	0.338
Demand dispersion	0.324 (2)	0.053 (3)	0.222	0.380
2. SERVICE LEVEL FACTORS				
Supplier lead time	0.158 (4)	0.026 (16)	0.171	0.150
Delivery time	0.277 (1)	0.045 (7)	0.248	0.292
Delivery reliability	0.258 (2)	0.042 (10)	0.259	0.264
Responsiveness	0.197 (3)	0.032 (12)	0.196	0.184
Returnability	0.109 (5)	0.018 (20)	0.124	0.108
3. PRODUCT CHARACTERISTICS FACTORS				
Product value density	0.333 (2)	0.036 (11)	0.396	0.308
Package density	0.259 (3)	0.028 (14)	0.268	0.221
Perishability	0.406 (1)	0.044 (8)	0.334	0.470
4. LOGISTICS COSTS FACTORS				
Transport costs - Inbound	0.259 (1)	0.060 (1)	0.384	0.290
Transport costs - Outbound	0.250 (2)	0.051 (4)	0.322	0.224
Inventory costs	0.213 (4)	0.043 (9)	0.141	0.242
Warehousing costs	0.240 (3)	0.049 (6)	0.150	0.242
5a. PROXIMITY-RELATED LOCATION FACTORS				
Distance DC to consumer markets	0.592 (1)	0.019 (18)	0.596	0.576
Distance DC to production facilities	0.184 (3)	0.006 (33)	0.189	0.184
Distance DC to suppliers	0.222 (2)	0.007 (31)	0.214	0.238
5b. ACCESSIBILITY-RELATED LOCATION FACTORS				
Available transport infrastructure	0.222 (1)	0.017 (21)	0.223	0.223
Distance DC to motorway	0.200 (2)	0.015 (22)	0.186	0.197
Distance DC to airport	0.110 (4)	0.008 (28)	0.121	0.104

Distance DC to seaport	0.107 (5)	0.008 (29)	0.126	0.107
Distance DC to inland port / terminal	0.099 (6)	0.007 (30)	0.097	0.103
Distance DC to rail terminal	0.086 (7)	0.007 (32)	0.071	0.095
Congestion	0.173 (3)	0.013 (23)	0.171	0.167
5c. RESOURCES-RELATED LOCATION FACTORS				
Labour market availability	0.274 (1)	0.012 (24)	0.286	0.267
Labour costs per region	0.247 (3)	0.011 (26)	0.183	0.263
Land availability for DC	0.256 (2)	0.011 (25)	0.253	0.249
Land costs for DC	0.221 (4)	0.010 (27)	0.275	0.219
6. INSTITUTIONAL FACTORS				
Taxes	0.282 (2)	0.026 (15)	0.299	0.286
Zoning	0.199 (4)	0.018 (19)	0.140	0.186
Laws, regulations, customs	0.307 (1)	0.028 (13)	0.357	0.314
Investment incentives	0.210 (3)	0.019 (17)	0.203	0.212
7. FIRM CHARACTERISTICS				
(local weight only)	0.120 (1)			

These results deviate from earlier research by Mangiaracina, Song, and Perego (2015), in which demand level emerges as the most important factor and demand volatility is ranked fourth out of five factors. Decision-makers consider demand volatility to be more important than experts do (0.404 versus 0.338), whereas experts consider demand dispersion to be more important (0.380 versus 0.222). It is possible that decision-makers currently face issues to do with demand volatility, or it could be that volatile demand is considered to be important because it complicates distribution structure selection (Mangiaracina, Song, and Perego 2015). High demand volatility drives companies to select centralised distribution layout to increase responsiveness and to save inventory costs because of unpredictable demand.

The most important service level sub-factor according to total respondent sample is delivery time. Decision-makers consider delivery reliability to be the most important sub-factor, while experts consider delivery time to be the most important sub-factor. Delivery time is especially important to companies selling low value goods. In cases involving high value goods, customers are willing to accept longer delivery times (Chopra 2003). A decentralized distribution layout enables fast deliveries. Responsiveness is ranked as the third most important sub-factor, which is not in line with the large number of studies on this topic. A possible explanation is that respondents consider responsiveness to overlap with fast delivery time – although factor definitions are presented in the survey – and accordingly select delivery time as being the most important sub-factor. Supplier lead-time is relatively unimportant – companies prefer short distances to customer locations - which can be explained in three ways. Firstly, companies could force suppliers to arrange frequent product deliveries. Secondly, companies have enough stock to compensate for supplier lead-times. Thirdly, supplier lead-times are always short because of sophisticated demand predictions combined with in-transit supplies.

Product characteristics are valued as the second least important main factor (Table 4.3). However, the global weights show that perishability is an important sub-factor (ranked #8 out of 33 factors). Companies that ship perishables demand fast delivery times, resulting in a decentralised layout, or a centralised layout in combination with fast transport modes. Of the logistics costs factors, inbound and outbound transport costs are the most important sub-factors (Table 4.4). Inbound and outbound transport costs show similar factor weights, which is remarkable, since outbound transport costs are generally higher than inbound transport costs (as supplies are often ordered at a delivered price). However, respondents value both inbound and outbound transport costs important. Generally speaking, high inbound transport costs drive companies towards centralised layout, whereas high outbound transport costs drive companies towards a decentralised layout.

For the location-related factors, three categories of sub-factors were developed to make pairwise comparisons easier and more comprehensible for the respondents. First, the proximity-related location factors. Literature disagrees to what extent distance DC to consumer markets influences decision-making (Holl 2004; Woudsma, Jakubicek, and Dablanc 2016). Our results, however, confirm that the distance between DC and consumer markets is the most important sub-factor. Today's customers expect rapid order deliveries. Distance from DC to production facilities is the least important sub-factor. Although large distances increase inbound transport costs and inventory costs, inbound transport scale advantages and economical product sourcing compensate for these costs. Second, the accessibility-related location factors. Decision-makers and experts both assign the same local ranking to accessibility-related sub-factors. Respondents value sub-factor available transport infrastructure more important than distance DC to motorway, probably because sub-factor transport infrastructure includes all transport modes. Similar results were found in Flanders (Belgium), where logistics firms locate near the available transport infrastructure (Verhetsel et al. 2015). The least important sub-factor is DC distance to rail terminal, which is in line with research from Bowen (2008), which states that rail transport is rarely used to deliver goods to or from DCs, as transport times are long compared to road transport (Verhetsel et al. 2015). Third, within the group of resources-related location factors, labour market availability is the most important sub-factor. Decision-makers value land costs as the second most important sub-factor. In terms of geography these two are consistent. Companies often locate large DCs in peripheral regions because of higher labour availability and lower land costs compared to urban regions (Klauenberg, Elsner, and Knischewski 2017). Experts consider labour costs per region the second most important factor. Labour costs will rise because of high demand for warehousing personnel. The tight West-European labour market negatively influences the attractiveness of popular logistics regions. Land costs have become more important because of the large increase in average DC floor space. Land costs are especially important to low value companies with limited financial capacity (Verhetsel et al. 2015).

The institutional factors are given same ranking by decision-makers and expert respondents. Here, *laws, regulations and customs* is the most important sub-factor. Its importance could be caused by regulations (and underlying policies) related to zoning or night work restrictions, which can be conditional factors in spatial distribution structure design. Sub-factor taxes follows at short distance. Many logistics clusters around the world have set up Free Trade Zones to attract companies to those clusters (Sheffi 2013). Local incentives, like land donations, are also known to have influenced DC locations (Melachrinoudis and Min 2000), but they are relatively unimportant in our study.

4.4.3 Cluster analysis

A K-means cluster analysis is performed to explore the heterogeneity of the respondent sample. The two-step cluster analysis is preferred over K-means cluster analysis, but this method only finds a single cluster from the data. K-means cluster analysis shows three homogeneous clusters. A disadvantage of K-means cluster analysis is that it provides no support in finding the optimal number of clusters (Magidson and Vermunt 2002). Table 4.5 presents the results of the cluster analysis.

Table 4.5 Results of the cluster analysis

	Cluster 1:	**Cluster 2:**	**Cluster 3:**
Common focus of cluster members	Logistics costs and service level	Location	Firm and product characteristics
Cluster size % (absolute)	0.48 (36)	0.24 (18)	0.28 (21)
Demand factors	0.160	0.163	0.164
Service level factors	0.218	0.119	0.107
Product characteristics factors	0.095	0.060	0.174
Logistics costs factors	0.274	0.158	0.120
Location factors	0.103	0.279	0.125
Institutional factors	0.065	0.152	0.086
Firm characteristics	0.085	0.069	0.223

Cluster 1 represents about half of the sample (48%) and has a main focus on logistics cost-related factors (mean weight of 0.274) and service level factors. Cluster 2 (24% of the sample) is mostly focused on location-related factors, followed by demand factors. Cluster 3 (28% of the sample) assigns the greatest importance to firm characteristics (mean weight of 0.223) and product characteristics. Although the latter two factors have a low overall score (ranked five and six out of seven main factors), there is a group of respondents who do value them very highly. Cluster 1 includes 15 decision-maker respondents. Half of these decision-makers (8 out of 15) apply the Operational excellence strategy, which is in line with the cluster's main focus on logistics costs. Three of the 15 decision-makers in Cluster 1 use the Customer intimacy strategy, while four decision-makers favour the Product leadership strategy. Cluster 2 has a main focus on location-related factors. In Cluster 2, most decision-makers (6 out of 8) adopt the Operational excellence strategy. As a result, it is to be expected that respondents in Cluster 2 choose DC locations that minimise logistics costs. Decision-makers in Cluster 3 have no preferred company strategy. Furthermore, respondents in the individual clusters are not homogeneous when it comes to company size, market area, or distribution channel layout. There are two main implications of the cluster analysis. Firstly, further research into subgroups could give interesting results for a differentiated design towards specific focus groups. Secondly, in practical terms, identification of subgroups may lead to different decisions; for example, in our case, a centralised spatial distribution structure directed at lowest logistics costs for Cluster 1 and a decentralised structure for specific products for Cluster 3.

4.5 Conclusion and further research

This chapter has examined the factors that determine the distribution channel layout and distribution centre location(s) that companies select. Spatial distribution structures are of strategic importance to companies wanting to deliver the right product on time and at the lowest logistics costs. A framework of seven main influencing factors and 33 sub-factors was proposed. An online survey was used to collect the data. Best-Worst Method (BWM) was applied to identify the relative factor weights, which are compared by two respondent groups, i.e. decision-makers – affiliated to shippers and LSPs – and experts. Respondents based their answers on the industry sector in which they work (decision-makers) or about which they have the most knowledge (experts). The results indicate that the two sub-groups vary when it comes to assigning factor weights.

Overall, the most important main factors are logistics costs, i.e. transport costs, inventory costs and warehousing costs, followed by service level and demand level. Both decision-makers and experts consider this main factor to be the most important one. Logistics costs versus service level continues to be the main trade-off – which confirms existing literature on logistics costs and service level factors. Decision-makers consider service level the second most important main factor, whereas experts rank customer demand as the second most important main factor. Companies focusing on providing high service levels tend to favour a decentralised distribution channel layout to realize short delivery times. Product characteristics (value density, package density) are the second least important main factor according to the overall respondent sample, which is remarkable considering the broad attention in existing literature to the distribution of different types of products. With regard to the sub-factor weights, it is remarkable to see that inbound transport costs and outbound transport costs receive similar local factor weights, since outbound transport costs are often higher than inbound transport costs. Respondents could consider inbound transport costs to be relatively important in the spatial distribution structure decision, because scale advantages on inbound transport costs are needed to minimise logistics costs. Companies with high inbound transport costs will prefer a centralised distribution channel layout, while companies with high outbound transport costs will prefer decentralised distribution. Important sub-factors that were identified are demand volatility, delivery time and perishability. Companies with volatile demand prefer a centralised distribution channel layout to increase responsiveness and to reduce unused inventories. Land availability, land costs and distance to suppliers are relatively unimportant sub-factors.

K-means cluster analysis of the survey data shows three homogeneous respondent clusters. Cluster 1 has a focus on logistics costs factors and service level factors, Cluster 2 on location factors followed by demand factors and Cluster 3 on firm characteristics and product characteristics. Half of the decision-maker respondents in Cluster 1 (8 out of 15) adopt the Operational excellence strategy, which is in line with the cluster's main focus on logistics costs. Firm characteristics and product characteristics are highly valued in Cluster 3. Further research into the clusters could yield interesting results for differentiated distribution structure design.

The proposed framework and factor weights have implications for both scholars and practitioners. For scholars, the framework demonstrates the important main factors and sub-factors to include in DC location models. Knowledge on their relative importance may be important when choices about modelling have to be made. Logistics practitioners affiliated to companies that ship a broad range of products (high value and low value) can use the factors as a checklist in their decision-making process and apply the factor weights to support future decision-making on spatial distribution structures. Public policy-makers can use the information to support the development of land use plans that aim to attract DCs from several industries. A limitation of this study is that the survey provides insufficient data to compare potential differences in factor weights between 1) companies with centralised and decentralised distribution channel layouts, or 2) SMEs versus large companies. The study also has limitations when it comes to the value it has for companies that ship a single product, as it builds on a broad survey representing a wider range of products. Moreover, respondents recommended additional factors to be included in future research, such as climate conditions, severance costs and business risks involved in implementing a new structure. Future research could test the importance of these factors in specific industry sectors. It could also compare factor weights for differences in context, such as distribution at a national and regional level. Finally, it would be useful to compare the factor weights derived by the BWM method to other methods.

References

Ashayeri, J., and J.M.J. Rongen. 1997. "Central Distribution in Europe: A Multi-Criteria Approach to Location Selection." *The International Journal of Logistics Management* 8 (1): 97 – 109.

Baker, P. 2006. "Designing Distribution Centres for Agile Supply Chains." *International Journal of Logistics Research and Applications* 9 (3): 207-221.

Bowen, J. 2008. "Moving Places: The Geography of Warehousing in the US." *Journal of Transport Geography* 16 (6): 379–387.

Chitsaz, N., and A. Azarnivand. 2017. "Water Scarcity Management in Arid Regions Based on an Extended Multiple Criteria Technique." *Water Resource Management* 31 (2017): 233–250.

Chopra, S. 2003. "Designing the Distribution Network in a Supply Chain." *Transportation Research Part E* 39 (2): 123-140.

Chopra, S., and P. Meindl. 2013. *Supply chain management: Strategy, planning, and operation*. New Jersey: Pearson Education Inc.

Christopher, M. 2011. *Logistics and Supply Chain Management*. Harlow: Pierson Education Limited.

Cidell, J. 2010. "Concentration and Decentralization: The New Geography of Freight Distribution in US Metropolitan Areas." *Journal of Transport Geography* 18 (3): 363-371.

Cidell, J. 2011. "Distribution Centers among the Rooftops: The Global Logistics Network Meets the Suburban Spatial Imaginary." *International Journal of Urban and Regional Research* 35 (4): 832 – 851.

Cooper, M. 1984. "Cost and Delivery Time Implications of Freight Consolidation and Warehousing Strategies." *International Journal of Physical Distribution & Materials Management* 14 (6): 47 – 67.

Dablanc, L. 2013. "Logistics Sprawl: The Growth and Decentralization of Warehouses in the L.A. Area." Paper presented at the 5th International Urban Freight Conference, Long Beach, USA, October 2013.

Dablanc, L., and D. Rakotonarivo. 2010. "The Impacts of Logistic Sprawl: How does the Location of Parcel Transport Terminals Affect the Energy Efficiency of Goods' Movements in Paris and what can we Do about It?" *Procedia Social and Behavioral Sciences* 2 (3): 6087–6096.

Dablanc, L., and C. Ross. 2012. "Atlanta: A Mega Logistics Center in the Piedmont Atlantic Megaregion (PAM)." *Journal of Transport Geography* 24 (2012): 432 – 442.

Davydenko, I.Y. 2015. "Logistics Chains in Freight Transport Modelling." PhD diss., Delft University of Technology.

Friedrich, H. 2010. "Simulation of Logistics in Food Retailing for Freight Transportation Analysis." PhD diss., Karlsruher Instituts für Technologie (KIT).

Friedrich, H., L.A. Tavasszy, and I.Y. Davydenko. 2014. "Distribution Structures." In *Modelling Freight Transport*, edited by L.A. Tavasszy, and G. de Jong, 65-88. New York: Elsevier.

Galesic, M., and M. Bosnjak. 2009. "Effects of Questionnaire Length on Participation and Indicators of Response Quality in a Web Survey." *Public Opinion Quarterly* 73 (2): 349 – 360.

Gomes, C.F.S., H.G. Costa, and A.P. de Barros. 2017. "Sensibility Analysis of MCDA Using Prospective in Brazilian Energy Sector." *Journal of Modelling in Management* 12 (3): 475-497.

Groenendijk, L., J. Rezaei, and G. Correia. 2018. "Incorporating the Travellers' Experience Value in Assessing the Quality of Transit Nodes: A Rotterdam Case Study." *Case Studies on Transport Policy* 6 (4): 564 – 576.

Gupta, H. 2018. "Assessing Organizations Performance on the Basis of GHRM Practices Using BWM and Fuzzy TOPSIS." *Journal of Environmental Management* 226: 201-216.

Hak, T., K. van der Veer, and H. Jansen. 2004. *The Three-Step Test-Interview (TSTI): An Observational Instrument for Pretesting Self-Completion Questionnaires*. ERIM Report Series Research in Management. ERS-2004-029-ORG.

Herman, M.W., and W.W. Koczkodaj. 1996. "A Monte Carlo Study of Pairwise Comparison." *Information Processing Letters* 57 (1): 25-29.

Hesse, M. 2004. "Land for Logistics: Locational Dynamics, Real Estate Markets and Political Regulation of Regional Distribution Complexes." *Tijdschrift voor Economische en Sociale Geografie* 95 (2): 162-173.

Hjort, K., and B. Lantz. 2016. "The Impact of Returns Policies on Profitability: A Fashion E-commerce Case." *Journal of Business Research* 69 (2016): 4980 – 4985.

Holl, A. 2004. "The Role of Transport in Firms' Spatial Organization: Evidence from the Spanish Food Processing Industry." *European Planning Studies* 12 (4): 537-550.

Jakubicek, P. 2010. "Understanding the Location Choices of Logistics Firms." Master thesis, University of Waterloo.

Keeney, R., and H. Raiffa. 1976. *Decision Analysis with Multiple Conflicting Objectives: Preferences and Value Trade-Offs*. New York: Wiley.

Klauenberg, J., L.-A. Elsner, and C. Knischewski. 2017. "Dynamics in the Spatial Distribution of Hubs in Groupage Networks: The Case of Berlin." Paper presented at the World Conference on Transport Research, Shanghai, July 10-15.

Korpela, J., K. Kyläheiko, A. Lehmusvaara, and M. Tuominen. 2001. "The Effect of Ecological Factors on Distribution Network Evaluation." *International Journal of Logistics Research and Applications* 4 (2): 257-269.

Kuipers, B., and J. Eenhuizen. 2004. "A Framework for the Analysis of Seaport-Based Logistics Parks." In *Proceedings of the 1st International Conference on Logistics Strategies for Ports*, Dalian University Press, 151–171. China: Dalian University Press.

Magidson, J., and J.K. Vermunt. 2002. "Latent Class Models for Clustering: A Comparison with K-means." *Canadian Journal of Marketing Research* 20 (1): 36-43.

Mangiaracina, R., G. Song, and A. Perego. 2015. "Distribution Network Design: A Literature Review and a Research Agenda." *International Journal of Physical Distribution & Logistics Management* 45 (5): 506-531.

McKinnon, A.C. 1984. "The Spatial Organization of Physical Distribution in the Food Industry." PhD diss., University College London.

McKinnon, A.C. 2009. "The Present and Future Land Requirements of Logistical Activities." *Land Use Policy* 26S (2009): S293-S301.

Meixell, M.J., and V.B. Gargeya. 2005. "Global Supply Chain Design: A Literature Review and Critique." *Transportation Research Part E: Logistics and Transportation Review* 41 (6): 531-550.

Melachrinoudis, E., and H. Min. 2000. "The Dynamic Relocation and Phase-Out of a Hybrid, Two-Echelon Plant/Warehousing Facility: A Multiple Objective Approach." *European Journal of Operational Research* 123 (1): 1-15.

Nozick, L.K., and M.A. Turnquist. 2001. "Inventory, Transportation, Service Quality and the Location of Distribution Centers." *European Journal of Operational Research* 129 (2): 362-371.

Olhager, J., S. Pashaei, and H. Sternberg. 2015. "The Design of Global Production and Distribution Networks: A Literature Review and Research Agenda." *International Journal of Physical Distribution & Logistics Management* 45 (1/2): 138-158.

Onstein, A.T.C., L.A. Tavasszy, and D.A. van Damme. 2019. "Factors Determining Distribution Structure Decisions in Logistics: A Literature Review and Research Agenda." *Transport Reviews* 39 (2): 243–260. doi:10.1080/01441647.2018.1459929.

Pedersen, S.G., F. Zachariassen, and J.S. Arlbjørn. 2012. "Centralisation vs. De-centralisation of Warehousing: A Small and Medium-Sized Enterprise Perspective." *Journal of Small Business and Enterprise Development* 19 (2): 352–369.

Picard, J. 1982. "Typology of Physical Distribution Systems in Multi-national Corporations." *International Journal of Physical Distribution & Materials Management* 12 (6): 26–39.

Porter, M.E. 1985. *Competitive Advantage*. New York: The Free Press.

Rezaei, J. 2015. "Best-Worst Multi-Criteria Decision-Making Method." *Omega* 53 (2015): 49-57.

Rezaei, J. 2016. "Best-Worst Multi-Criteria Decision-Making Method: Some Properties and a Linear Model." *Omega* 64 (2016): 126-130.

Rezaei, J., and H. Fallah Lajimi. 2018. "Segmenting Supplies and Suppliers: Bringing Together the Purchasing Portfolio Matrix and the Supplier Potential Matrix." *International Journal of Logistics Research and Applications*, 1-18.

Rezaei, J., T. Nispeling, J. Sarkis, and L.A. Tavasszy. 2016. "A Supplier Selection Life Cycle Approach Integrating Traditional and Environmental Criteria Using the Best Worst Method." *Journal of Cleaner Production*, 135: 577-588.

