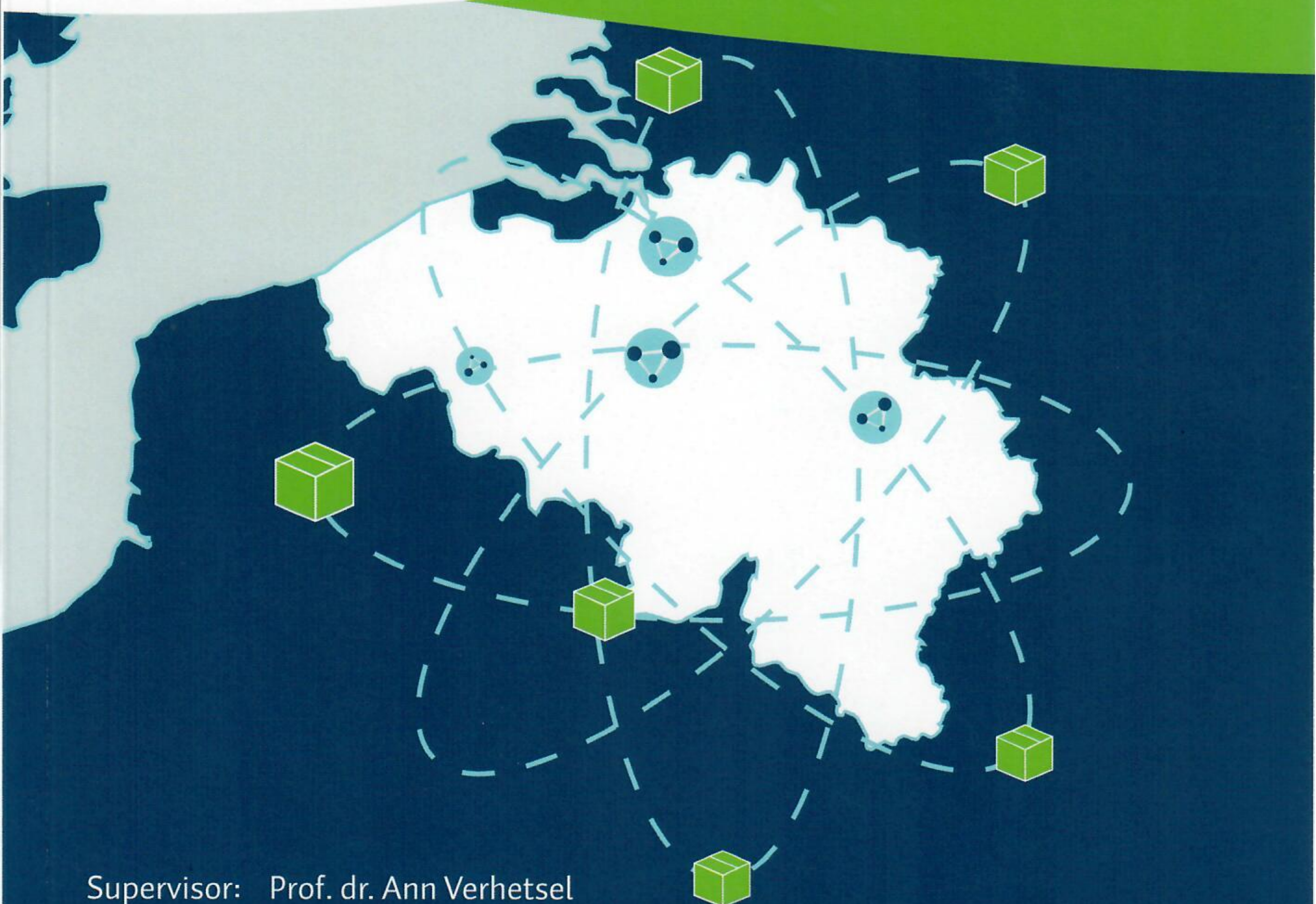
The logistics sector in a consumer driven society, essays on location and network structure