Rezaei, J., W.S. van Roekel, and L.A. Tavasszy. 2018. "Measuring the Relative Importance of the Logistics Performance Index Indicators Using Best Worst Method." *Transport Policy*, 68 (C): 158-169.

Rezaei, J., L. van Wulfften Palthe, L.A. Tavasszy, B. Wiegmans, and F. van der Laan. 2018. "Port Performance Measurement in the Context of Port Choice: An MCDA Approach." *Management Decision*.

Rezaei, J., J. Wang, and L.A. Tavasszy. 2015. "Linking Supplier Development to Supplier Segmentation Using Best Worst Method." *Expert Systems With Applications,* 42 (23): 9152–9164.

Rousseau, D.M., J. Manning, and D. Denyer. 2008. "Evidence in Management and Organizational Science: Assembling the Field's Full Weight of Scientific Knowledge through Synthesis." *Annals of the Academy of Management* 2 (1): 475–515.

Roy, B. 1996. *Multicriteria Methodology for Decision Aiding*. Dordrecht: Kluwer Academic Publishers.

Sheffi, Y. 2013. "Logistics-Intensive Clusters: Global Competitiveness and Regional Growth." In *Handbook of Global Logistics*, edited by J. Bookbinder, 463-500. New York: Springer.

Sivitadinou, R. 1996. "Warehouse and Distribution Facilities and Community Attributes: An Empirical Study." *Environment and Planning A* 28 (7): 1261-1278.

Song, G., and L. Sun. 2017. "Evaluation of Factors Affecting Strategic Supply Chain Network Design." *International Journal of Logistics Research and Applications* 20 (5): 405-425.

Souza, L.P. de, C.F.S. Gomes, and A.P. de Barros. 2018. "Implementation of New Hybrid AHP-TOPSIS-2N Method in Sorting and Prioritizing of an IT CAPEX Project Portfolio." *International Journal of Information Technology & Decision Making* 17 (2018): 977 – 1005.

Tavasszy, L.A., K. Ruijgrok, and I. Davydenko. 2012. "Incorporating Logistics in Freight Transport Demand Models: State-of-the-Art and Research Opportunities." *Transport Reviews* 32 (2): 203-219.

Tranfield, D., D. Denyer, and P. Smart. 2003. "Towards a Methodology for Developing Evidence-Informed Management Knowledge by means of Systematic Review." *British Journal of Management* 14 (3): 207-222.

Treacy, M., and F. Wiersema. 1993. "Customer Intimacy and other Value Disciplines." *Harvard business review* 71 (1): 84-93.

Triantaphyllou, E. 2000. "Multi-Criteria Decision-Making Methods." In *Multi-criteria Decision-making Methods: A Comparative Study*, edited by P.M. Pardalos, and D. Hearn, 5-21. Boston: Springer.

van de Kaa, G., M. Janssen, and J. Rezaei. 2018. "Standards Battles for Business-to-Government Data Exchange: Identifying Success Factors for Standard Dominance Using the Best Worst Method." *Technological Forecasting and Social Change* 137 (December 2018): 182 - 189.

van den Heuvel, F.P., P.W. de Langen, K.H. van Donselaar, and J.C. Fransoo. 2013. "Spatial Concentration and Location Dynamics in Logistics: The Case of a Dutch Province." *Journal of Transport Geography* 28 (2013): 39 – 48.

Verhetsel, A., R. Kessels, P. Goos, T. Zijlstra, N. Blomme, and J. Cant. 2015. "Location of Logistics Companies: A Stated Preference Study to Disentangle the Impact of Accessibility." *Journal of Transport Geography* 42 (2015): 110–121.

Vos, B. 1993. "International Manufacturing and Logistics: A Design Method." PhD diss., Eindhoven University of Technology.

Wanke, P.F., and W. Zinn. 2004. "Strategic Logistics Decision Making." *International Journal of Physical Distribution & Logistics Management* 34 (6): 466-478.

Warffemius, P.M.J. 2007. "Modeling the Clustering of Distribution Centers around Amsterdam Airport Schiphol: Location Endowments, Economies of Agglomeration, Locked-in Logistics and Policy Implications." PhD diss., Erasmus University Rotterdam.

Woudsma, C., P. Jakubicek, and L. Dablanc. 2016. "Logistics Sprawl in North America: Methodological Issues and a Case Study in Toronto." *Transportation Research Procedia* 12 (2016): 474-488.

Woudsma, C., J.F. Jensen, P. Kanaroglou, and H. Maoh. 2008. "Logistics Land Use and the City: A Spatial–temporal Modeling Approach." *Transportation Research Part E: Logistics and Transportation Review* 44 (2): 277-297.

5 A sectoral perspective on distribution structure design

Onstein, A.T.C., Tavasszy, L.A., Rezaei, J., van Damme, D.A., & Heitz, A. (2020). A sectoral perspective on distribution structure design. International Journal of Logistics Research and Applications, 1-29, DOI: 10.1080/13675567.2020.1849074.

Abstract

This chapter studies the factors that drive distribution structure design (DSD), which includes the spatial layout of distribution channels and location choice of logistics facilities. We build on a generic framework from existing literature, which we validate and elaborate using interviews among industry practitioners. Empirical evidence was collected from 18 logistics experts and 33 decision-makers affiliated to shippers and logistics service providers from the fashion, consumer electronics and online retail sectors. It turns out that interviewees share similar rankings of main factors across industries, and even confirm factor weights from earlier research established using multi-criteria decision analysis, which would indicate that the framework is sector-neutral at the highest level. The importance attached to subfactors varies between sectors according to our expectations. We were able to identify 20 possible new influencing subfactors. The results may support managers in their decision-making process, and regional policy-makers with regard to spatial planning and regional marketing. The framework is a basis for researchers to help improve further quantitative DSD support models.

5.1 Introduction

Physical distribution involves the movement and storage of goods in a supply chain and is a major determinant of customer service levels and supply chain costs (Chopra 2003). Organising physical distribution is challenging, however, as customers expect high service levels at low costs. Globalization and supply chain fragmentation make the distribution of goods more complex, as it takes place over ever longer distances, while passing through more and more stages in the supply chain (Rodrigue 2008). One of the strategic decisions companies have to make to satisfy these demands involves distribution structure design (DSD), which concerns the spatial layout of the distribution channel - i.e. the freight transport and storage system between production and consumption – as well as the location(s) of logistics facilities, i.e. warehouses and distribution centres (DCs). Figure 5.1 presents several possible distribution channel layouts. The answer to the question as to which distribution channel layout is best depends on different factors. Centralised layouts (Layouts 1, 2 and 3) will allow savings in inventory costs, which is important to high value products like consumer electronics. The drawback of a central layout is that outbound transport costs are relatively high.

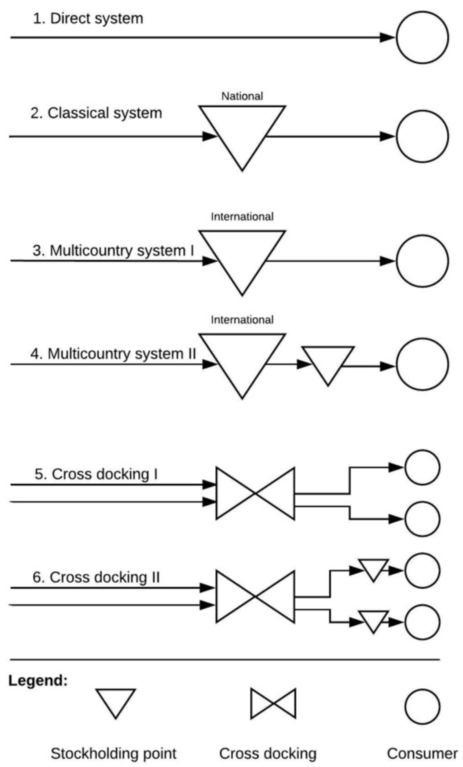


Figure 5.1 Distribution channel layouts (based on Kuipers and Eenhuizen, 2004, adapted)

A decentralised layout (Layouts 4 and 6) will favour high demand products for which outbound transport costs reduction is critical, e.g. groceries and office supplies. Advantages of a decentralised layout are low outbound transport costs and short delivery times, at the cost of additional inventory, warehousing and inbound transport costs. Companies may also implement hybrid distribution structures - combining centralised and decentralised layouts for several streams of products – in an attempt to achieve gains in several areas simultaneously (Van Hoek et al. 1998).

There are many factors that influence decision-making on DSD. However, despite the frequent treatment of DSD in supply chain handbooks, an empirically validated conceptual framework of factors is still lacking in the scientific literature. Most traditional distribution structure design models are prescriptive and few studies include empirical data (Mangiaracina et al. 2015; Olhager et al. 2015). A few works that propose conceptual frameworks are Lovell et al. (2005), Song and Sun (2017) and Onstein et al. (2019a and 2019b). However, these studies either examine a broader set of different decisions at a higher level or do not offer any empirical validation. Lovell et al. (2005) investigate the broader topic of supply chain fragmentation, while Song and Sun (2017) focus on broader supply chain decision-making, i.e. a range of decisions including sourcing, production and distribution locations, without looking at either of them specifically. Onstein et al. (2019a and 2019b) propose a generic DSD framework based on literature and measure the importance of factors, respectively, without differentiating between industry sectors, nor was the framework they proposed validated with practitioners or practical industry cases. Other studies on distribution centre location selection include Warffemius (2007), McKinnon (2009), Dablanc and Ross (2012), Verhetsel et al. (2015) and Heitz et al. (2018). These studies do not aim to consider the full scope of DSD factors, and/or include only a partial empirical analysis. In short, DSD-related factors have so far received insufficient attention in scientific literature, in particular due to a lack of systematic, empirical validation.

In order to contribute to filling this gap, we set out to validate the framework proposed by Onstein et al. (2019a) by conducting industry interviews and a subsequent analysis. We interviewed 51 respondents: 18 logistics experts, and 33 DSD decision-makers affiliated to shippers and LSPs in three sectors, i.e. fashion, consumer electronics and online retail. We focused on companies with DCs located in the Netherlands, which is a major node and a continental gateway for around 30% of goods imported into the EU (Holland International Distribution Council 2018). The analysis provides new insights into the empirical validity of existing frameworks and supports their quantitative analysis as well as adding new factors. Researchers can use the framework to improve quantitative DSD models, which are often still based on incorrect or incomplete sets of factors (Mangiaracina et al. 2015). The framework can also be of use for practitioners in government and industry. It may support companies - especially from the three selected industry sectors - to include the relevant factors when creating their DSD. As far as policy-makers and spatial planners are concerned, the framework is relevant to understanding how regional plans could attract logistics activities from industry.

The remainder of the chapter is organised as follows. Section 5.2 reviews the relevant literature and explains the generic, literature-based conceptual framework. Section 5.3 describes the research methods and data collection, while section 5.4 discusses the case results, which have been used to develop the validated conceptual framework. The conclusions, limitations and implications of the research and suggestions for future work are presented in Section 5.5.

5.2 Literature review

In this section, we briefly discuss the literature based framework for DSD as developed in Onstein et al. (2019a), which is the starting point for our research. Distribution structure design (DSD) includes DC location selection as well as distribution channel layout - i.e. the freight transport and storage system between production and consumption. Factors that explain DSD can be found in studies related to those two decisions, but also to broader supply chain design problems, like supply chain strategy, production location selection, capacity allocation, performance measurement and outsourcing (Song and Sun 2017). Studies related to DSD can relate to quantitative as well as qualitative research. Quantitative research can be found using multicriteria analysis (Ashayeri and Rongen 1997; Önden et al. 2016), multicriteria decision-making (Agrebi et al. 2017; Onstein et al. 2019b), statistical analysis (McKinnon 1984; Hilmola and Lorentz 2011), factor analysis (Song and Sun 2017), discrete choice analysis (Nozick and Turnquist 2001; Verhetsel et al. 2015), spatial modelling (Heitz and Beziat 2016; Klauenberg et al. 2016) and other quantitative models (e.g. Cooper 1984; Ashayeri and Rongen 1997; Olhager et al. 2015). Qualitative research includes literature reviews (Meixell and Gargeya 2005; Chopra and Meindl 2013; Mangiaracina et al. 2015; Olhager et al. 2015; Onstein et al. 2019a), interviews (Picard 1982; Klauenberg et al. 2016) and case studies (Nozick and Turnquist 2001; Lovell et al. 2005; Pedersen et al. 2012). The list presented above is limited to those studies that aim to identify and explain factors in relation to DSD; the many studies that only use factors from other sources are not included. Reviewing existing literature shows there is no study that proposes a framework of factors influencing DSD at the industry level. Lovell et al. (2005), Song and Sun (2017) and Onstein et al. (2019a and 2019b) are the only authors that propose relevant frameworks, but they have a much wider scope. Lovell et al. (2005) focus on the broader concept of supply chain fragmentation and Song and Sun (2017) focus on a broad range of supply chain decisions including sourcing, production and DC locations, while Onstein et al. (2019a) do not differentiate between industry sectors, but propose a generic literature-based DSD framework. We used their framework to continue the empirical exploration of the factors discussed in this chapter.

The framework includes 47 factors, classified into seven main groups: service level, logistics costs, business strategy, demand pattern, product characteristics, location factors and institutional factors. The factors are based on two main research disciplines, i.e. Supply Chain Management and (Economic) Geography. As known from the literature, the main trade-off influencing DSD is the one between service level factors and logistics costs (Chopra 2003; Christopher 2011). The others are the contextual factors that influence this trade-off:

- Business strategy and company characteristics, including size and management capacity;
- Demand factors, related to volume, frequency and regularity of products sold;
- Product characteristics that are cost or service drivers, e.g. value density and package density;
- Location factors related to local facilities, accessibility and labour market;
- Institutional factors related to legal and fiscal regulations.

The main factors and subfactors are explained in more detail below.

5.2.1 Service level factors

Service level factors are among the most important factors influencing DSD (Onstein et al. 2019b). They include supplier lead-time, delivery time, delivery reliability, responsiveness, returnability, and order visibility. Service level requirements vary per industry sector. High value pharmaceutical industries require higher distribution service levels compared to low value fashion industries. The delivery time (from DC to the customer) is influenced by the product type, i.e. customers do not accept long delivery times for substitutable products. In general, all companies aim for short delivery times, which is possible by storing sufficient inventories close to consumer markets or by using a centralised distribution layout combined with high-speed transport modes. High delivery reliability is important to companies that ship high-value goods (Christopher 2011). Responsiveness (i.e. reaction speed and flexibility to fulfil customer demand) can be increased by using a decentralised distribution layout, i.e. making sure products are available at all logistics facilities. Returnability (i.e. the ease of returning products) increases when there are more logistics facilities available to return products (Chopra 2003). Online retail customers expect they can easily return their goods (Xing et al. 2011).

5.2.2 Logistics costs factors

Logistics costs are – together with service level factors – the most important factors in DSD selection (Nozick and Turnquist 2001; Chopra 2003). Existing literature stresses three important logistics cost-related factors: transport costs, warehousing costs and inventory costs. Transport costs consist of the transport mode, labour costs and capital costs. Inventory costs include capital costs, insurances and management costs, and risk costs (damage, deterioration, obsolescence). Transport costs are divided into inbound transport (from production to DC) and outbound transport (from DC to the customer). Warehousing costs consist of labour costs, storage costs and handling materials (Christopher 2011). High outbound transport costs drive companies towards decentralised distribution, because outbound transport costs are reduced if the number of DCs increases. High inventory and warehousing costs, on the other hand, drive companies towards centralised distribution, since inventories and warehousing activities increase with the number of distribution centres (McKinnon 2009).

5.2.3 Business strategy and company characteristics

Business strategy is a company characteristic that affects DSD (Treacy and Wiersema 1993). Three renowned business strategies are customer intimacy, operational excellence and product leadership. Customer intimacy focuses on delivering high distribution service levels, which can be offered by applying a broad network of DCs near customer markets. Operational excellence focuses on competitive prices and low-cost distribution, for example by minimising the number of warehouses, while product leadership focuses on flexible operations that enable new product introductions (Treacy and Wiersema 1993).

The position of the DC within the supply chain (before or after production) is another influencing factor. In case of weight loss during production, a supplier DC is preferably located near the production location, to reduce inbound transport costs (McCann 2015). The factor 'retail store ownership' may persuade a company to locate logistics facilities within the centre of gravity of the retail stores, to reduce outbound transport costs. The size of the company also influences DSD. Small and medium-sized enterprises (SMEs) have less management or financial capacity and can therefore adjust their DSD less often (Pedersen et al. 2012).

5.2.4 Demand factors

Demand factors influencing DSD are demand level, demand dispersion and demand volatility. Demand level affects the number of DCs needed to distribute products. In case of high demand, more facilities are needed to distribute products on time (Chopra 2003; Mangiaracina et al. 2015). In case of geographically dispersed demand, it is advantageous to centralise distribution, because demand may fluctuate across regions. Demand volatility can influence a company to select a centralised distribution layout to prevent oversupplies (Friedrich et al. 2014).

5.2.5 Product characteristics

Product characteristics influencing DSD are product value density, package density and perishability (Onstein et al. 2019b). High value density products involve high inventory costs, influencing companies to select a centralised distribution layout (Ashayeri and Rongen 1997; Lovell et al. 2005). Companies that ship high-value products are more sensitive to location decisions than companies shipping low-value products (McCann and Sheppard 2003). Package density influences warehousing costs. High package density products that require rigorous product handling influence companies to centralise warehouse operations, because that reduces warehousing complexity and warehousing costs. Perishable products require short delivery times, causing companies to select a decentralised distribution layout (McKinnon 1984; Lovell et al. 2005; Christopher 2011).

5.2.6 Location factors

There are many location-related factors that influence DSD. Accessibility by road and possibly other modes of transport is essential. As the size of warehouses increases, land availability becomes a more important factor in selecting the location of DCs (Heitz and Beziat 2016). Proximity to airports and seaports can be important as well - air transport, for example, is often used for high value goods and spare parts (Warffemius 2007; Hall and Jacobs 2012; Verhetsel et al. 2015). Proximity of the DC location to a rail freight terminal is relatively unimportant, as goods are less often transported to and from DCs by rail (Bowen 2008). The factor ‘proximity to consumer markets’ is very important, because this enables fast customer deliveries (Heitz et al. 2019). According to previous research by Onstein et al. (2019b), proximity to suppliers or production locations is less important. The growth in average warehouse floor space motivates companies to locate logistics facilities in peripheral areas where land prices are lower (Dablanc and Ross 2012). Other advantages of peripheral locations include the lower costs of living and less congestion. The availability of warehouse employees is a key factor. Warehouse employees are easier to find in urban agglomerations than they are in peripheral areas, although labour scarcity in urban agglomerations can also be a push factor (agglomeration diseconomy) in locating logistics facilities outside those areas (Verhetsel et al. 2015; Heitz and Beziat 2016).

5.2.7 Institutional factors

Institutions like rules, laws, values and norms (North 1990) also influence DSD. Beneficial tax rules reduce inventory costs, which encourage companies to locate DCs in Free Trade Zones. Fast customs procedures also attract companies, because they enable them to reduce delivery times. Zoning rules can restrict the localisation of logistics activities (Sheffi 2012). Investment incentives and the presence of a development company are found to have a moderate effect on DSD (Davydenko 2015; Onstein et al. 2019b). In their distribution structure design, companies do value countries with high political stability (Onstein et al. 2019a).

Two limitations of the framework outlined above are the following: (1) because the framework does not distinguish between sectors of industry, it may not contain sufficient detail to indicate differences in preferences between sectors; (2) the framework itself still has little grounding in empirical research - despite the mention of factors in the literature, it has not yet been confronted with practitioners’ experience as a framework purpose-built for DSD. The aim of our empirical research is to help remedy that state of affairs; the next section describes the approach we adopted, including the cases we studied.

5.3 Research approach

5.3.1 Research method

An interview-based, qualitative, multiple case research design is applied to validate the important factors at a sectoral level and, in doing so, validate the general conceptual framework. The advantage of case research including interviews lies in the possibility to study factors at the level of individual companies or sectors, with an understanding of the case-specific context (Voss et al. 2002; Frankel et al. 2005; Bryman 2008; Yin 2014). Case research can be divided into three modes: theory generation, theory elaboration, and theory testing (Ketokivi and Choi 2014). Our goal is to validate the existing general conceptual framework i.e. examine its applicability to specific sectors, and identify opportunities to elaborate the framework.

5.3.1.1 Case selection

We selected three sectors (fashion, consumer electronics, and online retail) to test the framework in different industry contexts (Eisenhardt and Graebner 2007). The sectors were selected based on their contrasting product characteristics and distribution channel layout (see Tables 5.1 - 5.3). We contacted shippers or Logistics Service Providers (LSPs) with DCs located in different regions of the Netherlands. To increase cross-case comparability, the selected shippers and LSPs are all large companies that mainly focus on international customer markets for well-known brands. Companies were assigned to a sector based on their most important product in terms of annual turnover – most of the companies we interviewed only sell products from one industry sector. Online retail companies included those that only sell products online ('pure players'). LSPs were interviewed taking in mind one specific sector and a customer (shipper) from this sector. The interviewees were individual decision-makers on DSD, working at shippers or LSPs. The basis for selecting these decision-makers was their active involvement in the decision-making involving DSD, as was also verified during the interviews. Ultimately, 33 decision-makers were selected. As a basis of comparison for these sector-specific interviews and a source for general validation of the framework, we also interviewed 18 general experts in the area of logistics.

5.3.1.2 Data collection, data analysis and framework validation

We conducted semi-structured interviews, as is common in case research (Yin 2014), where semi-structured interviews are used to identify the important factors and to collect information on the companies' DSD. Three test interviews with potential respondents were used to improve and complete the questionnaire. The 33 sectoral respondents included 12, 12 and 9 interviewees from fashion, consumer electronics and online retail, respectively. All 33 were logistics managers or directors of logistics. The 18 logistics experts included 5 academic experts and 13 industry experts.

The interview protocol was designed as follows. The first part focused on the general characteristics of the company, and mainly included fixed response questions designed to simplify the analysis of the cases. The second part aimed at describing the current distribution structure. We asked the respondents to draw a schematic overview of their current structure, including sourcing, production locations, DCs, customer locations and transport between them. The third part, which focused on the influencing factors, included in-depth discussions in which the respondents were asked to explain why factors are important. Factor definitions were included in the questionnaire to obtain comparable interview data. To prevent anchoring bias of the respondents to our framework, we first asked each respondent to list the five most important factors by heart. Next, we presented a list of factors and asked the respondents to reflect on their importance. No interviews were conducted after saturation of the decision-making factors. The interviews were transcribed and filed to create a trail of case evidence. The transcripts were sent to the respondents for corrections and approval and then coded using NVivo software. We grouped answers based on code and case to identify differences and similarities across industry sectors (Voss et al. 2002). The coding protocol was based on the factors included in the generic conceptual framework. Additionally, open coding was applied, to allow us to extract new factors from the interviews. To check the intercoder reliability, 6 of the 51 interviews were double coded by a second independent researcher familiar with the research topic. Diverging codes and case results were discussed within the research team to reach a consensus.

We synthesised the results of the three cases on a within-case and across-case basis. We constructed a chart showing the number of respondents indicting a given factor as being important in DSD (Table 5.5). This also allowed us to conduct the cross-case analysis, including a match with the expert interviews and a statistical analysis of the results. Eventually, based on the comparison between interview results and the generic framework, we adapted the framework, which constitutes one of the main results of the research. We discuss the outcomes in greater detail in Section 5.4, after describing the industry cases in the next subsection.

5.3.2 Industry cases

In this subsection, we provide a more detailed description of the three industry cases.

5.3.2.1 Fashion

Today's fashion supply chains face multiple logistics challenges according to the interview respondents. Supplier lead times are long (i.e. up to 3 months), which means companies need responsive logistics operations to meet customer demand in time. The large number of fashion seasons also creates logistics challenges, i.e. accurate demand forecasts and responsive distribution are needed to prevent over/undersupplies.

The case interviews included nine well-known fashion shippers and three LSPs. The fashion shippers focus on international customer target markets (Table 5.1). Five of the nine shippers have their own retail stores in European shopping streets. At a European scale, all shippers apply centralised distribution channel layout (i.e. a single DC). In case of intercontinental sales, the companies use overseas regional DCs - often owned by local LSPs - to serve local customer target markets. Marketing channels vary from company to company – i.e. up to 40% online business to consumer (B2C) orders (Table 5.1).

5.3.2.2 Consumer electronics

Companies that sell consumer electronics products are faced with high inventory costs, because they sell high value density products. Fast air distribution networks are used by the interviewed companies to reduce the number of inventory days, thereby reducing inventory costs. Companies also use fast distribution networks because consumer electronics products have short product life cycles.

Table 5.1 Characteristics of fashion case interviews

Inter-view	Ship-per (S) / LSP	Most important product	No. of employees (and turnover in 2018)	Customer target market	Segment (B2B, B2C)	Company strategy	Value density (low, high) *	Package density (low, high)*	Marketing channels (W = wholesale, R = retail, IO = individual online consumers)	Distribu-tion channel layout	DC location(s)
F1	S	Under-clothing	6,200 (452.4 million Euro)	West-Europe	B2C	Customer intimacy	Low	High	600 retail stores (Europe), IO	Centralised DC	Hilversum
F2	S	African women's dresses	500 (N/A)	Africa, UK	B2C, B2B	Customer intimacy	High	High	80% sales offices, 19% W, 1% IO	Centralised DC, outsourced to LSP	Helmond
F3	S	Women's fashion	5,000 (134.7 million Euro) (2017)	West-Europe	B2C	Customer intimacy	High	High	90% R, 10% IO	Centralised DC, outsourced to LSP	Helmond
F4	S	High value fashion	5,400 (1.5 billion USD) (2017)	West-Europe	B2C, B2B	Product leadership	High	High	60% R, 20% W, 20% IO	Centralised DC, outsourced to LSP	Twente
F5	S	High value fashion	N/A	Northwest Europe, USA, Japan	B2B, B2C	Product leadership (retail)	High	High	60% R, 40% IO	De-centralised layout:	Amsterdam

			(750 million Euro) (2017)			and customer intimacy (online)				1 central DC in Amsterdam 8 regional DCs abroad	Regional DCs: USA, Canada, Australia, Hong Kong, Japan, South-America, China, South-Africa
F6	S	Suits	1,500 (245.6 million Euro) (2017)	Worldwide	B2C	Customer intimacy	High	High	65% R, 35% IO	De-centralised layout: 1 central DC in The Nether-lands, outsourced to LSP. 4 regional DCs abroad	Helmond (The Netherlands) New Jersey (USA), Toronto (Canada), Shanghai (China), Hong Kong
F7	LSP	Fashion distribution	822 (122.4 million Euro) (2017)	Benelux	B2B, B2C	Customer intimacy	High	Medium	N/A	Centralised DC for customer	Helmond
F8	LSP	Fashion distribution	1,075 (2016) (171 million Euro) (2015)	N/A	B2B	Customer intimacy	Low	High	N/A	Centralised DC for customer	Amsterdam
F9	LSP	Fashion distribution	50,000	Europe	B2B, B2C	Customer intimacy	Low	High	N/A	Centralised DC for customer	The Netherlands:

			(8.5 billion Euro) (2017)								Rotterdam, Almere, Venlo
F10	S	High value fashion	N/A (339 million Euro) (2017)	Worldwide	B2C, B2B	Customer intimacy	High	High	R, IO, W	De-centralised system: 1 central DC and 3 regional DCs	Central DC Hoofddorp (The Netherlands). Regional DCs: Swalmen (The Netherlands), Los Angeles (USA), Hong Kong
F11	S	High value fashion	1,500 (141 million Euro) (2017)	West-Europe	B2C	Customer intimacy	High	High	80% R, 20% IO	Centralised DC	Amsterdam
F12	S	Mid-range fashion	40 (N/A)	West-Europe	B2B	Customer intimacy, opera-tional excel-lence	Low	High	99% R, 1% IO	Centralised DC	Amsterdam

* Of the most important product (turnover).

Table 5.2 Characteristics of consumer electronics (CE) case interviews

Inter-view	Ship-per (S) / LSP	Most important product	No. of employees (and turnover in 2018)	Customer target market	Segment (B2B, B2C)	Company strategy	Value density (low, high) *	Package density (low, high) *	Marketing channels (W = wholesale, R = retail, IO = individual online consumers)	Distribu-tion channel layout	DC location(s)
CE1	LSP	Distribution	1,500 (169 million Euro)	Nether-lands	B2B, B2C	Customer intimacy	N/A	N/A	N/A	Centralised DC for shipper	Waalwijk
CE2	S	Anonymous	Anonymous	N/A	N/A	N/A	N/A	N/A	R, IO	Centralised	N/A
CE3	LSP	Distribution	1,500+ (500+ million Euro, 2017)	Benelux	N/A	Customer intimacy	High	High	N/A	Centralised DC for shipper, in network of DCs	30+ DCs in Benelux
CE4	S	Printers	1,100 (210 million Euro, 2017)	West-Europe	B2B, B2C	Opera-tional excel-lence	High	Low	W, R, IO	De-centralised, outsourced	Central DC in Bergen op Zoom, RDCs** in Europe, Turkey and South -Africa
CE5	S	Consumer photo cameras	21,000 (6.7 billion USD)	Europe, Russia, Turkey	B2B, B2C	Product leadership	High	High	R, IO	Centralised, outsourced	Limburg

CE6	S	Smart-phones	80,000 (Anonymous)	Worldwide	B2B, B2C	Product leadership	High	High	R, IO	De-centralised, outsourced	RDC in Eindhoven, 3 RDCs in East-Europe, 1 RDC in Germany
CE7	S	Smart-phones	320,000 (191 billion Euro)	Worldwide	B2B, B2C	Product leadership	High	High	R, IO	De-centralised, outsourced	Central DC in the Netherlands, RDC Schiphol, 7 RDCs in North- and South-Europe
CE8	S	Printers	32,000 (10 billion USD)	Europe, USA	B2B, B2C	Customer intimacy	High	Low	W, R, IO	Centralised, outsourced	Limburg
CE9	LSP	Distribution	24,000 (3.7 billion Euro, 2017)	Europe	N/A	Depends on customer	High	High	N/A	Centralised DC for shipper	Rotterdam
CE 10	S	PC accessories	7,000 (2.6 billion USD)	EMEA	B2B, B2C	Opera-tional excel-lence	Low	High	R, IO	Centralised on European level, outsourced	Central DC in Limburg, 7 RDCs worldwide
CE 11	S	Anonymous	Anonymous	EMEA	B2B, B2C	Depends on customer	High	Low	W, R, IO	De-centralised, outsourced	Central DC in the Netherlands, 1 RDC North-Europe, 3 RDCs South-Europe
CE 12	LSP	Distribution	1,600 (198 million Euro)	Europe	B2B	Depends on customer	High	High	N/A	Centralised DC for shipper	Maarssen

* Of the most important product (turnover).
** RDC = Regional DC.

Table 5.3 Characteristics of online retail (OR) case interviews

Inter-view	Ship-per (S) / LSP	Most important product	No. of employees (and turnover in 2018)	Customer target market	Segment (B2B, B2C)	Company strategy	Value density (low, high) *	Package density (low, high)*	Marketing channels (W = wholesale, R = retail, IO = individual online consumers)	Distribu-tion channel layout	DC location(s)
OR1	S	Online consumer electronics	3,600 (1.35 billion Euro)	Nether-lands, Belgium	B2C	Customer intimacy	High	High	IO	De-centralised	Central DC in Tilburg, 1 RDC**
OR2	S	Home furniture	260 (66 million Euro)	West-Europe	B2B, B2C	Customer intimacy	Low	Low	IO	Centralised	Utrecht
OR3	S	Fashion, home furniture, sports	N/A	Nether-lands	B2C	Customer intimacy	Low	Low	IO	De-centralised	Central DC Zwolle, 4 RDCs
OR4	S	Food	4,500 (1.3 billion Euro)	Europe	B2C	Customer intimacy	Low	Low	IO	De-centralised	> 10 RDCs, Netherlands
OR5	S	Party apparel, party accessories	7 (1 million Euro)	Nether-lands, Belgium, Germany	B2B, B2C	Customer intimacy	Low	High	IO	Centralised	Emmen
OR6	S	Food	> 1,500 (200 million Euro)	Nether-lands, Germany	B2C	Opera-tional excel-lence	Low	Low	IO	De-centralised	5 RDCs and > 20 hubs in the Netherlands
OR7	S	Flowers	> 100 (N/A)	West-Europe	B2C, B2B	Customer intimacy	Low	Low	IO	De-centralised	Central DC Aalsmeer, > 30 RDCs in West Europe

OR8	S	Home furniture	100 (20 million Euro)	West-Europe	B2C, B2B	Customer intimacy	Low	Low	IO	Centralised	Amsterdam
OR9	LSP	Online fashion distribution	> 800 (> 120 million Euro)	Benelux	N/A	Customer intimacy	N/A	N/A	N/A	Centralised	N/A

* Of the most important product (turnover).
** RDC = Regional DC.

The interviews included eight shippers that focus on international consumer markets and four LSPs (Table 5.2). The shippers we interviewed sell their goods via consumer electronics stores (like MediaMarkt), store-in-store or online, but do not have own retail stores, unlike the fashion case. The main inbound transport modes being used are air and sea, while the main outbound transport mode is by road. Due to the high value density of consumer electronics products, inventory cost reduction was found to be the main logistics challenge according to consumer electronics (CE) companies. Four of the eight consumer electronics companies apply a centralised distribution channel layout, while the other four shippers apply a decentralised distribution channel layout (Table 5.2); however, two of the latter apply direct-ship-to-air hub distribution – bypassing a central DC – to reduce inventory costs and improve delivery times (Anonymous). Outsourcing warehousing and distribution (7 of 8 shippers) to LSPs is standard in this sector, as shippers are unable to organise (low volume) high speed distribution for competitive prices in-house.

5.3.2.3 Online retail

Online retail (OR) companies are retail companies that only sell their products online ('pure players'). They face high warehousing costs caused by complex warehousing processes. Online retail companies use highly responsive distribution networks, because their customers expect fast deliveries. According to the respondents, major logistics challenges include delivery time reduction, demand peaks and volatile customer demand.

We interviewed eight shippers (retailers) and one LSP, while other OR companies refused to cooperate. The companies we did manage to interview ship a diverse range of products, e.g. furniture, food and flowers (Table 5.3). The main inbound transport modes they use are by sea and air, while the main outbound transport mode is by road. Three OR shippers apply a centralised distribution channel layout, while two other shippers apply a decentralised layout, i.e. they use a central DC to ship parcels and another (often smaller) DC to ship large goods. The remaining three shippers use a decentralised layout to ship perishable products, i.e. food and flowers. Five of the eight shippers outsource outbound transport (from DC to customer) to LSPs who are able to offer extensive distribution networks for competitive prices. Warehousing operations are mostly insourced (i.e. by 7 of the 8 shippers) due to the complexity of warehousing processes – i.e. different from the CE case in which all shippers outsource warehousing operations.

5.4 Results

The analysis of the interviews is presented below. The first subsection compares the main factors that influence DSD for three sectors. This is followed by the cross-case comparison of the subfactors and the validated conceptual framework.

Based on the case results, we identified several new factors, i.e. keep factors, personal location preferences and LSP influence (Table 5.5, Appendix 5.1 for the links to the individual interviews). We explain these factors below:

- The case results show five 'keep' factors that may contribute to the decision whether or not to relocate within the current region. Cost of severance - i.e. costs of firing employees - influenced four fashion companies and five CE companies. Knowledge retention of warehousing employees (see also Christensen and Drejer 2005), penalties of ending current lease contracts and links with the historical location are other possible keep factors. Historical links are moderately important to fashion companies; five fashion companies value historical links with the Amsterdam fashion cluster.

- Personal location preferences can be a decisive factor for individual companies. The role of personal location preferences has been studied for headquarter locations (Blair and Premus 1987); our research confirms that they can also play a role in DC location selection. Three fashion shippers located the DC near the home address of the CEO to reduce commuting times.
- When distribution is outsourced, the logistics service provider (LSP) will influence DSD. Shippers may accept a DC location nearer to its transport centre of gravity compared to if the shipper were to make distribution arrangements itself, or accept a larger DC than chosen otherwise, to allow for sales volume fluctuations.

We classified these new factors in our framework as follows. Because keep factors involve the dynamics of change itself, they are of a different nature than the current main factors, which is why we added them as a new main factor. Personal location preferences are classified as subfactors under location factors. LSP influence relates to the organisation of logistics within a company and is therefore included under the main factor 'Business strategy and company characteristics'. We continued our analysis with this new set of factors.

5.4.1 Main factors: cross-case comparison

Table 5.4 shows the number of respondents that have confirmed a factor as being important for DSD. The table presents the main factors (detailed factor scores can be found in Appendix 5.1). To arrive at these scores, the number of subfactor mentions for each main factor was added, e.g. logistics costs subfactors together were mentioned 35 times by the fashion sector respondents (Table 5.4A). To correct for splitting bias (Jacobi and Hobbs 2007), we corrected for the number of subfactors in each main factor; e.g. logistics costs consists of 4 subfactors, while location consists of 24 subfactors – the scores are therefore divided by 4 and 24, respectively (Table 5.4B). This provides us with comparable information on the ordering of the main factors. Table 5.4C shows a correlations matrix of the scores. The sectoral scores correlate very well, in particular for the respondents from the three industry sectors, which suggests that the framework at the level of main factors is robust for use across sectors. In other words, the factors do not appear to discriminate between these three sectors.

Table 5.4 Sum of mentions of subfactors per main factor and sector

	Decision-makers				
Industry sector	Fashion	Consumer electronics	Online retail	**Experts**	
# of interview respondents	12	12	9	18	
Total mentions of subfactors across all the sectors	271	305	188	160	
5.4A. Sum of mentions of subfactors per main factor and sector	Fashion	Consumer electronics	Online retail	Experts	# of subfactors
Service level factors	47	50	33	13	6
Logistics costs factors	35	40	28	30	4
Business strategy & company characteristics	6	11	6	4	6

Demand factors	17	22	19	4	3
Product characteristics	13	19	11	7	3
Location factors	98	111	60	71	24
Institutional factors	41	43	22	28	14
Keep factors	14	9	9	3	5
5.4B. Scores corrected for number of subfactors	Fashion	Consumer electronics	Online retail	Experts	
Service level factors	7.8	8.3	5.5	2.2	
Logistics costs factors	8.8	10.0	7.0	7.5	
Business strategy & company characteristics	1.0	1.8	1.0	0.7	
Demand factors	5.7	7.3	6.3	1.3	
Product characteristics	4.3	6.3	3.7	2.3	
Location factors	4.1	4.6	2.5	3.0	
Institutional factors	2.9	3.1	1.6	2.0	
Keep factors	2.8	1.8	1.8	0.6	
5.4C. Correlations matrix of scores corrected for number of subfactors	Fashion	Consumer electronics	Online retail	Experts	
Fashion		0.976	0.952	0.690	
Consumer electronics			0.905	0.714	
Online retail				0.571	

Figure 5.2 shows a ranking of the main factor scores (#1 highest rank). The decision-makers from each of the industry sectors give almost the same ranking to each of the main factors, i.e. the most important main factors (with highest rank) are logistics costs, service level, demand and product characteristics. It is well-known from literature that logistics costs and service level are the important main factors influencing DSD (Chopra 2003; Christopher 2011). Our results indicate a broad agreement on the importance of all the main factors across these sectors – although there are important differences between sectors on the importance of the various subfactors, as we will show later. The scores of the expert respondents correlate less well with the sectoral decision-makers than the mutual decision-makers, although correlations are still strong (Table 5.4C). In particular, experts rank location factors and product characteristics higher, and demand and service level lower than any sectoral decision-maker.

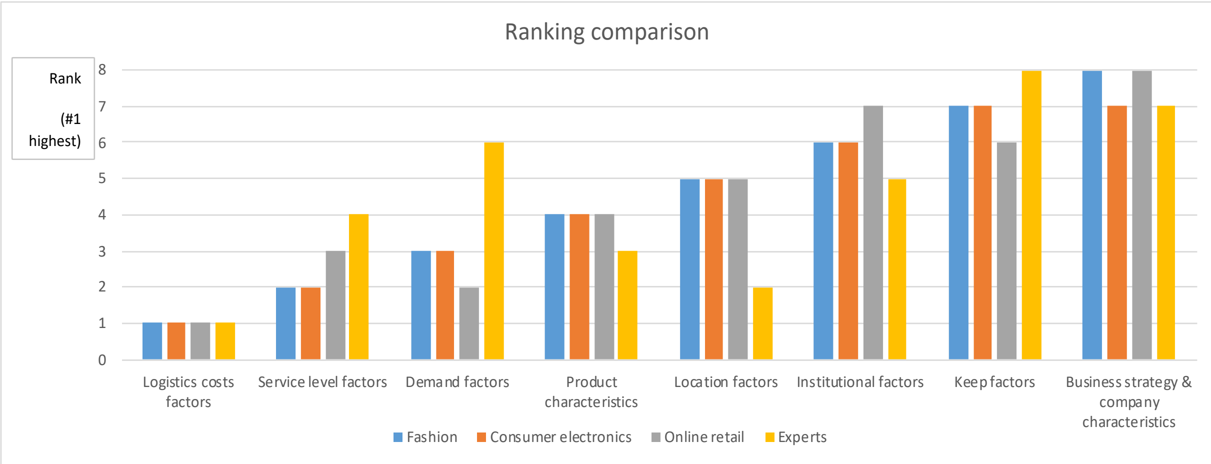
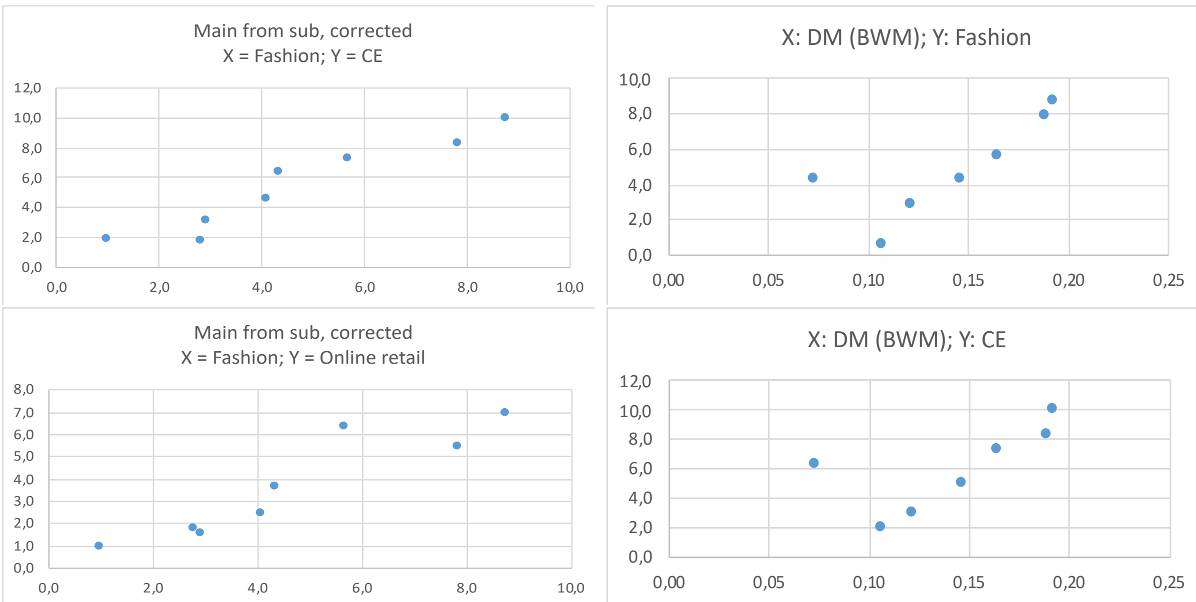


Figure 5.2 Ranking of main factors based on scores corrected for splitting bias

Figure 5.3 shows scatter plots of the corrected main factor scores. Figure series 5.3 (left) confirms the correlation between sectors showing the individual factors, including their relative position. We also used this visualization to examine how our results relate to findings in earlier studies concerning the importance of the main factors. Onstein et al. (2019b) measured the weights of the main factors (i.e. excluding the new factors found in our interviews) using the Best-Worst Method (BWM) from Multi-Criteria Decision Analysis (MCDA). Interestingly, if we compare the scores of the same factors, they correlate very well. The fact that two such different research methods (i.e. interviews versus MCDA for the same primary framework) lead to highly comparable scores is surprising and encouraging, as it confirms the results through triangulation of literature, surveys and interviews. Moreover, it leads to the important conjecture that a low-cost and fast MCDA survey can provide similar results as a time-intensive series of detailed interviews with industry decision-makers. The one main factor that fits relatively less well into the pattern is 'product characteristics' (see outliers in Figure series 5.3 (right)). We can only explain this by pointing to the fact that the interviewees were conscious of a specific product during the interview, while the BWM survey was generic in nature.