Joris Beckers



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The logistics sector in a consumer driven society, essays on location and network structure

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Abstract

Over the past twenty years globalization forces have internationalized production and consumption. The global disintegration of the production process severely complicated the in- and outflow of materials and significantly expanded the operational scale of logistics companies. Combined with an increasing awareness for the consumer, with a faster delivery of qualitative goods, this global scope demanded close cooperation between producers, suppliers and distributors and gave rise to a strategy of supply chain management and the advent of contemporary logistics. Recently, the popularity of the internet as an extra retail channel further complicated the organization of logistics flows. The emergence of free home deliveries implied a fragmentation of both destinations and volumes and constituted the consumer as an inherent part of the distribution process.

The changing role of logistics implied new locational factors for the physical distribution processes and caused a spatial reconfiguration of the logistics network. By using four case studies, this dissertation studies how local spatial interactions shape this new spatial configuration of the logistics network in Belgium. The first two cases engage in network methodologies to quantify this objective for the whole logistics sector. They confront network-based insights gained from a microeconomic dataset of buyer-supplier linkages with location- and domain-specific insights. The last two case studies focus on a subset of the sector: the courier, express and parcel (CEP) services. They highlight the impact of the consumer on the logistics chain by means of a mixed method methodology.

The network analysis identifies the presence of spatially contiguous communities within the Belgian logistics networks, proving the importance of geography in this scattered sector. Contrasting these with indicators of employment concentration results in a typology of logistics clusters. The hierarchical structure of the network is eventually uncovered by iterating the community detection algorithm. Third case study maps the geography of online shopping behavior in Belgium. This lays the founda-

tion for an assessment of the spatial distribution of the demand for online ordered parcels and leads to the development of a framework of new infrastructures in e-commerce delivery chains.

Drawing inspiration from network methodologies allows for a richer description of the geography, especially with the increasing availability of ever growing datasets. Its application demonstrates how interactions differ geographically and impact the spatial configuration of the logistics network on a local level, resulting in a *spiky* landscape. The spikiness is centered around the cities, which are the focal points of logistics chains where spatial interactions converge. However, this logistics network is not static. The rise in online shopping, with the demand for ever faster and more customized deliveries by consumers, extended current CEP networks with a new *urban* layer of logistics infrastructures. This way, individual consumers are increasingly leaving their mark on the logistics landscape, prompting the debate concerning the responsibility of the associated negative externalities.

Nederlandstalige samenvatting

Intensieve globalisering over de voorbije twintig jaar leidde tot een internationalisering van productie- en consumptieprocessen. De globale desintegratie van het productieproces bemoeilijkte de in- en uitstroom van goederen en zorgde voor een ongeziene schaalvergroting van de operaties van logistieke bedrijven. Deze expansie eiste een nauwere samenwerking tussen producenten, leveranciers en distributeurs en leidde zo tot de ontwikkeling van supply chain management en de opkomst van de hedendaagse logistiek. De recente populariteit van het internet als nieuw retailkanaal zet de logistieke organisatie echter onder druk. Zo zorgde de vraag naar gratis thuisleveringen voor een spreiding van de leveradressen en een fragmentatie van de transportvolumes. De consument installeerde zich als het ware als een inherent deel van de distributieketen.

De veranderende rol van de logistiek impliceert nieuwe locatiefactoren voor de fysieke distributieprocessen en zorgt voor een ruimtelijke herschikking van het logistieke netwerk. Aan de hand van vier case studies onderzoekt deze thesis hoe lokale ruimtelijke interacties de nieuwe geografische configuratie van de Belgische logistieke sector vorm geven. De eerste twee cases halen hun methodologische inspiratie uit het veld van de netwerkanalyse om deze impact op een kwantitatieve manier te beschrijven. Zij combineren de inzichten uit een micro-economische dataset van koper-leverancier relaties met locatie- en domeinspecifieke kennis. De netwerkanalyse identificeert de aanwezigheid van ruimtelijk homogene *communities* in het Belgisch logistieke netwerk en toont zo de relevantie van geografie in deze verspreide sector. Door deze *communities* te combineren met ruimtelijke indicatoren op basis van de tewerkstelling in de sector wordt een typologie van logistieke clusters gevormd. Een iteratie van het oorspronkelijke algoritme ontleedt tot slot de verdere hiërarchische structuur van het netwerk.