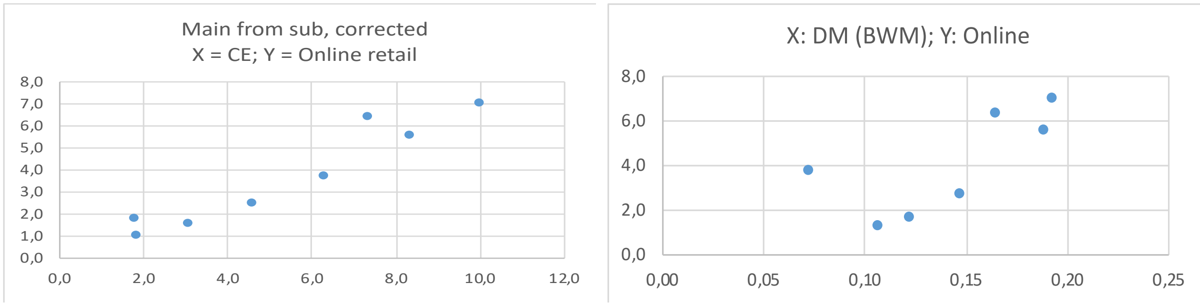


Figure 5.3 Correlations of main factor scores between sectoral decision-makers (left) and between sectoral decision-makers and previous BWM research by Onstein et al. (2019b) (right)

5.4.2 Subfactors: cross-case comparison

Although decision-makers gave similar rankings to the main factors across industries, there are important differences between industry sectors with regard to the importance of the various subfactors, which we describe below. To arrive at comparable subfactor scores, we corrected for the number of respondents per sector (i.e. 12, 12 and 9 respondents; see Appendix 5.1). The normalized scores are compared using radar charts for each main factor, with the importance of subfactors indicated between 0 (mentioned by no respondent) and 1 (mentioned by all).

5.4.2.1 Service level factors

Subfactor 'supplier lead time' is most important in the fashion sector (Figure 5.4). Supplier lead times are long, i.e. often 3-5 months, according to fashion respondents which is why many fashion shippers use Quick Response production systems to reduce supplier lead times (Şen 2008). Supplier lead times are unimportant to the OR respondents, possibly because some of them source nearby (e.g. food, flowers, furniture, see Table 5.3) and thus already have short supplier lead times. Responsiveness (reaction speed to fulfill demand) is most important to online retail companies (Figure 5.4). Online customers show volatile demand patterns, while at the same time expecting short delivery times (Xing et al. 2011) - i.e. within one or few days (Interview OR3) - forcing OR companies to maintain highly responsive distribution operations (Interview OR1). The relatively high importance of the subfactor returnability may be explained by the differences between products. A CE product return will have a higher value density compared to a fashion product return, making it important to CE companies to receive their product returns. In the OR case, only OR companies with high return rates confirm the importance of this factor (i.e. OR5, OR8, OR9); those that do not mention this factor, i.e. home furnishing, food and flowers, are also the ones with few returns (OR2, OR6, OR7).

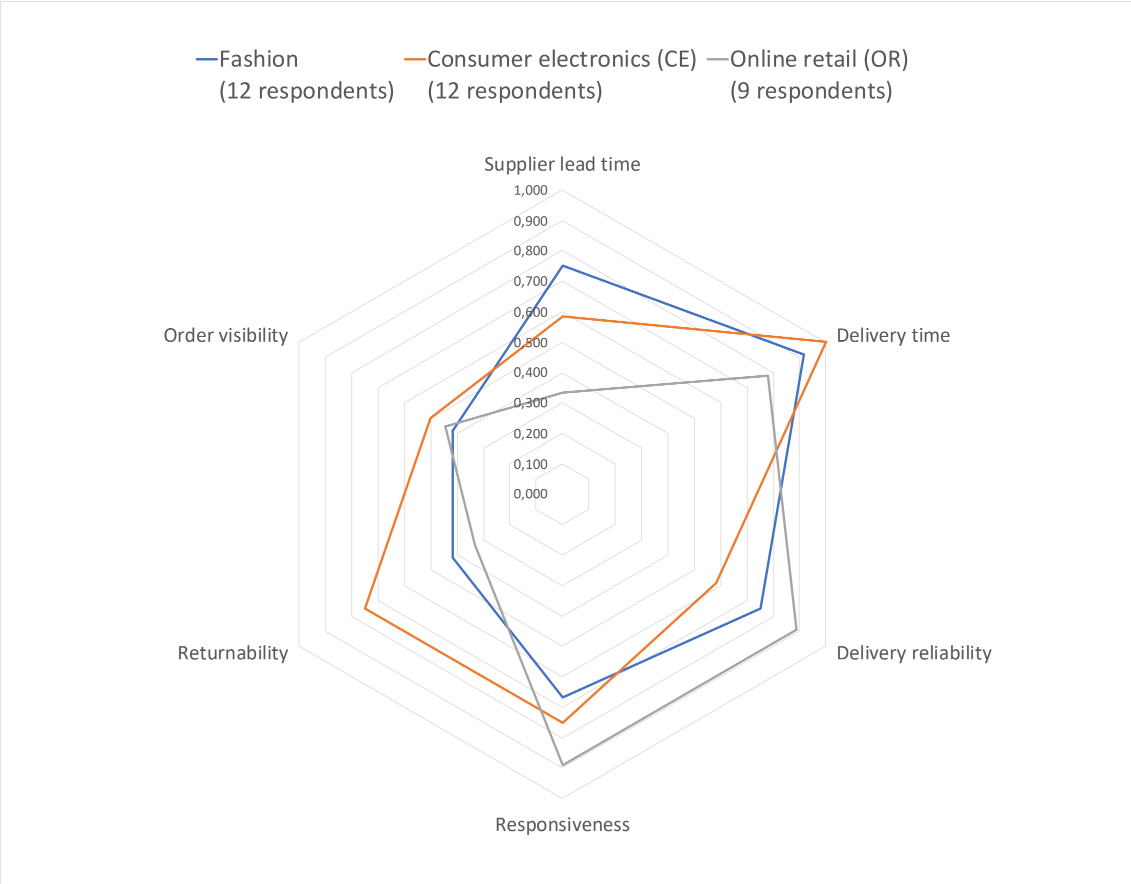


Figure 5.4 Service level subfactor importance (0 = low, 1 = high)

5.4.2.2 Logistics costs factors

Warehousing costs and outbound transport costs are the most important subfactors in this category (Figure 5.5). Outbound transport costs may be considered more important than inbound transport costs, because they often allow fewer advantages of scale (Christopher 2011). Products with a lower package density typically show this pattern to a lesser extent, as is shown in the case of the fashion industry. Inventory costs are most important to CE companies, probably because their products have a high value density.

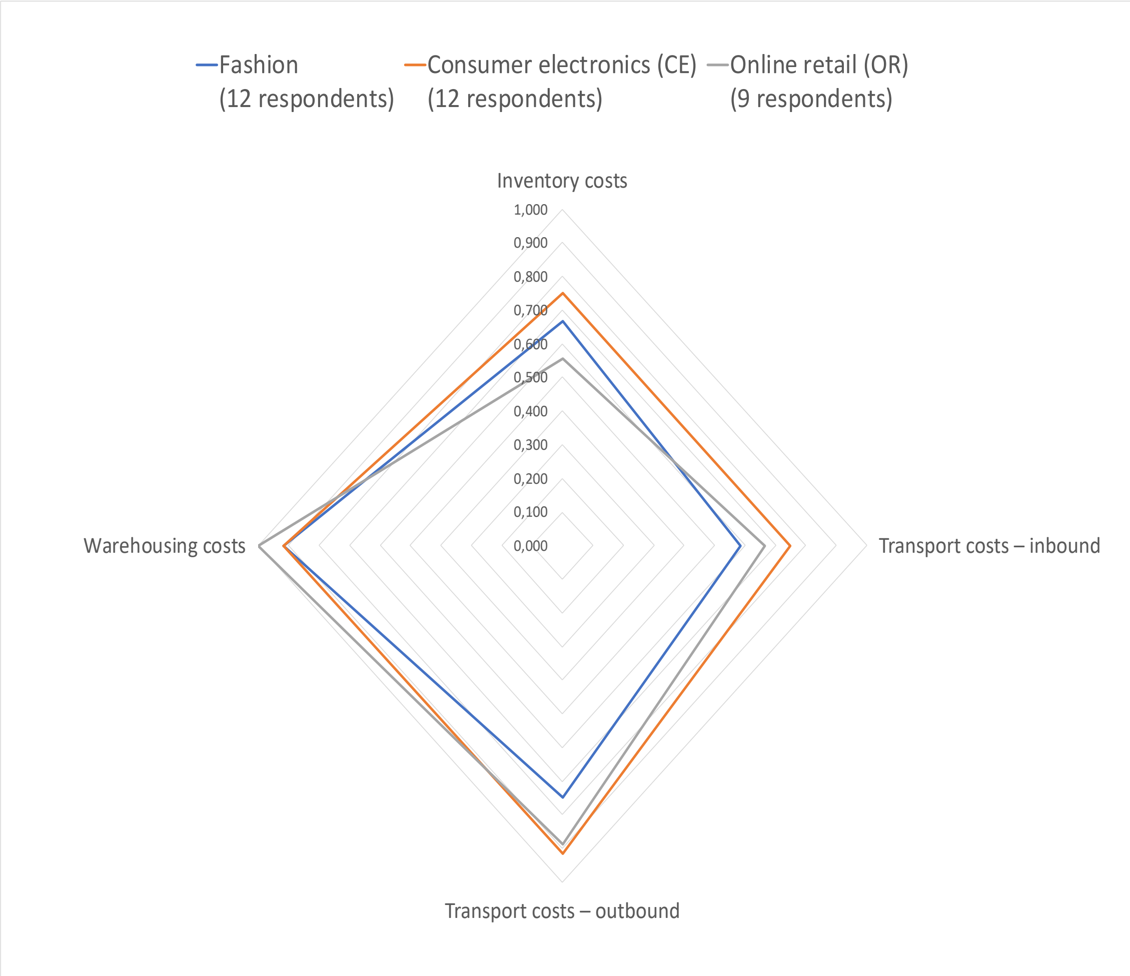


Figure 5.5 Logistics costs subfactor importance (0 = low, 1 = high)

5.4.2.3 Business strategy and company characteristics

Overall, business strategy and company characteristics are a relatively unimportant main factor (Figure 5.2). The subfactors in this category, however, do vary in terms of their influence. Managerial and financial capacity were the most dominant of all the subfactors, especially within the CE and OR sectors (Table 5.5). As also argued by Pedersen et al. (2012), sufficient management and financial capacity stimulates DSD implementation.

5.4.2.4 Demand factors

Demand levels are considered to be an important subfactor in this category (Figure 5.6). Varying demand volumes and geographies pose a major logistics challenge to companies. Demand volatility is especially important in the OR case. OR companies face volatile demand, because their customers can easily switch between suppliers (Boyer and Hult 2005). Six out of nine of the OR companies we interviewed have outsourced outbound distribution to parcel carriers, because they are able to handle volatile goods volumes well (Table 5.3). Demand volatility is relatively unimportant to fashion companies – presumably because their demand levels are relatively stable.

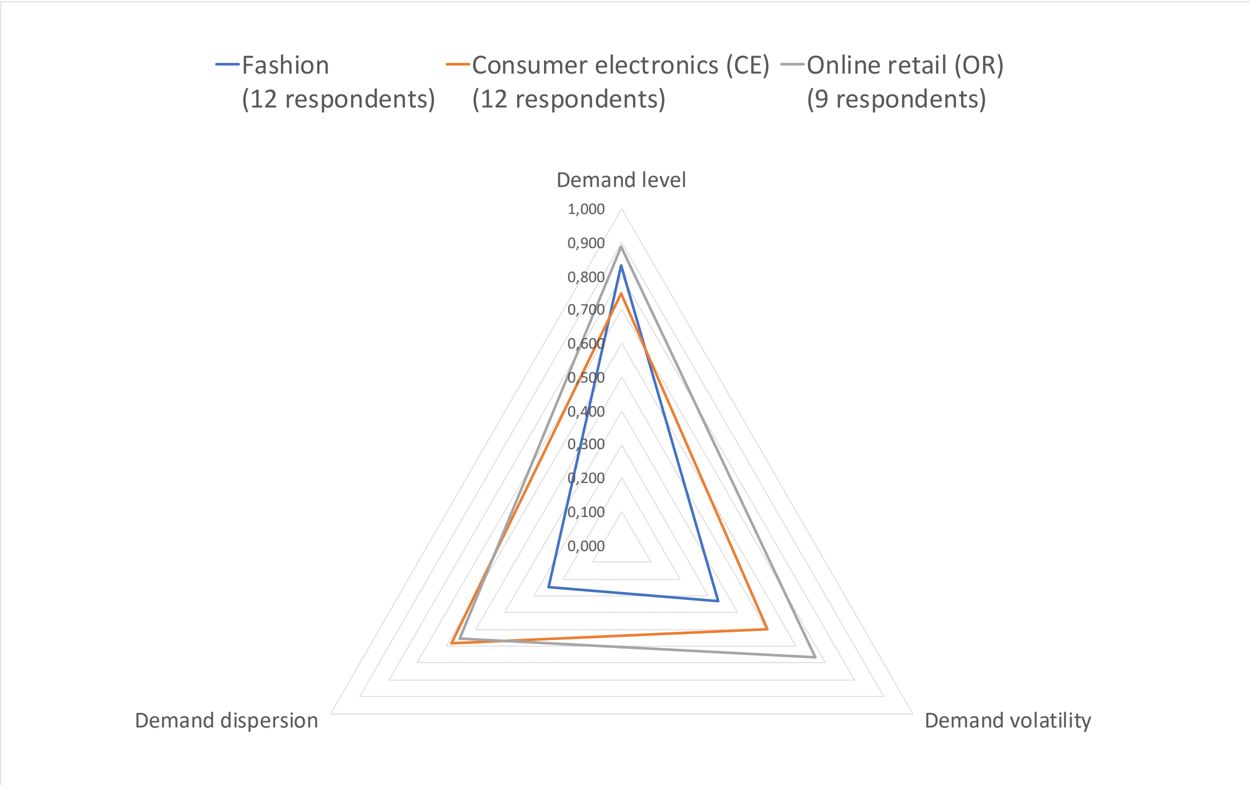


Figure 5.6 Demand subfactor importance (0 = low, 1 = high)

5.4.2.5 Product characteristics

Within the main factor 'product characteristics' (Figure 5.7), the scores of the subfactor 'product value density' follow the order of the value density of products quite well, with CE products showing the highest scores (Li et al. 2005). The fact that most CE companies (8 out of 12) use a centralised distribution channel layout may be related to this aspect. The subfactor 'package density' is moderately important in all sectors, without much difference between the sectors. Products from all three sectors need to be repackaged from wholesale to retail units. Perishability (i.e. shelf life length) is moderately important in the CE and OR cases, but relatively unimportant in the fashion case – note that perishability here does not refer to products being out of fashion, but relates to shorter term value loss, during distribution. At the individual company level, we found that perishability depended strongly on the product being sold, with OR companies that sell food and flowers reporting high scores (interviews OR4, OR6, OR7). The shippers involved distribute products via local hubs to allow for fast deliveries.

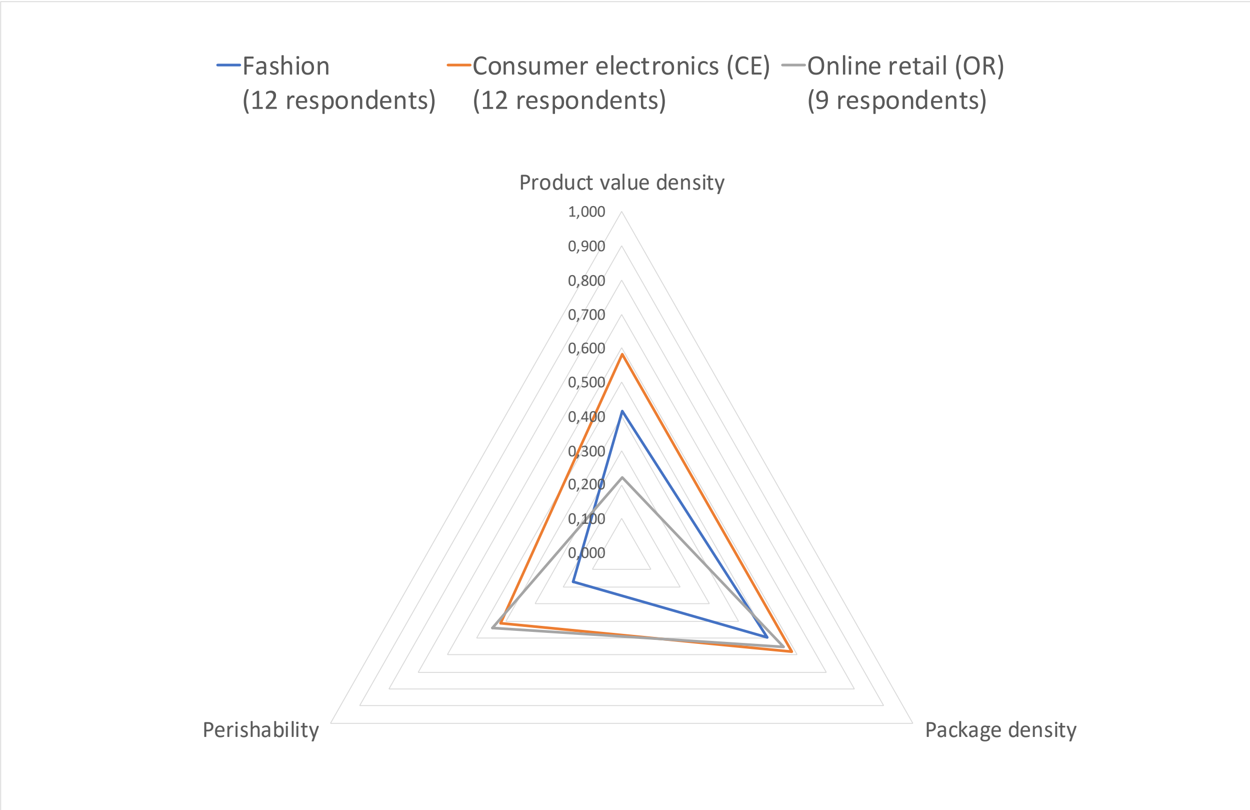


Figure 5.7 Product characteristics subfactor importance (0 = low, 1 = high)

5.4.2.6 Location factors

Proximity of the DC to the motorway is relatively important compared to other subfactors in this category (Figure 5.8), which is in line with existing literature (e.g. Bowen 2008; Dablanc and Ross 2012). Proximity of the DC to airports largely follows the value density of products, where pipeline capital costs will be balanced against shipping rates. Especially CE and fashion will be moved across larger distances. CE companies use air as their main inbound transport mode, while fashion companies use air transport for important collection reorders during a fashion season. Proximity to seaports largely follows the same pattern, with CE and fashion product DCs likely to locate relatively nearby. Proximity of the DC to consumer markets is generally known to be an important factor, which is here confirmed for the OR and CE case, although less so for the fashion case. Customer lead times are shorter in the OR and CE sectors (Nguyen et al. 2018; Li et al. 2005) compared to the fashion sector, because expected service levels are higher and products tend to be more perishable.

Labour market availability is an important location factor to CE and Fashion companies and moderately important to OR companies. In all three industry sectors, there are respondents who confirm there was labour scarcity in the Netherlands at the time the interviews were conducted. The relatively low importance of labour market availability to OR may be explained by the lower (non-specialized) job skills requirements, or the fact that, in the Netherlands OR, different labour conditions apply compared to conventional retail supply chains.

There are no marked differences between sectors with regard to land availability, except for the fact that OR scores relatively low. Land costs are important to fashion companies, but relatively unimportant to CE and OR companies. Fashion DCs typically serve a larger geographic area, which implies that they have more search opportunities when it comes to securing lower land rents.

Eight possible new location factors were identified based on the case interviews. Accessibility of the DC for employees by public transport could be a new influencing factor according to five respondents (all cases), because companies start to locate DCs further away from urban areas (explained in interview CE1, E12). In the OR case, a new location factor could be proximity of the DC to an LSP hub. Six out of nine OR shippers prefer to locate the DC near their parcel carrier, to reduce delivery times.

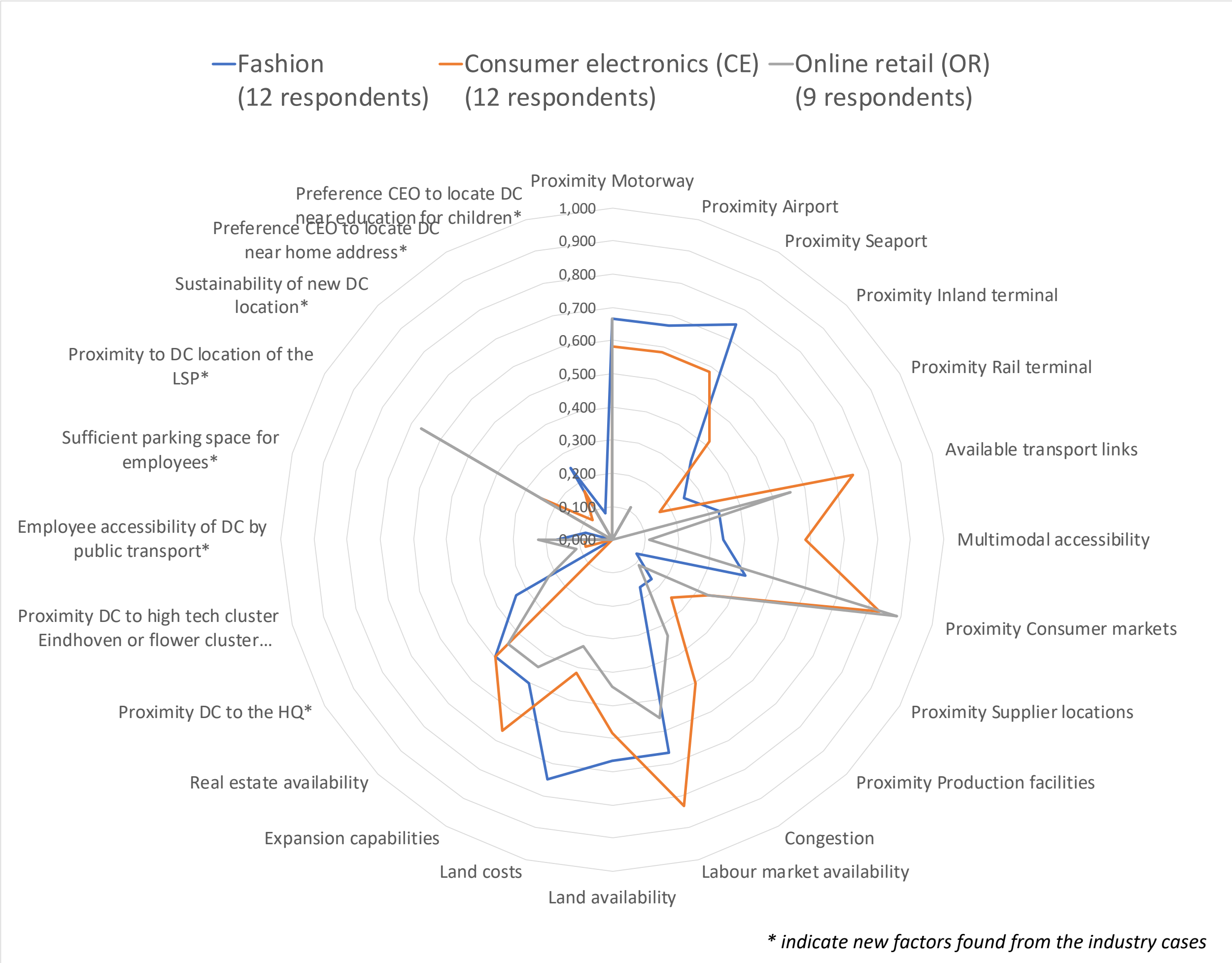


Figure 5.8 Location subfactor importance (0 = low, 1 = high)

5.4.2.7 Institutional factors

Overall, the institutional subfactors that have a direct economic impact on investment and operations were the ones mentioned during the interviews (Figure 5.9). The patterns of the sectors are quite comparable, although to a lesser extent for OR. Efficient customs procedures are considered important, because they reduce customer delivery times and increase product availability. High taxes are a push factor, while tax advantages (such as VAT deferment) may help persuade companies to locate their DCs in Free Trade Zones (Sheffi 2012). The relatively low importance of some institutional factors to OR companies could be caused by their focus on smaller regions for distribution (domestic or sub-continental), where differences between location options are relatively minor.

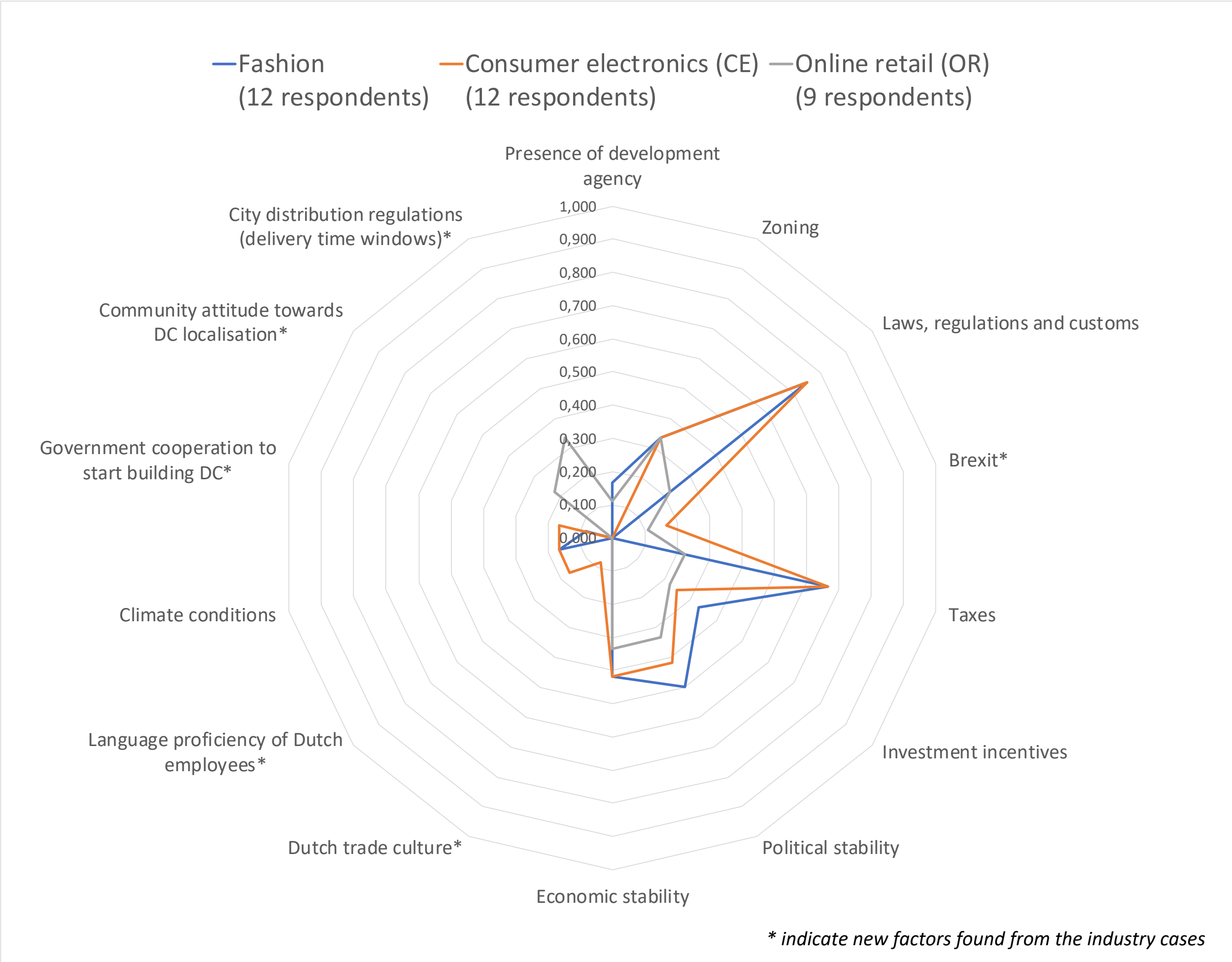


Figure 5.9 Institutional subfactor importance (0 = low, 1 = high)

Table 5.5 Factors influencing distribution structure design (DSD) according to case interviews

	Decision-makers (33 respondents)			Experts (18 respondents)
	Fashion (12 respondents)	Consumer electronics (CE) (12 respondents)	Online retail (OR) (9 respondents)	
Factors	Number of fashion respondents indicating that the factor is important	Number of consumer electronics respondents indicating that the factor is important	Number of online retail respondents indicating that the factor is important	Number of expert respondents indicating that the factor is important
1. Business strategy & company characteristics**				
- Managerial capacity	-	5 *(CE3, CE5, CE7, CE10, CE12)*	3 *(OR3, OR4, OR6)*	-
- Financial capacity	-	4 *(CE5, CE7, CE10, CE12)*	3 *(OR2, OR3, OR4)*	-
- In-house or outsourcing strategy	2 *(F1, F8)*	-	-	2 *(E13, E15)*
- Store ownership	1 *(F8)*	1 *(CE7)*	-	1 *(E15)*
- Position within the supply chain	-	-	-	1 *(E6)*
- LSP influence on shipper*	3 *(F2, F3, F9)*	1 *(CE5)*	-	-
2. Demand factors				
- Demand level	10 *(F1, F2, F3, F4, F5, F6, F7, F8, F9, F10)*	9 *(CE2, CE3, CE4, CE7, CE8, CE9, CE10, CE11, CE12)*	8 *(OR1, OR2, OR3, OR4, OR5, OR6, OR7, OR9)*	3 *(E13, E17, E18)*
- Demand volatility	4 *(F2, F4, F5, F7)*	6 *(CE4, CE5, CE7, CE10, CE11, CE12)*	6 *(OR1, OR3, OR4, OR5, OR7, OR9)*	-
- Demand dispersion	3 *(F5, F6, F9)*	7 *(CE4, CE5, CE7, CE8, CE9, CE10, CE11)*	5 *(OR1, OR2, OR4, OR6, OR7)*	1 *(E15)*
3. Service level factors				

- Supplier lead time	9 *(F1, F2, F3, F4, F5, F6, F7, F8, F9)*	7 *(CE4, CE5, CE6, CE7, CE9, CE10, CE11)*	3 *(OR4, OR7, OR9)*	3 *(E7, E15, E17)*
- Delivery time	11 *(F1, F2, F3, F4, F5, F6, F7, F8, F9, F10, F11)*	12 *(CE1, CE2, CE3, CE4, CE5, CE6, CE7, CE8, CE9, CE10, CE11, CE12)*	7 *(OR1, OR2, OR3, OR4, OR5, OR6, OR9)*	5 *(E7, E8, E13, E15, E17)*
- Delivery reliability	9 *(F2, F3, F4, F5, F6, F7, F8, F9, F10)*	7 *(CE4, CE7, CE8, CE9, CE10, CE11, CE12)*	8 *(OR1, OR3, OR4, OR5, OR6, OR7, OR8, OR9)*	1 *(E7)*
- Responsiveness	8 *(F2, F3, F4, F5, F6, F7, F8, F9)*	9 *(CE3, CE4, CE5, CE7, CE8, CE9, CE10, CE11, CE12)*	8 *(OR1, OR3, OR4, OR5, OR6, OR7, OR8, OR9)*	2 *(E7, E8)*
- Returnability	5 *(F5, F6, F7, F8, F9)*	9 *(CE4, CE7, CE8, CE9, CE10, CE11, CE12)*	3 *(OR5, OR8, OR9)*	2 *(E13, E17)*
- Order visibility	5 *(F5, F6, F7, F8, F9)*	6 *(CE4, CE7, CE9, CE10, CE11, CE12)*	4 *(OR6, OR7, OR8, OR9)*	-
4. Product characteristics				
- Product value density	5 *(F3, F5, F6, F8, F9)*	7 *(CE4, CE5, CE7, CE8, CE9, CE11, CE12)*	2 *(OR7, OR8)*	4 *(E6, E13, E15, E18)*
- Package density	6 *(F3, F4, F5, F6, F8, F9)*	7 *(CE4, CE5, CE7, CE8, CE9, CE11, CE12)*	5 *(OR1, OR4, OR6, OR7, OR8)*	2 *(E6, E17)*
- Perishability	2 *(F5, F8)*	5 *(CE4, CE7, CE10, CE11, CE12)*	4 *(OR4, OR6, OR7, OR8)*	1 *(E6)*
5. Logistics costs factors				
- Inventory costs	8 *(F3, F4, F5, F6, F7, F8, F9, F10)*	9 *(CE2, CE3, CE4, CE5, CE7, CE8, CE9, CE10, CE11)*	5 *(OR1, OR6, OR7, OR8, OR9)*	7 *(E5, E7, E8, E13, E15, E17, E18)*
- Transport costs – inbound	7 *(F1, F4, F5, F6, F7, F8, F9)*	9 *(CE2, CE3, CE4, CE5, CE7, CE8, CE9, CE10, CE11)*	6 *(OR1, OR3, OR4, OR5, OR6, OR9)*	7 *(E5, E7, E8, E13, E15, E17, E18)*
- Transport costs – outbound	9 *(F3, F4, F5, F6, F7, F8, F9, F10, F11)*	11 *(CE1, CE2, CE3, CE4, CE5, CE7, CE8, CE9, CE10, CE11, CE12)*	8 *(OR1, OR2, OR3, OR4, OR5, OR6, OR7, OR9)*	10 *(E5, E6, E7, E8, E12, E13, E15, E16, E17, E18)*

- Warehousing costs	11 *(F1, F2, F3, F4, F5, F6, F7, F8, F9, F10, F11)*	11 *(CE1, CE2, CE3, CE4, CE5, CE7, CE8, CE9, CE10, CE11, CE12)*	9 *(OR1, OR2, OR3, OR4, OR5, OR6, OR7, OR8, OR9)*	6 *(E5, E7, E8, E14, E15, E17)*
6. Location factors				
- Proximity to:				
o Motorway	8 *(F2, F4, F5, F7, F8, F9, F11, F12)*	7 *(CE4, CE7, CE8, CE9, CE10, CE11, CE12)*	6 *(OR3, OR4, OR6, OR7, OR8, OR9)*	4 *(E12, E15, E17, E18)*
o Airport	8 *(F2, F4, F5, F6, F8, F10, F11, F12)*	7 *(CE5, CE7, CE8, CE9, CE10, CE11, CE12)*	-	7 *(E5, E8, E12, E13, E14, E17, E18)*
o Seaport	9 *(F2, F4, F5, F6, F8, F9, F10, F11, F12)*	7 *(CE4, CE7, CE8, CE9, CE10, CE11, CE12)*	1 *(OR1)*	4 *(E5, E14, E17, E18)*
o Inland terminal	4 *(F4, F5, F8, F9)*	5 *(CE2, CE4, CE7, CE8, CE10)*	-	1 *(E15)*
o Rail terminal	3 *(F4, F8, F9)*	2 *(CE7, CE11)*	-	-
- Available transport links	4 *(F2, F3, F4, F5)*	9 *(CE4, CE5, CE6, CE7, CE8, CE9, CE10, CE11, CE12)*	5 *(OR2, OR3, OR4, OR7, OR8)*	5 *(E5, E11, E15, E17, E18)*
- Multimodal accessibility	4 *(F4, F6, F8, F9)*	7 *(CE5, CE7, CE8, CE9, CE10, CE11, CE12)*	1 *(OR1)*	5 *(E3, E8, E11, E12, E15)*
- Proximity to:				
o Consumer markets	5 *(F6, F7, F8, F9, F11)*	10 *(CE1, CE3, CE4, CE5, CE7, CE8, CE9, CE10, CE11, CE12)*	8 *(OR1, OR2, OR3, OR4, OR5, OR6, OR8, OR9)*	12 *(E1, E2, E3, E5, E6, E7, E11, E13, E14, E15, E16, E17)*
o Supplier locations	1 *(F5)*	4 *(CE4, CE7, CE10, CE11)*	3 *(OR3, OR4, OR7)*	1 *(E6)*
o Production facilities	2 *(F2, F9)*	3 *(CE4, CE7, CE10)*	1 *(OR4)*	1 *(E3)*
- Congestion	2 *(F4, F6)*	6 *(CE1, CE7, CE9, CE10, CE11, CE12)*	3 *(OR4, OR6, OR7)*	1 *(E13)*

- Labour market availability	8 *(F1, F4, F5, F6, F8, F9, F10, F11)*	10 *(CE1, CE3, CE4, CE5, CE7, CE8, CE9, CE10, CE11, CE12)*	5 *(OR2, OR3, OR4, OR6, OR7)*	12 *(E1, E3, E4, E8, E10, E11, E12, E13, E14, E15, E17, E18)*
- Land availability	8 *(F2, F4, F5, F6, F8, F10, F11, F12)*	7 *(CE3, CE4, CE5, CE7, CE9, CE10, CE11)*	4 *(OR2, OR3, OR4, OR8)*	5 *(E8, E11, E12, E13, E17)*
- Land costs	9 *(F2, F3, F4, F5, F6, F8, F10, F11. F12)*	5 *(CE4, CE5, CE7, CE10, CE11)*	3 *(OR2, OR3, OR4)*	8 *(E3, E4, E7, E10, E11, E12, E15, E17)*
- Expansion capabilities	6 *(F2, F3, F4, F5, F11, F12)*	8 *(CE4, CE5, CE7, CE8, CE9, CE10, CE11, CE12)*	4 *(OR1, OR3, OR4, OR7)*	2 *(E3, E13)*
- Real estate availability	6 *(F2, F5, F6, F8, F10, F11)*	6 *(CE3, CE5, CE7, CE8, CE9, CE10)*	4 *(OR4, OR6, OR7, OR8)*	1 *(E13)*
- Proximity DC to the HQ*	4 *(F1, F3, F5, F11)*	-	2 *(OR3, OR7)*	-
- Proximity DC to high tech cluster Eindhoven (CE case) or flower cluster Aalsmeer*	-	1 *(CE6)*	1 *(OR7)*	-
- Employee accessibility of DC by public transport*	2 *(F9, F11)*	1 *(CE1)*	2 *(OR3, OR8)*	2 *(E12, E18)*
- Sufficient parking space for employees*	1 *(F12)*	-	-	-
- Proximity to DC location of the LSP*	-	3 *(CE7, CE9, CE10)*	6 *(OR1, OR2, OR3, OR4, OR5, OR7)*	-
- Sustainability of new DC location*	-	1 *(CE3)*	-	-
- Preference CEO to locate DC near home address*	3 (Anonymous)	2 (Anonymous)	1 (Anonymous)	-
- Preference CEO to locate DC near education for children*	1 *(F4)*	-	-	-
7. Institutional factors				
- Presence of development agency	2 *(F4, F8)*	-	1 *(OR4)*	1 *(E14)*
- Zoning	4 *(F4, F5, F8, F12)*	4 *(CE3, CE4, CE7, CE11)*	3 *(OR3, OR4, OR6)*	4 *(E3, E9, E11, E16)*

- Laws, regulations and customs	9 *(F2, F3, F4, F5, F6, F7, F8, F9, F10)*	9 *(CE3, CE4, CE5, CE7, CE8, CE9, CE10, CE11, CE12)*	2 *(OR3, OR9)*	7 *(E12, E13, E14, E15, E16, E17, E18)*
- Possible Brexit*	-	2 *(CE7, CE9)*	1 *(OR7)*	-
- Taxes	8 *(F2, F5, F6, F7, F8, F9, F10, F12)*	8 *(CE4, CE5, CE6, CE7, CE8, CE9, CE10, CE11)*	2 *(OR4, OR9)*	7 *(E4, E7, E10, E11, E13, E14, E17)*
- Investment incentives	4 (Anonymous)	3 (Anonymous)	2 (Anonymous)	5 *(E8, E11, E13, E15, E17)*
- Political stability	6 *(F2, F3, F4, F5, F6, F7)*	5 *(CE4, CE5, CE7, CE8, CE11)*	3 *(OR3, OR4, OR9)*	3 *(E10, E14, E15)*
- Economic stability	5 *(F2, F4, F5, F6, F7)*	5 *(CE4, CE5, CE7, CE8, CE11)*	3 *(OR3, OR4, OR9)*	-
- Dutch trade culture*	-	1 *(CE6)*	-	-
- Language proficiency of Dutch employees*	-	2 *(CE6, CE8)*	-	-
- Climate conditions	2 *(F6, F8)*	2 *(CE7, CE11)*	-	1 *(E18)*
- Government cooperation to start building DC*	1 *(F4)*	2 *(CE4, CE7)*	-	-
- Community attitude towards DC localisation*	-	-	2 *(OR3, OR4)*	-
- City distribution regulations (delivery time windows)*	-	-	3 *(OR3, OR4, OR7)*	-
8. Keep factors				
- Knowledge retention of employees*	3 *(F2, F5, F8)*	2 *(CE7, CE8)*	4 *(OR1, OR2, OR3, OR4)*	-
- Cost of severance*	4 (Anonymous)	5 (Anonymous)	2 (Anonymous)	3 *(E3, E13, E15)*
- Investments in current assets*	-	1 *(CE5)*	-	-
- Penalties of ending lease contracts*	2 (Anonymous)	-	-	-
- Historical links with DC location*	5 *(F7, F8, F9, F10, F11)*	1 *(CE6)*	3 *(OR3, OR5, OR9)*	-

* New factors extracted from the industry case interviews.
** Main factor Business strategy & company characteristics is extracted from the fashion case and was added to the interview questionnaires of the other two cases.

5.4.3 Conceptual framework

Based on (the relationships between) the factors extracted from the case results, we propose the following validated conceptual framework (Figure 5.10). Compared to the initial literature-based framework, the framework includes 20 new subfactors and one new main factor, i.e. the keep factors. The hierarchy of factors presented here can be used by private companies as a starting point for analysis and decision-making. In addition, we expect this to be a useful tool for discussion and analysis in a public policy environment, supporting spatial planning and regional marketing.

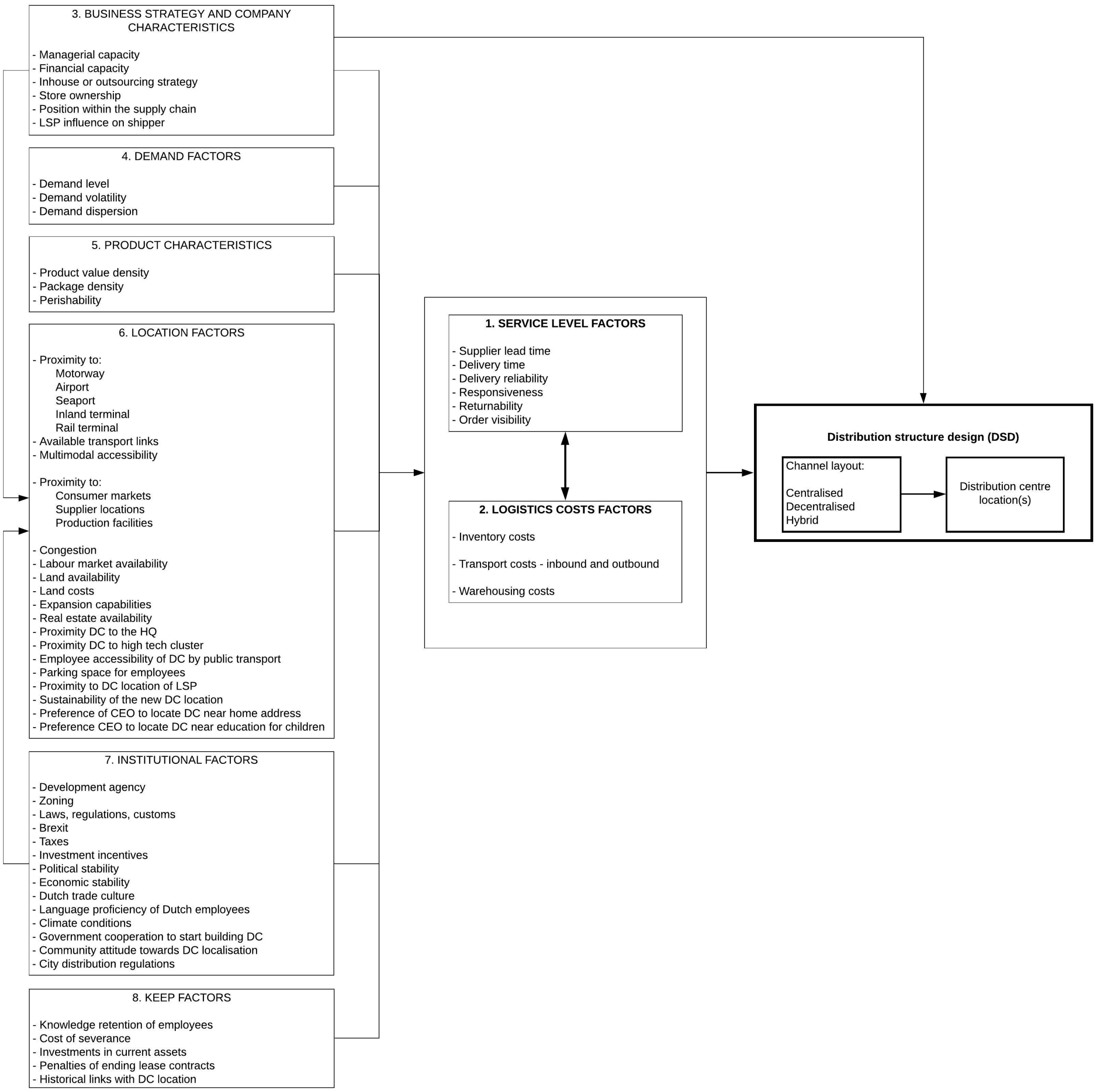


Figure 5.10 Validated conceptual framework

5.5 Conclusions and future research

In this chapter, we analysed the factors that influence distribution structure design (DSD) in three industry sectors, i.e. fashion, consumer electronics (CE) and online retail (OR). Despite the frequent treatment of DSD in supply chain handbooks, the importance of factors influencing DSD in different industry sectors has thus far received little attention and an empirically validated conceptual framework is lacking. To fill these gaps, this research used a multiple case research design to examine DSD in different industry sectors and develop an empirically validated framework. The empirical evidence for the cases was collected during 18 interviews with logistics experts and 33 interviews with decision-makers on DSD, affiliated to shippers and logistics service providers. The result, and a first contribution of this chapter, is an empirically validated conceptual framework for DSD.

Statistical analysis of the case interview results shows that decision-makers of the three industry sectors place very similar importance on the main factors. In all three cases, the most important main factors are logistics costs, service level, demand factors and product characteristics – which is in line with SCM literature. These results imply that the validated conceptual framework at the level of main factors is robust for cross-sectoral comparison. However, although decision-makers agree on the importance of the main factors, there are differences when it comes to the importance of the various subfactors at a sectoral level, which can be explained to a large extent from the typical product and organizational attributes of the sectors under examination. Moreover, the interviews lead us to identify new factors, that were previously not included in the literature-based framework. We found 20 new subfactors and one new main factor, i.e. keep factors.

In our analysis we find that the main factor scores of the sectoral decision-makers correlate well with previous survey-based research in which the main factor weights were quantified using the Best-Worst Method (BWM) from Multi-Criteria Decision Analysis (Onstein et al. 2019b). This cross-validation of findings is a second main contribution of the chapter.

This study contributes to the existing literature by conducting empirical research into DSD at a sectoral level. We analysed the factors that influence DSD in three specific industry sectors, building on an earlier and generic framework from existing literature. The new framework can help companies in their DSD process, and support governments and consultants to carry out regional land use planning in a way that is attractive for selected industries. The framework can also help researchers improve quantitative distribution channel and distribution centre location models, which are often based on incorrect or incomplete sets of factors.

One of the limitations in terms of the scope of this study is that the companies involved focus on the distribution of finished goods (wholesale and retail). Companies that sell semi-finished products (business-to-business) may provide different results when it comes to the importance of subfactors. New research could extend the base of interviews to include sectors that produce semi-finished goods. As our interviews were limited to global supply chains around DCs within the Netherlands, we also recommend broadening the geographic scope of the empirical research.

References

Agrebi, M., Abed, M., and Omri, M.N. 2017. “ELECTRE I based relevance decision-makers feedback to the location selection of distribution centers.” *Journal of Advanced Transportation* 2017 (1), doi: 10.1155/2017/7131094.

Ashayeri, J., and Rongen, J.M.J. 1997. “Central Distribution in Europe: A Multi-Criteria Approach to Location Selection.” *The International Journal of Logistics Management* 8 (1): 97-109.

Blair, J.P., and Premus, R. 1987. “Major Factors in Industrial Location: A Review.” *Economic Development Quarterly* 1 (1): 72-85.

Bowen, J. 2008. “Moving places: the geography of warehousing in the US.” *Journal of Transport Geography* 16 (6): 379-387.

Boyer, K.K., and Hult, G.T.M. 2005. “Customer behavior in an online ordering application: A decision scoring model.” *Decision Sciences* 36 (4): 569-598.

Bryman, A. 2008. *Social Research Methods.* Oxford: Oxford University Press, 2008.

Chopra, S. 2003. “Designing the distribution network in a supply chain.” *Transportation Research Part E: Logistics and Transportation Review* 39 (2): 123-140.

Chopra, S., and Meindl, P. 2013. *Supply Chain Management. Strategy, Planning, and Operations*. Harlow, UK: Pierson Education Limited, 2013.

Christensen, J. and Drejer, I. 2005. “The strategic importance of location: Location decisions and the effects of firm location on innovation and knowledge acquisition.” *European Planning Studies* 13 (6): 807-814.

Christopher, M. 2011. *Logistics and Supply Chain Management (4th Edition)*. Harlow, UK: Pierson Education Limited, 2011.

Cooper, M. 1984. “Cost and delivery time implications of freight consolidation and warehousing strategies.” *International Journal of Physical Distribution & Materials Management* 14 (6): 47-67.

Dablanc, L., and Ross, C. 2012. “Atlanta: a mega logistics center in the Piedmont Atlantic Megaregion (PAM).” *Journal of Transport Geography* 24 (2012): 432-442.

Davydenko, I.Y. 2015. “Logistics Chains in Freight Transport Modelling.” PhD diss., Delft University of Technology, The Netherlands.

Eisenhardt, K.M., and Graebner, M.E. 2007. “Theory Building from Cases: Opportunities and Challenges.” *Academy of Management Journal* 50 (1): 25–32.

Frankel, R., Naslund, D., and Bolumole, Y. 2005. “The “white space” of logistics research: A look at the role of methods usage.” *Journal of Business Logistics* 26 (2): 185–209.

Friedrich, H., Tavasszy, L.A., and Davydenko, I.Y. 2014. “Distribution structures.” In *Modelling Freight Transport*, edited by L.A. Tavasszy and G. de Jong, 65-88, London: Elsevier.

Hall, P.V., and Jacobs, W. 2012. “Why are maritime ports (still) urban, and why should policy makers care?” *Maritime Policy & Management* 39 (2): 189-206.

Heitz, A., and Beziat, A. 2016. “The parcel industry in the spatial organization of logistics activities in the Paris Region: inherited spatial patterns and innovations in urban logistics systems.” *Transportation Research Procedia* 12 (2016): 812-824.

Heitz, A., Dablanc, L., Olsson, J., Sanchez-Diaz, I., and Woxenius, J. 2018. “Spatial patterns of logistics facilities in Gothenburg, Sweden.” *Journal of Transport Geography* (2018), Available online, https://doi.org/10.1016/j.jtrangeo.2018.03.005.

Heitz, A., Launay, P., and Beziat, A. 2019. “Heterogeneity of logistics facilities: an issue for a better understanding and planning of the location of logistics facilities.” *European Transport Research Review* 11 (5), 2019, doi:10.1186/s12544-018-0341-5.

Hilmola, O.P., and Lorentz, H. 2011. “Warehousing in Northern Europe: longitudinal survey findings.” *Industrial Management & Data Systems* 111 (3): 320-340.

Holland International Distribution Council. 2018. *Dutch Logistics Sector. Holland is a key logistics hub that connects global markets*. Zoetermeer: HIDC.

Jacobi, S.K., and Hobbs, B.F. 2007. “Quantifying and Mitigating the Splitting Bias and Other Value Tree-Induced Weighting Biases.” *Decision Analysis* 4 (4): 194-210.

Ketokivi, M., and T. Choi. 2014. “Renaissance of Case Research as a Scientific Method.” *Journal of Operations Management* 32 (5): 232–240.

Klauenberg, J., Elsner, L.-A., and Knischewski, C. 2016. “Dynamics in the spatial distribution of hubs in groupage networks - the case of Berlin.” Paper presented at World Conference on Transport Research (WCTR), Shanghai, July 10-15, 2016.

Kuipers, B, and J. Eenhuizen. 2004. “A Framework for the Analysis of Seaport-Based Logistics Parks.” Proceedings of the 1st International Conference on Logistics Strategies for Ports. Dalian, China.

Li, K.P., Ganesan, V.K., and Sivakumar, A.I. 2005. “Synchronized scheduling of assembly and multi-destination air-transportation in a consumer electronics supply chain.” *International Journal of Production Research* 43 (13): 2671-2685.

Lovell, A., Saw, R., and Stimson, J. 2005. “Product value-density: managing diversity through supply chain segmentation.” *The International Journal of Logistics Management* 16 (1): 142-158.

Mangiaracina, R., Song, G., and Perego, A. 2015. “Distribution network design: a literature review and a research agenda.” *International Journal of Physical Distribution & Logistics Management* 45 (5): 506-531.

McCann, P., and Sheppard, S. 2003. “The Rise, Fall and Rise Again of Industrial Location Theory.” *Regional Studies* 37 (6-7): 649-663.

McCann, P. 2015. Interview, Professor Economic Geography, University of Groningen (RUG), December 4, 2015.

McKinnon, A.C. 1984. “The Spatial Organization of Physical Distribution in the Food Industry.” PhD diss., University College London, London.

McKinnon, A.C. 2009. “The present and future land requirements of logistical activities.” *Land Use Policy* 26: S293–S301.

Meixell, M.J., and Gargeya, V.B. 2005. “Global supply chain design: A literature review and critique.” *Transportation Research Part E* 41 (6): 531-550.

Nguyen, D.H., De Leeuw, S., and Dullaert, W.E.H. 2018. “Consumer Behaviour and Order Fulfilment in Online Retailing: A Systematic Review.” *International Journal of Management Reviews* 20 (2): 255-276.

North, D.C. 1990. *Institutions, institutional change and economic performance*. Cambridge, UK: Cambridge University Press.

Nozick, L.K., and Turnquist, M.A. 2001. "Inventory, transportation, service quality and the location of distribution centers." *European Journal of Operational Research* 129 (2): 362-371.

Olhager, J., Pashaei, S., and Sternberg, H. 2015. "Design of global production and distribution networks: A literature review and research agenda." *International Journal of Physical Distribution & Logistics Management* 45 (1/2): 138-158.

Önden, I., Acar, A.Z., and Eldemir, F. 2016. "Evaluation of the logistics centre locations using a multi-criteria spatial approach." *Transport* 33 (2): 322-334.

Onstein, A.T.C., Tavasszy, L.A., and van Damme, D.A. 2019a. "Factors determining distribution structure decisions in logistics: a literature review and research agenda." *Transport Reviews* 39 (2): 243-260.

Onstein, A.T.C., Ektesaby, M., Rezaei, J., Tavasszy, L.A., and van Damme, D.A. 2019b. "Importance of factors driving firms' decisions on spatial distribution structures." *International Journal of Logistics: Research and Applications* 2019, doi: 10.1080/13675567.2019.1574729.

Pedersen, S.G., Zachariassen, F., and Arlbjørn, J.S. 2012. "Centralisation vs de-centralisation of warehousing." *Journal of Small Business and Enterprise Development* 19 (2): 352-369.

Picard, J. 1982. "Typology of Physical Distribution Systems in Multi-national Corporations." *International Journal of Physical Distribution & Materials Management* 12 (6): 26-39.

Rodrigue, J.-P. 2008. "The Thruport Concept and Transmodal Rail Freight Distribution in North America." *Journal of Transport Geography* 16 (4): 233-246.

Şen, A. 2008. "The U.S. fashion industry: A supply chain review." *International Journal of Production Economics* 114 (2): 571-593.

Sheffi, Y. 2012. *Logistics clusters. Delivering value and driving growth*. Cambridge, Massachusetts: The MIT Press, 2012.

Song, G., and Sun, L. 2017. "Evaluation of factors affecting strategic supply chain network design." *International Journal of Logistics Research and Applications* 20 (5): 405-425.

Treacy, M., and Wiersema, F. 1993. "Customer intimacy and other value disciplines." *Harvard business review* 71 (1): 84-93.

van Hoek, R., Commandeur, H., and Vos, B. 1998. "Reconfiguring logistics systems through postponement strategies." *Journal of Business Logistics* 19 (1): 33-54.

Verhetsel, A., Kessels, R., Goos, P., Zijlstra, T., Blomme, N., and Cant, J. 2015. "Location of logistics companies: a stated preference study to disentangle the impact of accessibility." *Journal of Transport Geography* 42 (2015): 110-121.

Voss, C., Tsikriktsis, N., and Frohlich, M. 2002. "Case Research in Operations Management." *International Journal of Operations & Production Management* 22 (2): 195–219.

Warffemius, P.M.J. 2007. "Modeling the Clustering of Distribution Centers around Amsterdam Airport Schiphol: location endowments, economies of agglomeration, locked-in logistics and policy implications." PhD diss., Erasmus University Rotterdam, The Netherlands.

Xing, Y., Grant, D.B., McKinnon, A.C, and Fernie, J. 2011. "The interface between retailers and logistics service providers in the online market." *European Journal of Marketing* 45 (3): 334-357.

Yin, R.K. 2014. *Case study research: Design and methods*. Thousand Oaks, CA: Sage publications, 2014.

Appendix 5.1 Subfactor scores

Factors	Decision-maker interviews (33 respondents)			Expert interviews (18 respondents)
	Fashion (12 respondents)	Consumer electronics (CE) (12 respondents)	Online retail (OR) (9 respondents)	
1. Business strategy & company characteristics				
Managerial capacity	0.000	0.417	0.333	0.000
Financial capacity	0.000	0.333	0.333	0.000
In-house or outsourcing strategy	0.167	0.000	0.000	0.111
Store ownership	0.083	0.083	0.000	0.056
Position within the supply chain	0.000	0.000	0.000	0.056
LSP influence on shipper*	0.250	0.083	0.000	0.000
2. Demand factors				
Demand level	0.833	0.750	0.889	0.167
Demand volatility	0.333	0.500	0.667	0.000
Demand dispersion	0.250	0.583	0.556	0.056
3. Service level factors				
Supplier lead time	0.750	0.583	0.333	0.167
Delivery time	0.917	1.000	0.778	0.278
Delivery reliability	0.750	0.583	0.889	0.056
Responsiveness	0.667	0.750	0.889	0.111
Returnability	0.417	0.750	0.333	0.111
Order visibility	0.417	0.500	0.444	0.000
4. Product characteristics				
Product value density	0.417	0.583	0.222	0.222
Package density	0.500	0.583	0.556	0.111
Perishability	0.167	0.417	0.444	0.056
5. Logistics costs factors				
Inventory costs	0.667	0.750	0.556	0.389
Transport costs – inbound	0.583	0.750	0.667	0.389
Transport costs – outbound	0.750	0.917	0.889	0.556
Warehousing costs	0.917	0.917	1.000	0.333
6. Location factors				
Proximity Motorway	0.667	0.583	0.667	0.222
Proximity Airport	0.667	0.583	0.000	0.389

Proximity Seaport	0.750	0.583	0.111	0.222
Proximity Inland terminal	0.333	0.417	0.000	0.056
Proximity Rail terminal	0.250	0.167	0.000	0.000
Available transport links	0.333	0.750	0.556	0.278
Multimodal accessibility	0.333	0.583	0.111	0.278
Proximity Consumer markets	0.417	0.833	0.889	0.667
Proximity Supplier locations	0.083	0.333	0.333	0.056
Proximity Production facilities	0.167	0.250	0.111	0.056
Congestion	0.167	0.500	0.333	0.056
Labour market availability	0.667	0.833	0.556	0.667
Land availability	0.667	0.583	0.444	0.278
Land costs	0.750	0.417	0.333	0.444
Expansion capabilities	0.500	0.667	0.444	0.111
Real estate availability	0.500	0.500	0.444	0.056
Proximity DC to the HQ*	0.333	0.000	0.222	0.000
Proximity DC to high tech cluster Eindhoven or flower cluster Aalsmeer*	0.000	0.083	0.111	0.000
Employee accessibility of DC by public transport*	0.167	0.083	0.222	0.111
Sufficient parking space for employees*	0.083	0.000	0.000	0.000
Proximity to DC location of the LSP*	0.000	0.250	0.667	0.000
Sustainability of new DC location*	0.000	0.083	0.000	0.000
Preference CEO to locate DC near home address*	0.250	0.167	0.111	0.000
Preference CEO to locate DC near education for children*	0.083	0.000	0.000	0.000
7. Institutional factors				
Presence of development agency	0.167	0.000	0.111	0.056
Zoning	0.333	0.333	0.333	0.222
Laws. regulations and customs	0.750	0.750	0.222	0.389
Brexit*	0.000	0.167	0.111	0.000
Taxes	0.667	0.667	0.222	0.389
Investment incentives	0.333	0.250	0.222	0.278
Political stability	0.500	0.417	0.333	0.167

Economic stability	0.417	0.417	0.333	0.000
Dutch trade culture*	0.000	0.083	0.000	0.000
Language proficiency of Dutch employees*	0.000	0.167	0.000	0.000
Climate conditions	0.167	0.167	0.000	0.056
Government cooperation to start building DC*	0.083	0.167	0.000	0.000
Community attitude towards DC localisation*	0.000	0.000	0.222	0.000
City distribution regulations (delivery time windows)*	0.000	0.000	0.333	0.000
8. Keep factors				
Knowledge retention of employees*	0.250	0.167	0.444	0.000
Cost of severance*	0.333	0.417	0.222	0.167
Investments in current assets*	0.000	0.083	0.000	0.000
Penalties of ending lease contracts*	0.167	0.000	0.000	0.000
Historical links with DC location*	0.417	0.083	0.333	0.000

* New factors extracted from the industry case interviews.

6 Conclusions and recommendations

6.1 Introduction

This thesis conceptually and empirically investigates the factors that influence company decision-making on *Distribution Structure Design* (DSD). Distribution structure design is important to companies to fulfil expected distribution service levels (i.e. deliver products at the right location, at the right time, in the right condition) while at the same time controlling logistics costs.

There are few descriptive studies on distribution structure design and an empirically validated conceptual framework of factors is lacking. In order to investigate what the important factors are and to develop a conceptual framework of these factors, multiple research methods were used. First, a state-of-the-art literature review was conducted to identify important factors (Chapter 3). Second, we determined factor importance by using a Multi-Criteria Decision-Making approach (Chapter 4). Third, an empirical validation was done of the important factors with logistics experts and decision-makers from three industry sectors, i.e. Fashion, Consumer electronics, and Online retail (Chapter 5). As background information about the variety of logistics facilities that can be observed in practice, we developed a typology based on logistics real estate data (Chapter 2).

Here, the main results of the thesis are summarised and discussed. The main findings from the four studies are presented in relation to the formulated research questions. This is followed by recommendations for research. Finally, recommendations are given to companies and policy makers.

6.2 From XXS to XXL: Towards a typology of distribution centre facilities

RQ 1: How can we characterize different types of DCs?

The first study developed a typology of logistics facilities. Although scholars use multiple concepts to denote logistics facilities – e.g. distribution centre, warehouse, city hub, logistics depot, fulfilment centre – a standard typology is lacking in the literature. It is the first typology that combines size with other functional characteristics of DC facilities, e.g. activity type, product type, product range and speed, network structure, and market service area. Public policy makers can apply the typology to discuss preferred locations for individual DC types. The typology can also be used by scholars to distinguish between facility types in their research - e.g. transhipment centres, parcel hubs, or e-fulfilment centres - and to analyse the impact of specific types on urban areas, for example, in terms of local emissions.

The typology is grounded in literature and empirical data of DC real estate in the Netherlands. Literature was used to develop a framework of relevant criteria for the typology, while empirical data are used to exemplify the types and to analyse common size ranges (m^2) per type. In the typology the sectoral dimension is leading, the functional criteria help to explain variations in size and other characteristics.

We identify eight facility types (in order of ascending average size): 1) Parcel lockers and pick-up points, 2) City hubs, 3) Parcel and postal sorting facilities, 4) Regional food wholesale and retail facilities, 5) National retail and e-commerce facilities, 6) Manufacturer DC facilities, 7) Bulk facilities, and 8) Global agricultural auctions. Packaging units differ per type, e.g. parcels, pallets, bulk. Each type has been categorised into size ranges from XXS to XXL - for example, manufacturer DC facilities range from size L to XXL. The contexts in which very large and small size DCs operate are relatively easy to identify, while the context for medium sized DCs is heterogeneous, e.g. very small facilities (XXS) only include type 1 (Parcel lockers and pick-up point facilities), but the medium (M) and large (L) sizes include multiple facility types. The results also indicate the importance of large facilities (>20,000m^2) in the total constructed surface area – i.e. only 19% of the facilities has a large size, but these facilities represent almost half (46%) of the total logistics surface area in the Netherlands (in 2016). In absolute numbers, there are 2,888 DC facilities (excluding parcel lockers and pick-up points), of which most facilities have a size S between 2,000 – 8,000m^2 (995) or M between 8,000 – 15,000m^2 (1024). Furthermore, results show that there are types represented in multiple size ranges (e.g. M to XXL). Spatial planners are recommended to design spatial policies for each of the eight types, but also to differentiate between sizes within each type. A limitation of this study is that it is based on a database including DC real estate in the Netherlands. Research into other countries could reveal other DC types.

6.3 Factors determining distribution structure decisions in logistics: a literature review and research agenda

RQ 2: What are, according to the academic literature, important factors influencing companies' distribution structure design (DSD)?

The second study reviewed the literature on the factors that influence company decision-making on distribution structure design (DSD) and proposes a high-level framework of the influencing factors. Results show that the literature on DSD is scattered across multiple research streams. Three relevant research streams were identified and consulted: Supply Chain Management (SCM), Transportation and Geography.

We find seven groups of main factors that drive DSD, these are (1) demand level, (2) service level, (3) product characteristics, (4) logistics costs (transport, inventory, warehousing), (5) labour and land availability, (6) accessibility, and (7) contextual factors. Each main factor includes multiple sub-factors, for example, main factor product characteristics includes product value density, packaging density and inventory policy. Based on the literature review we developed a conceptual framework showing how the main factors are connected. The framework indicates that service level versus logistics costs is the main trade-off that drives distribution structure design – i.e. in general, higher distribution service levels will cause higher transport costs. The other five main factors influence this trade-off. For example, product characteristics such as value density influence the required service level – i.e. high value density products may require higher delivery speed.

Our synthesis of the three research streams shows that each stream has its own research focus and popular research methods. Distribution structure design includes the level of centralisation (centralised / decentralised) as well as the locations of distribution centres (DCs). The streams of Supply Chain Management and Transportation have a research focus on both the level of centralisation and DC location selection, while the Geography research stream mainly studies factors that influence DC locations. The SCM stream uses OR techniques to model optimal DSD. A limitation of the SCM stream is that it is complicated to model all relevant factors and it is often unknown whether all relevant factors are modelled. The Transportation research stream focuses on cost-based quantitative models that predict freight flows, describing distribution patterns of individual companies (micro models) as well as cities, regions, or countries (macro models). The Geography research stream has a tradition to analyse factors that influence individual company DC locations. It also studies spatial DC patterns on city or regional level, for example by using barycentre analysis. A limitation of the Geography stream is that it gives little attention to the level of centralisation (influenced by service levels and logistics costs) as a factor. In conclusion, the three research streams show little overlap in the research methods used.

Apart from the factors, the literature is fragmented on the process steps that companies follow or should follow in DSD. The reviewed process step models include qualitative and quantitative elements. Qualitative steps may include examining or discussing potential DC locations, while a quantitative step could include Centre of Gravity (CoG) calculation. As process steps and methods used differ in the literature, this will influence the distribution structure outcome. We also find that process steps models are linear, while in practice strategic decisions are often taken in multiple rounds or iterations. Therefore, we argue that process models on DSD should include more feedback loops.

6.4 Importance of factors driving firms′ decisions on spatial distribution structures

RQ 3: What is the importance of factors that determine companies' distribution structure design (DSD)?

The third study examined the relative importance of the factors in our framework. The framework and factors are based on the literature review (RQ 2). We tested the importance of seven main factors and 33 sub-factors. To identify the factor weights we applied the Best-Worst Method (BWM) from Multi-Criteria Decision-Making. The data were collected using an online survey. In this study the findings coming from two respondent groups are compared, i.e. the findings coming from experts versus decision-makers affiliated to shippers or Logistics Service Providers (LSPs). The respondent answers are based on the sector about which they have expert knowledge or on the sector in which they work (decision-makers).

This study shows there are differences in factor importance between the two respondent groups. Both experts and decision-makers consider logistics costs the most important main factor. Logistics costs versus service-level is the main influencing trade-off, and this confirms the results from the literature review. However, experts consider customer demand the second most important main factor, whereas for decision-makers service level is the second most important main factor. Decision-makers that focus on high distribution service will favour decentralised distribution layout as this enables to realise short delivery times. The least important main factor according to decision-makers is product characteristics. This is a remarkable finding given the broad attention in the literature on how to distribute different types of products, e.g. online retail versus pharma products. Experts consider institutional factors the least important main factor - although tax incentives can attract companies to locate DCs.

Regarding the sub-factors, inbound transport costs and outbound transport costs show similar factor weights (from total respondent group) - this could be expected as they are both costs. Other important sub-factors are demand volatility, demand dispersion, demand level, warehousing costs, delivery time and product perishability. The influence of demand volatility on distribution design is that companies with volatile demand will prefer centralised distribution as this increases responsiveness towards the customer (because of higher product availability compared to decentralised distribution) and reduces unused inventories. Relatively unimportant sub-factors are distance from the DC to suppliers or production facilities, distance from DC to a rail terminal, land availability, and land costs. Large distances to suppliers will increase inbound transport costs, but economical product sourcing can compensate for these costs. Distance to a rail terminal may have turned out to be less important because most companies use road instead of rail transport to deliver goods from DCs.

K-means cluster analysis of the respondent sample has been performed, which shows three homogeneous clusters. Each cluster focuses on different factors, i.e. cluster 1 has a main focus on logistics costs factors and service level factors, while cluster 2 focuses on location factors and demand factors, and cluster 3 on firm characteristics and product characteristics. The patterns of the preferences of each cluster largely matches the strategy of the decision-makers - for example, half of the decision-makers in cluster 1 adopt the Operational excellence strategy, which matches their focus on logistics costs. Future research could investigate differentiated distribution structure design for each cluster. A limitation of this study is that the survey provides insufficient data to differentiate between industry sectors. Nevertheless, companies that ship a broad range of products can use the factor weights in decision-making on distribution structures. In the last study (Chapter 6.5) we explore the differences in main factor and sub-factor importance between industry sectors.

6.5 A sectoral perspective on distribution structure design

RQ 4: What are the differences between industry sectors in terms of factors influencing distribution structure design (DSD)?

The fourth study analysed the factors that drive distribution structure design in the Fashion, Consumer electronics (CE) and Online retail (OR) sector. The study uses the important factors from the studies of research question 2 and 3 as input for case interviews. Based on the results, this study proposes a more detailed and empirically validated conceptual framework of factors. The data collection includes 18 logistics expert interviews and 33 interviews with decision-makers, affiliated to shippers or logistics service providers. The decision-makers are – or have recently been – actively involved in distribution structure design for their company.

The statistical analysis of the case interviews reveals that the decision-makers of the three industry sectors agree on main factor importance, i.e. in all three industry sectors, the important main factors are logistics costs, service level, demand factors and product characteristics. As the decision-makers agree on main factor importance, this suggests that the main factors in the conceptual framework can be used for cross-sectoral comparisons. The factor 'product characteristics' is more important here than it appeared in the earlier analysis, which can be explained by the focus on individual sectors with own product characteristics, whereas earlier we analysed factor importance for a wide range of companies from multiple sectors.

Although the decision-makers agree on main factor importance, there are differences in sub-factor importance between the three industry sectors. Sub-factor 'supplier lead times' is the most important in the Fashion sector, while Online retail companies consider supplier lead times relatively unimportant. Responsiveness is the most important in the Online retail (OR) sector compared to the other sectors. Online retail customers expect fast deliveries, which influences OR companies towards highly responsive distribution. From the logistics costs factors, the importance of sub-factor 'inventory costs' follows the value density of the products in the three sectors, i.e. Consumer electronics, Fashion, Online retail (from high to low). An important location factor in all sectors is the 'proximity of the DC to the motorway', this finding is in line with the literature. Sub-factor 'proximity of the DC to the airport' is more important to higher value products (Consumer electronics and Fashion) compared to the lower value products (Online retail), and this finding also confirms the existing literature. Twenty new factors were found from the case interviews, including the new main factor 'Keep factors' (influencing companies to keep the DC at the current location, e.g. cost of severance, or historical links with the DC location). These new factors are included in the detailed conceptual framework.

Another major finding of this study is that there is a high correlation between the scores of the decision-maker interviews with the quantitative results of study 3 in which we quantified the main factor weights using Best-Worst Method (BWM). The fact that multiple research methods (BWM survey and case interviews) show similar results related to main factor importance is encouraging and supports general validity of our findings.

6.6 Recommendations for research

This thesis has empirically investigated the factors that influence Distribution Structure Design. Although many data were gathered on these factors, the sectoral study in this thesis (Chapter 5) mainly focuses on firms that sell finished goods: wholesale and retail companies (business to consumer). Companies selling semi-finished goods (business to business) may show other important factors influencing DSD. For example, semi-finished goods suppliers in the automotive industry may give high importance to (fast) customer delivery times. To support distribution design of semi-finished goods companies, it would be interesting to study the factors that are relevant to them.

Another limitation is that this thesis focused on companies that organise distribution structure design via DCs within the Netherlands. Research into other geographic areas may indicate other important factors. For example, proximity to a large seaport (for outbound transport) may be a decisive factor for DCs located in Asian production countries to reduce transport times between Asia and Europe. Scholars could compare the important factors for DCs in Asian production countries with DCs located in European countries having a main distribution function. A limitation of the factors' importance study (Chapter 4) is that the survey results provide insufficient data to differentiate factor weights between industry sectors. Scholars could use the BWM questionnaire to collect additional data on factors importance in various industries.

A topic disregarded in this thesis is the direction and strength of the relationships of the proposed conceptual framework. Based on the factor weights (included in Chapter 4) it can be expected that factors such as product characteristics will have stronger relation with logistics costs than institutional factors. Multiple regression analysis can be used to measure the influence of many factors on DSD.
Factor weights can also change over time - under the influence of social and economic developments. Dynamics in factor weights would be an interesting topic for future research. For example, a hypothesis could be that factors such as 'delivery time' and 'proximity to consumer markets' (Chapter 5) have become even more important because of the rise in online sales (Janjevic and Winkenbach, 2020). It would also be interesting to study the influence of the COVID-19 pandemic on factor weights (and DSD) as many companies shifted from offline (physical channels) to online sales (Mollenkopf et al., 2020).
It must be noted that this thesis studied distribution structure design as a single, composite decision. This means that it does not study the influencing factors at the level of sub-issues such as decisions on the number or size of warehouses in DSD, the allocation of inventories, or layout of individual warehouses. Future research could therefore study the influencing factors at the level of sub-issues.

Although this thesis studied distribution structure design from company and logistics expert perspective, other actors - that are outside the control of the companies - such as real estate developers, investors, government departments and local communities may also influence distribution design. Investors may influence companies to rent space in their warehouses, as there is an increase in speculative investments in the Netherlands - according to interviews with decision-makers and logistics experts (Chapter 5). Raimbault (2019) studied the influence of investors and concludes that investors have other important location factors than companies, i.e. they prefer to locate DCs in urban areas because this minimises risks if tenants move out. Outside the Netherlands, investors even develop private logistics zones including multiple warehouses (Barbier, Cuny and Raimbault, 2019). This indicates that investors also influence DC localisation. Logistics consultants can influence decision-making by deciding which DSD scenarios they include in their advice – as was found from the case interviews. Government departments can use zoning plans to attract or hinder DC localisation (Quan, 2019). Future research could investigate how these actors influence company decisions.

Another topic that deserves more attention from scholars is the decision-making process that takes place within companies to design their distribution structure. To the best of our knowledge, the broad decision-making process literature has not studied DSD. From the case interviews it can be concluded that DSD decisions are often prepared either by the logistics / supply chain department or by a company management team including e.g. supply chain manager, sales manager, operations manager, and financial manager. The final DSD decision is often taken by the board of directors, or sometimes a management team is mandated to take the DSD decision. Questions that remain unanswered relate to how the decision-making process influences distribution structure design. For example, what was the influence of the participants in the decision-making process? Who were the participants with decision-making power? Was an external moderator involved and how did this moderator influence decision-making? The decision-making literature provides a broad overview of decision-making theories – e.g. from rational phase models to game approach - that could be tested on DSD decisions.

A limitation of the DC typology proposed in Chapter 2 is that there are little data available on the smallest type (i.e. XXS) facilities in the Netherlands. XXS facilities include parcel lockers and pick-up points. Future research could focus on the contribution of XXS facilities to the total number as well as the total logistics surface area (m^2) in the Netherlands. As the evolution of logistics facilities proceeds, the typology will also need to be updated on a regular basis. Future research could therefore address possible new types of logistics facilities. For example, the recent construction of mega city hubs in Paris and Amsterdam is not included in the typology (the typology only includes small city hubs). In the new mega hub in Amsterdam, goods flows from multiple shippers will be consolidated for distribution into the city. As public authorities start to ban freight trucks from their cities, an increased demand for mega city hubs at the edge of the city - or even within large cities such as Paris - can be expected at which freight trucks drop-off their goods.

Finally, it would be interesting to study the influence of new technologies such as the physical internet on the factors that influence distribution structure design. For example, if companies can use a network of DCs, there is no longer a need to have own logistics facilities. This could imply that DC location factors become less important in distribution structure design as products are distributed via a network of logistics facilities controlled by the physical internet.

6.7 Managerial and policy recommendations

The case interviews with decision-makers (Chapter 5) indicate that decision-making on distribution structure design is a complex process involving multiple stakeholders and decision-making rounds. There is often a management team (including e.g. supply chain manager, operations manager, sales manager, financial manager) that prepares a DSD advice for the Board of Directors. The Board of Directors usually takes the final DSD decision. At the start of the decision-making process, the management team needs information to design the optimal distribution structure. For example, information about goods volumes, production locations, customer locations, or local tax policies. At the beginning of the process, managers can use the conceptual framework included in Chapter 5 as an overview of the aspects that should be considered.

The results from Chapter 4 include the weights of the factors that influence distribution structure design based on companies from multiple industry sectors. Companies that have composed a set of factors that are important to them can use the factor weights as default values for DSD. Logistics Service Providers can use the weights of the factors for DSD in case they transport goods for a range of companies from diverse industries.

This thesis also proposes a typology of distribution centre facilities (Chapter 2). The typology includes eight types of logistics facilities - e.g. city hubs, parcel and postal sorting facilities, national retail and e-commerce facilities. Each facility type is characterised according to functional criteria. The criteria include the warehousing and distribution activities that can be performed at the facility, the product type(s) that can be handled, distribution speed of the products, the geographic market focus of the facility, and the delivery time (in days) between the facility and its customer. Managers can use the features of each type to analyse which DC types are suited to apply in their distribution structure. Spatial planners can use the typology to discuss the features of individual DC types, which can support discussion of what are suitable locations for each type, e.g. maybe it is possible to develop clusters for single or multiple DC types.
Spatial planners are also recommended to use the factors studied to guide planning decisions in a way that plans meet the preferences of the studied industry sectors for logistics locations. Spatial planners that do not target at a specific industry can use the conceptual framework as a general checklist of companies' preferences for logistics locations.

References

Barbier, C., Cuny, C., and Raimbault, N. (2019). The production of logistics places in France and Germany: a comparison between Paris, Frankfurt-am-Main and Kassel, *Work Organisation, Labour & Globalisation*, Vol. 13(1), pp. 30-46.

Janjevic, M., and Winkenbach, M. (2020). Characterizing urban last-mile distribution strategies in mature and emerging e-commerce markets, *Transportation Research Part A: Policy and Practice*, Vol. 133(2020), pp. 164-196.

Mollenkopf, D.A., Ozanne, L.K., and Stolze, H.J. (2021). A transformative supply chain response to COVID-19, *Journal of Service Management*, Vol. 32(2), pp. 190-202.

Quan, Y. (2019). Planning Matters, *Journal of the American Planning Association*, Vol. 85(4), pp. 525-543.

Raimbault, N. (2019). Multiplication of logistics parks and invisibilisation of blue-collar workplaces in post-industrial metropolises, *Lo Squaderno*, Vol. 51, pp. 65-69.

Summary

Physical distribution includes all activities related to goods transport and storage in a supply chain. Components are transported to manufacturers, while finished goods are shipped to traders and retailers, or sometimes directly to customer's homes. Managing physical distribution is challenging to companies because customers expect high service levels (e.g. fast delivery times, flexible delivery options) at low costs. At the same time, globalisation and supply chain fragmentation are factors that have complicated physical distribution. A strategic decision companies have to make to satisfy customer demand is to select a *Distribution Structure Design (DSD)*, which includes the spatial layout of the distribution channel - i.e. the goods transport and storage system between production and consumption - as well as the location(s) of logistics facilities such as warehouses, hubs, or distribution centres (DCs).

Companies can apply diverse distribution channel layouts (or combinations of layouts) to distribute products to their customers. A well-known distinction is between centralised and decentralised layouts. A centralised layout includes single or no facilities, while a decentralised layout includes multiple logistics facilities. Companies that sell high value products often apply a centralised layout because inventory costs make up a large share of the companies' total logistics costs. Decentralised layouts are often used by companies that sell low value products, because transport costs make up a significant share of the companies' total logistics costs. Companies can apply many types of logistics facilities in their distribution structures such as warehouses and distribution centers, but also parcel hubs, city hubs or parcel pickup points.

This thesis studies the factors that determine companies' *Distribution Structure Design (DSD)*. Although distribution structure design is often explained in supply chain handbooks, there is little or no descriptive research into the influencing factors. Most studies on DSD are prescriptive, i.e. they calculate and prescribe distribution structure design with lowest logistics costs given a companies' preferred customer service level. However, these studies are often still based on incomplete or incorrect sets of factors resulting in suboptimal DSD decision. An

empirically validated conceptual framework of the influencing factors is missing in the literature.

The thesis applies multiple research methods (triangulation) to study the important factors and develop the conceptual framework. As background information about the range of logistics facilities that can be observed in practice, the first study proposes a typology (Chapter 2). In chapters 3 – 5 we investigate three aspects related to the main research goal, i.e. we review the important factors from literature, measure their importance, and investigate whether there are differences in factor importance between industry sectors. The studies build on each other. The literature review (Chapter 3) includes a set of important factors. Based on these factors, an initial conceptual framework is developed; this framework is detailed out and validated later with the studies included in chapters 4 and 5.

Chapter 2 proposes a typology of logistics facilities, based on DC real estate data from the Netherlands. Although there are diverse terms and concepts to denote logistics facilities - e.g. warehouse, distribution centre, logistics hub, depot, e-fulfilment centre, city hub - a standard typology is lacking in the literature. We propose a first typology that combines surface size with functional characteristics of DC facilities, such as product range and the market service area of the facility. Public policy makers can use the typology to discuss suitable locations for individual DC types. Scholars can use the typology to distinguish between facility types in their research and to analyse the impact of specific types on urban areas - for example, in terms of land use and emissions. The typology is grounded by a literature-based framework of relevant criteria. DC real estate data are used to analyse and exemplify the types. We arrive at eight logistics facility types: 1) Parcel lockers and pick-up points, 2) City hubs, 3) Parcel and postal sorting facilities, 4) Regional food wholesale and retail facilities, 5) National retail and e-commerce facilities, 6) Manufacturer DC facilities, 7) Bulk facilities, and 8) Global agricultural auctions. These types are categorized into size ranges from very small (XXS) to very large (XXL). The function of small sized DCs is easy to identify as dominantly Type 1 facilities, while the functions of medium (M) and large (L) sized facilities are heterogeneous. The results also indicate the relative importance of large DC facilities in the total logistics surface area. Only 19% of the facilities have a large size but represent almost half (46%) of the total logistics surface area in the Netherlands. In absolute numbers, most facilities have a small or medium size. The typology can help public policy makers to develop spatial policies for each facility type.

Chapter 3 includes a review of the state-of-the-art concerning the factors that determine companies' distribution structure design (DSD). The academic literature reveals seven main factors, i.e. 1) service level, 2) logistics costs, 3) demand level, 4) product characteristics, 5) labour and land, 6) accessibility, and 7) contextual factors. Each main factor consists of multiple sub-factors, for example, transport costs and inventory costs are sub-factors under logistics costs. The main result of the chapter is a conceptual framework of main factors. The framework indicates that the main trade-off influencing distribution structure design is service level versus logistics costs, the other five main factors influence this trade-off. The review shows there are three relevant research disciplines that study DSD, i.e. Supply Chain Management (SCM), Transportation and Geography. Each stream has a different focus, methods and limitations. SCM and Transportation study distribution channel layout as well as DC location selection, whereas Geography mainly focuses on DC location selection. Popular methods in the SCM stream are Operations Research (OR) techniques to model distribution structure options. Transportation scholars primarily apply cost-based quantitative models to predict freight flows, and Geography uses spatial analysis (such as barycentre analysis) and quantitative models to investigate geographical DC patterns. A limitation of the SCM stream is that it is complicated to include qualitative factors in DSD models. Apart from the factors, the literature is fragmented on the process that companies should follow in distribution structure design.

Chapter 4 studies the importance of seven main factors and 33 sub-factors that were identified from the literature review. A Multi-Criteria Decision-Making (MCDM) method called Best-Worst Method (BWM) is used to elicite the factor weights. BWM is a suitable method to consistently study a large set of influencing factors. The research is based on an online survey amongst industry decision-makers and logistics experts. The results indicate that logistics costs is the most important main factor. We find differences between the groups as well. Decision-makers consider service level second most important, while experts consider customer demand second most important main factor. According to decision-makers, the least important main factor is product characteristics, which is remarkable given the extensive literature on the distribution of diverse types of products. Experts value institutional factors as the least important main factor. Important sub-factors are transport costs (inbound and outbound), demand level, demand volatility, delivery time, warehousing costs, and product perishability. Sub-factors that are relatively unimportant according to the respondents are distance from DC to suppliers, land availability and land costs. Due to the generic nature of the survey, these results are mostly relevant to companies that ship a broad range of products and for spatial planners or policy makers that do not target a specific industry. In the next chapter we study differences in factor importance between industry sectors.

Chapter 5 investigates the factors that influence distribution structure design for three industry sectors - Fashion, Consumer electronics (CE) and Online retail (OR). The chapter proposes a further empirically validated conceptual framework of factors. Using a multiple case research design, we interviewed logistics experts and decision-makers affiliated to shippers or logistics service providers. Statistical analysis of the interview results indicates that decision-makers from the three industry sectors agree on main factor importance. The most important main factors are logistics costs, service level, demand factors and product characteristics. This result suggests that the main factors in the conceptual framework can be used for comparison between sectors. There are, however, differences in sub-factor importance between industries. Sub-factor 'supplier lead times' is the most important in the Fashion sector (compared to the other sectors), while responsiveness is the most important to Online retail (OR) companies. Sub-factor inventory costs follows the value density of the products - Consumer Electronics products have the highest value density, followed by Fashion and OR products. From the location factors, 'proximity of the DC to the motorway' is an important factor in all three sectors. The case results also reveal twenty new factors and one new main factor (i.e. so-called Keep factors, or factors that keep a DC at its current location). When comparing the scores of the decision-makers with the results of the BWM study, our findings indicate a high correlation between the two studies. This is a promising outcome, because it implies that multiple research methods (BWM survey and case interviews) result in similar main factor importance, which supports the general validity of the work.

In conclusion, this thesis provides insights into the factors that determine companies' distribution structure design. Factor weights reveal the relative importance of each factor. Based on the results, the thesis proposes an empirically validated conceptual framework of factors. Finally, the thesis includes a typology of logistics facilities. Future research could study DSD factors for semi-finished goods companies, as this thesis mainly focuses on wholesale and retail companies (business to consumer). Future research could also focus on how to include the new main factor and sub-factors in quantitative DSD models. Furthermore, future research could study the influence of actors such as real estate developers, government and local communities on distribution structure design. Another research avenue that deserves more attention is the effect of the decision-making process (for example, the setup of the decision-making team) on DSD outcome.

The results of this thesis should be of use to practitioners and policy makers. At the beginning of the decision-making process, practitioners can use the conceptual framework as an overview of the factors that should be considered in DSD. After companies have composed a set of factors that are important to them, the factor weights included in this thesis can be used as default values for DSD. The results are also relevant to spatial planners. They can use the DC typology (Chapter 2) to discuss the characteristics of individual DC types, which can be used as input to discuss suitable locations for these types. Spatial planners could also use the important factors to plan industrial land that meets the preferences of the studied industry sectors.

Samenvatting

Fysieke distributie omvat alle activiteiten met betrekking tot goederentransport en -opslag in een logistieke keten. Componenten worden naar productielocaties getransporteerd en eindproducten naar de groothandel, detailhandel, of soms direct naar de klant thuis. Het managen van fysieke distributie is uitdagend voor bedrijven omdat klanten hoge serviceniveaus verwachten (denk aan snelle levertijden en aan flexibele afleverlocaties) tegen zo laag mogelijke kosten. Tegelijkertijd hebben globalisering en versnippering van de keten ervoor gezorgd dat fysieke distributie steeds complexer is geworden. Een strategische beslissing die bedrijven moeten nemen om aan de klantvraag te kunnen voldoen is het kiezen van een *Distributiestructuur Ontwerp (DSO)*. Distributiestructuur ontwerp bestaat uit twee onderdelen; het ruimtelijke ontwerp van het distributiekanaal (dit betreft de lay-out van het goederentransport- en opslagsysteem tussen productielocaties en de klant) en de locatie(s) van logistieke centra zoals magazijnen, hubs of distributiecentra (DC's).

Een bedrijf kan kiezen uit verschillende typen distributiekanalen (of combinaties hiervan) om de klant te beleveren. Twee standaard typen zijn het centrale en decentrale distributiekanaal. Een centrale lay-out omvat geen of een enkel distributiecentrum, terwijl de decentrale lay-out uitgaat van meerdere logistieke centra. Bedrijven die hoogwaardige producten verkopen hanteren vaak een centrale lay-out omdat de voorraadkosten het grootste deel vormen van de logistieke kosten van het bedrijf. Een decentrale lay-out wordt vaak gebruikt door bedrijven die laagwaardige producten verkopen, omdat transportkosten tussen DC en klant het grootste deel vormen van de logistieke kosten van het bedrijf. Er zijn verschillende soorten logistieke centra die bedrijven toe kunnen passen in hun distributiestructuur zoals magazijnen en distributiecentra, maar ook pakkethubs, stadshubs of pakket afhaalpunten.

Dit proefschrift bestudeert de factoren die bedrijven hanteren in het ontwerp van hun distributiestructuur (DSO). Het ontwerp van een distributiestructuur wordt vaak behandeld in Supply Chain Management handboeken, maar toch is er nog weinig beschrijvend onderzoek gedaan naar de factoren die DSO beïnvloeden. De meeste studies zijn prescriptief, dit houdt in dat ze de distributiestructuur berekenen en voorschrijven die leidt tot de laagste logistieke kosten gegeven het gewenste klantenserviceniveau. Deze studies zijn echter vaak gebaseerd op een onvolledige of onjuiste set van factoren wat leidt tot een suboptimaal DSD besluit. Ook is er nog geen empirisch gevalideerd conceptueel raamwerk van factoren aanwezig in de literatuur.

Voor het onderzoeken van de belangrijke factoren en het opstellen van het conceptueel raamwerk worden in dit proefschrift verschillende methoden gehanteerd (triangulatie). Om de verscheidenheid aan logistieke centra te kunnen duiden, is eerst een typologie van logistieke centra ontwikkeld (Hoofdstuk 2). In hoofdstukken 3 - 5 worden drie aspecten met betrekking tot het belang van de factoren nader onderzocht; zo onderzoeken we wat volgens de literatuur belangrijke factoren zijn, meten we het belang van deze factoren, en onderzoeken we of er verschil zit tussen sectoren met betrekking tot het belang van de factoren. De studies bouwen voort op elkaar. De literatuurstudie (Hoofdstuk 3) bevat een set van belangrijke factoren. Op basis van deze factoren is een conceptueel raamwerk ontwikkeld op hoofdfactoren. Dit raamwerk is verder uitgewerkt en gevalideerd met de studies uit hoofdstuk 4 en 5.

Hoofdstuk 2 bevat een typologie van logistieke centra gebaseerd op logistiek vastgoed data uit Nederland. Uit literatuuronderzoek blijkt dat er verschillende termen worden gebruikt voor logistieke centra (zoals magazijn, distributiecentrum, logistieke hub, depot, e-fulfilmentcentrum, stadshub), maar een standaard typologie ontbreekt nog. De ontwikkelde typologie is vernieuwend omdat deze oppervlaktes van logistieke centra combineert met andere functionele kenmerken als productassortiment en verzorgingsgebied. Beleidsmakers kunnen de typologie gebruiken om per type geschikte vestigingslocaties aan te wijzen. Wetenschappers kunnen de typologie gebruiken om binnen hun onderzoek onderscheid te maken tussen specifieke typen DC's en om de impact van verschillende typen op het stedelijk gebied te analyseren. Denk bijvoorbeeld aan de impact op grondgebruik en aan uitstoot van schadelijke stoffen. De typologie is gebaseerd op een raamwerk van relevante criteria. Om de verschillende typen te analyseren en te illustreren is gebruik gemaakt van logistiek vastgoeddata. Uit de resultaten blijkt dat er acht typen logistieke centra zijn: 1) Pakketautomaten en ophaalpunten, 2) Stadshubs, 3) Pakket- en postsorteercentra, 4) Regionale groothandel- en detailhandelcentra voor levensmiddelen, 5) Nationale detailhandel en e-commerce centra, 6) Fabrikant DC's, 7) Bulk DC's, en 8) Mondiale landbouwveilingen. Deze typen zijn gegroepeerd op basis van oppervlakte (m^2) van zeer klein (XXS) tot zeer groot (XXL). De context van kleine DC's was eenvoudig te achterhalen omdat dit alleen Type 1 centra (Pakketautomaten en ophaalpunten) betreft, terwijl de context van middelgrote (M) en grote (L) logistieke centra heterogeen van aard is. De resultaten tonen ook het belang van grote distributiecentra in het totale logistieke vloeroppervlak. Grote logistieke centra vormen slechts 19% van het totaal, maar vertegenwoordigen gezamenlijk bijna de helft (46%) van het Nederlandse logistieke vastgoedoppervlak. In absolute aantallen hebben de meeste logistieke centra echter een kleine of middelgrote oppervlakte. De typologie kan beleidsmakers ondersteunen om per type ruimtelijk beleid te ontwikkelen.

Hoofdstuk 3 bevat een literatuurstudie naar de factoren die van invloed zijn op Distributiestructuur Ontwerp (DSO). De wetenschappelijke literatuur onderscheid zeven hoofdfactoren, dit zijn 1) service level, 2) logistieke kosten, 3) vraagniveau, 4) productkenmerken, 5) arbeid en land, 6) bereikbaarheid en 7) contextuele factoren. Iedere hoofdfactor bevat verschillende subfactoren, zo bestaan de logistieke kosten onder meer uit transportkosten en voorraadkosten. Het belangrijkste resultaat van dit hoofdstuk is een conceptueel raamwerk op het niveau van hoofdfactoren. De belangrijkste trade-off in het raamwerk is service level versus logistieke kosten. De andere vijf hoofdfactoren beïnvloeden deze trade-off. Uit de literatuurstudie komt naar voren dat er drie onderzoeksscholen zijn die het ontwerp van de distributiestructuur bestuderen; Supply Chain Management (SCM), Transport en Geografie. Iedere school heeft een eigen onderzoeksfocus, methoden en beperkingen. Zo ligt de focus bij de SCM en Transport scholen op zowel het distributiekanaal (centraal/decentraal) als de DC locatie, terwijl Geografie voornamelijk onderzoek doet naar distributiecentrum locatiekeuze van bedrijven. Populaire onderzoeksmethoden binnen de SCM-school zijn Operations Research (OR) technieken waarmee distributiestructuren gemodelleerd kunnen worden. Transportwetenschappers gebruiken op kosten gebaseerde kwantitatieve modellen om goederenstromen te voorspellen. Geografen passen ruimtelijke analysemethoden (bijvoorbeeld zwaartepuntanalyse) en kwantitatieve modellen toe om DC-locatiepatronen te onderzoeken. Een beperking van de SCM-school is dat het lastig is om kwalitatieve factoren te modelleren. Naast de belangrijke factoren blijkt dat de literatuur gefragmenteerd is ten aanzien van de processtappen die bedrijven dienen te volgen in het ontwerp van de distributiestructuur.

Hoofdstuk 4 onderzoekt het belang van de zeven hoofdfactoren en 33 subfactoren afkomstig uit het literatuuronderzoek (Hoofdstuk 3). Het gewicht van de factoren is onderzocht met behulp van een Multi-Criteria Analyse (MCA) methode genaamd Best-Worst Method (BWM). BWM is een geschikte methode om op een consistente manier een groot aantal beïnvloedende factoren te onderzoeken. Het onderzoek is gebaseerd op een online enquête onder beslissers over DSO (werkzaam bij verladers of logistiek dienstverleners uit de sector) en logistiek experts. De resultaten laten zien dat logistieke kosten de belangrijkste hoofdfactor vormen. Er zijn ook verschillen tussen de twee groepen respondenten. Zo vinden beslissers service level en experts het vraagniveau de op een na belangrijkste hoofdfactor. Volgens beslissers zijn productkenmerken het minst belangrijk. Dit is opmerkelijk omdat de distributie van diverse soorten producten veel aandacht krijgt in de literatuur. Volgens experts zijn institutionele factoren het minst belangrijk. Belangrijke subfactoren zijn transportkosten (inbound en outbound), vraagniveau, volatiliteit van de klantvraag, levertijd, handlingkosten en bederfelijkheid van producten. Onbelangrijke subfactoren (beide groepen) zijn de afstand van het DC tot leveranciers, evenals de beschikbaarheid en de prijs van grond. Door de generieke aard van de enquête zijn de resultaten vooral relevant voor bedrijven die een breed scala aan producten verschepen en voor ruimtelijk planners of beleidsmakers die niet focussen op de vestiging van specifieke sectoren. In het volgende hoofdstuk bestuderen we verschillen in factorbelang tussen sectoren.

In *hoofdstuk 5* is voor drie sectoren onderzocht wat de belangrijke factoren zijn bij het ontwerp van de distributiestructuur. De onderzochte sectoren zijn Mode, Consumentenelektronica (CE) en Online retail (OR). Op basis van de gevonden factoren is een gedetailleerd en gevalideerd conceptueel raamwerk opgesteld dat gebruikt kan worden door bedrijven uit deze sectoren. De resultaten zijn gebaseerd op casestudie onderzoek waarin twee groepen respondenten, experts versus beslissers (werkzaam bij verladers of logistiek dienstverleners), zijn onderzocht op de belangrijke factoren. De interviewresultaten zijn statistisch onderzocht en laten zien dat beslissers uit de drie sectoren het eens zijn over de belangrijke hoofdfactoren. De belangrijkste hoofdfactoren zijn logistieke kosten, service level, vraagfactoren en productkenmerken. Aangezien beslissers het eens zijn over het belang van de hoofdfactoren, kan het conceptueel raamwerk op hoofdfactorniveau gebruikt worden om sectoren met elkaar te vergelijken. Er zijn echter wel belangrijke verschillen gevonden tussen sectoren in het belang van de subfactoren. Zo is subfactor ‘doorlooptijd vanuit de leverancier’ het belangrijkste in de Mode sector (in vergelijking met de andere sectoren) en is reactievermogen om snel te kunnen reageren op de klantvraag het belangrijkste voor Online retail (OR) bedrijven. Het belang van voorraadkosten is positief gerelateerd aan de waardedichtheid van de producten. Zo hebben

Consumentenelektronica producten de hoogste waardedichtheid, gevolgd door Mode producten en OR producten. Nabijheid van het DC tot de snelweg is een belangrijke factor voor alle drie de sectoren. Verder komen uit het onderzoek 20 nieuwe subfactoren en één nieuwe hoofdfactor (‘Keep’-factoren, dit zijn factoren die bedrijven beïnvloeden om het DC op de huidige locatie te behouden) naar voren die het ontwerp van de distributiestructuur kunnen beïnvloeden. Wanneer de resultaten van de beslissers worden vergeleken met de resultaten van de BWM-studie (uit hoofdstuk 4), blijkt dat er een hoge correlatie bestaat tussen de twee studies. Dit is een veelbelovende uitkomst omdat beide onderzoeksmethoden (BWM-enquête en case studie interviews) resulteren in een vergelijkbaar hoofdfactorbelang. Deze uitkomst draagt ook bij aan de validiteit van het gehele onderzoek.

Concluderend geeft dit proefschrift inzicht in de factoren die het distributiestructuur ontwerp van bedrijven bepalen. De berekende factorgewichten tonen het relatieve belang van de factoren. Gebaseerd op deze resultaten is een gedetailleerd en empirisch gevalideerd conceptueel raamwerk opgesteld. Tot slot bevat het proefschrift een typologie van logistieke centra. Toekomstig onderzoek kan zich richten op het bestuderen van de belangrijke factoren voor bedrijven die halffabricaten produceren, aangezien dit proefschrift hoofzakelijk focust op groothandel- en detailhandel bedrijven (business to consumer). Toekomstig onderzoek kan zich ook richten op de vraag hoe de nieuwe hoofdfactor en subfactoren opgenomen kunnen worden in kwantitatieve DSO-modellen. Daarnaast kan in toekomstig onderzoek aandacht worden besteed aan de invloed van verschillende actoren (denk aan vastgoedontwikkelaars, overheden of lokale gemeenschappen) op het distributiestructuur ontwerp van bedrijven. Een andere onderzoeksrichting die meer aandacht verdient is de invloed van het besluitvormingsproces (bijvoorbeeld de samenstelling van het team van beslissers) op DSO.

De resultaten van dit proefschrift zijn relevant voor zowel managers als beleidsmakers. Bij aanvang van het besluitvormingsproces kunnen managers het conceptueel raamwerk gebruiken als overzicht van factoren die meegenomen dienen te worden in distributiestructuur ontwerp. Nadat bedrijven een lijst met belangrijke factoren hebben opgesteld, kunnen ze de factor gewichten uit dit proefschrift gebruiken als standaardwaarden voor distributiestructuur ontwerp. De resultaten zijn ook van belang voor planologen. Zij kunnen de DC typologie (Hoofdstuk 2) gebruiken om de kenmerken van verschillende DC typen te onderzoeken, wat gebruikt kan worden als input in de discussie over geschikte vestigingslocaties voor verschillende typen DC’s. Daarnaast kunnen planologen de belangrijke factoren gebruiken voor het plannen van industrieterreinen die aansluiten bij de voorkeuren van bedrijven uit de onderzochte sectoren.

About the author

Sander Onstein was born on the 17th of October 1985 in Maastricht, the Netherlands. He obtained a bachelor degree (cum laude) in Urban and Regional Planning from Breda University of Applied Sciences and master degree in Urban and Regional Planning from University of Amsterdam in 2011. After graduation he started working as a lecturer and researcher at the Logistics department of the Amsterdam University of Applied Sciences (AUAS). His teaching activities include, amongst others, Supply Chain Management, Physical Distribution, and bachelor thesis supervision. As a researcher of 'Smart Mobility & Logistics' he is part of the Urban Technology research group, an interdisciplinary research team (logistics, engineering, built environment) within the Faculty of Technology. From 2012 – 2014 he worked on the RAAK-PRO financed research project "Supply Chain and Network Strategies for Logistics SMEs". The research focused on strengthening the position of logistics SMEs at Schiphol airport and the Port of Amsterdam. During the project he coordinated (student) research for several companies, e.g., KLM Cargo and FloraHolland.

From 2016 he started his PhD research (part-time) at the Transport and Logistics section of the Faculty of Technology, Policy and Management. His research focused on the factors that influence Physical Distribution Structure Design. The PhD trajectory was supported by the Netherlands Organisation for Scientific Research (NWO) - Doctoral Grant for Teachers. Over 50 bachelor students and two master students participated in the project. In the future he will continue (and expand) his teaching and research activities at the Amsterdam University of Applied Sciences.

Publication list

Peer reviewed journal

Onstein, A.T.C., Tavasszy, L.A., and van Damme, D.A. (2018). Factors determining distribution structure decisions in logistics: A literature review and research agenda. *Transport Reviews*, Vol. 39 No. 2, 243-260.

Onstein, A.T.C., Ektesaby, M., Rezaei, J., Tavasszy, L.A. and van Damme, D.A. (2020). Importance of factors driving firms' decisions on spatial distribution structures. *International Journal of Logistics Research and Applications*, Vol. 23 No. 1, 24-43. DOI: 10.1080/13675567.2019.1574729.

Onstein, A.T.C., Tavasszy, L.A., Rezaei, J., van Damme, D.A., and Heitz, A. (2020). A sectoral perspective on distribution structure design. *International Journal of Logistics Research and Applications*, 1-29. DOI: 10.1080/13675567.2020.1849074.

Onstein, A.T.C., Bharadwaj, I., Tavasszy, L.A., van Damme, D.A., and el Makhloufi, A. (2021). From XXS to XXL: Towards a typology of distribution centre facilities. *Journal of Transport Geography*, Vol. 94 (June 2021).

Book chapter

de Goeij, C.A.J., Onstein, A.T.C., Steeman, M.A. (2015). Impediments to the Adoption of Reverse Factoring for Logistics Service Providers, in: Zijm, H., Klumpp, M., Clausen, U., ten Hompel, M. (Eds.), *Logistics and Supply Chain Innovation. Bridging the Gap between Theory and Practice.* Springer International Publishing, Cham, pp. 261–277. https://doi.org/10.1007/978-3-319-22288-2.

Scientific conference presentation

Onstein, A.T.C., Ektesaby, M., Rezaei, J., Tavasszy, L.A. and van Damme, D.A. (2017). Factors driving the spatial layout of distribution channels. Presentation I-NUF Metrans (International Urban Freight Conference). October 17 - 19, Long Beach, CA.

Onstein, A.T.C., Tavasszy, L.A. and van Damme, D.A. (2019). Distribution Structure Design (DSD): inventory of practices in 3 industry sectors. Presentation I-NUF Metrans (International Urban Freight Conference). October 16 - 18, Long Beach, CA.

Conference papers

Onstein, A.T.C., Visser, J.G.S.N., Ham, J.C. van, and Tavasszy, L.A. (2016). Trends in Distribution Centres and their Locations: Sprawl and Polarization. Bijdragen Vervoerslogistieke werkdagen 2016.

Onstein, A.T.C., Ektesaby, M., Rezaei, J., Tavasszy, L.A. and van Damme, D.A. (2017). Factors driving firms' spatial decisions on distribution channel layout. Bijdragen Vervoerslogistieke Werkdagen 2017.

Onstein, A.T.C., Tavasszy, L.A. and van Damme, D.A. (2018). Factoren achter grondvorm en DC-locatiekeuze: interviewresultaten uit 3 sectoren. Bijdragen Vervoerslogistieke Werkdagen 2018. Best Paper Award VLW 2018.

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Summary

This thesis studies the factors that influence physical distribution structure design. Distribution Structure Design (DSD) concerns the spatial layout of the distribution channel as well as the location(s) of logistics facilities. Despite the frequent treatment of DSD in supply chain handbooks, an empirically validated conceptual framework of factors is still lacking. This thesis studies DSD in multiple industry sectors (Fashion, Consumer Electronics, Online Retail) and proposes a conceptual framework.

About the Author

Sander Onstein is lecturer-researcher at the Amsterdam University of Applied Sciences (AUAS). He performed his PhD research on Physical Distribution Structure Design at Delft University of Technology. His research interests include supply chain management, physical distribution and urban planning.

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