De twee laatste case studies focussen op een subset van de logistieke sector: de postdiensten en koeriers. Zij beschrijven de impact van de consument op de logistieke keten door middel van een mixed method analyse. De eerste van deze twee cases brengt de geografie van de Belgische online shopper in kaart. Deze is fundamenteel voor een analyse van de ruimtelijke spreiding van de vraag naar online bestelde pakjes. Dit leidt in de vierde case tot de ontwikkeling van een framework van nieuwe logistieke infrastructuur in de e-commerce keten.

De toepassing van een netwerkanalyse zorgt voor een rijkere beschrijving van de geografie, zeker in een context van almaar groter wordende datasets. De analyse toont hoe interacties de ruimtelijke configuratie van het logistieke netwerk vorm geven op een lokaal niveau. Het resulterend heterogene logistieke landschap is gecentreerd rond de steden waar ruimtelijke interacties convergeren. Het logistieke netwerk is echter niet statisch. De opkomst van online shopping met de vraag naar almaar snellere en persoonlijke leveringen zorgde voor een extensie van logistieke ketens en het ontstaan van een *stedelijke* laag van logistieke infrastructuur. Op deze manier drukken consumenten meer en meer hun stempel op het logistieke landschap, wat aanleiding geeft tot een debat rond wie nu zijn verantwoordelijkheid moet nemen om de stijgende negatieve impact hiervan te counteren.

Listing of Acronyms

3PL	Third party logistics
4PL	Fourth party logistics
APS	Automated Parcel System
B2B	Business-to-Business
B2C	Business-to-Consumer
BIPT	Belgian Institute for Postal and Parcel Services
C2C	Consumer-to-Consumer
CEP	Courier, Express and Parcel
CDP	Collection and Delivery Point
EEG	Evolutionary Economic Geography
ESDA	Exploratory Spatial Data Analysis
FTE	Full Time Equivalent
NBB	National Bank of Belgium
ULS	Urban Logistics Space
VKT	Vehicle Kilometers Travelled

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1
Introduction

1.1 Background

The logistics sector is a hidden sector. It consists of a vast amount of companies of all sizes and despite being present, especially on busy roads, its operations remain a background phenomenon where the majority of the population are hardly ever confronted with. Unsurprisingly, the perception of the sector remains that of a tattooed trucker whose presence on the road is only good for increasing your commuting time. Nonetheless, logistics are vital to our economy and society. The handling and transportation of goods allow factories to produce, supermarket shelves to be filled, concerts to be organized and relief to be brought to disaster areas. Logistics activities generate employment and spur economic growth.

However, the general attitude towards the crucial role of logistics has changed slowly over the past two decades. First, globalization ensured the establishment of logistics as a structural sector within the economy, more than just a transport service (Hesse, 2007). The geographical disintegration of the production process complicated the flow of goods through the supply chain and brought along significantly more interest from businesses for logistics operations (Mentzer et al., 2001). This thoroughly changed the outlook of the sector and its position in relation to other economic sectors, resulting in a spatial reconfiguration of the logistics network. Yet, while this process expanded the pivotal role of the sector, a consumer visiting a media store to buy a new computer with components from all over the planet was still unaware of the logistics efforts undertaken to land these computers in the showroom.

Nowadays, the consumer's perception towards the sector is changing too. Due to a growing consumer-driven mindset within the logistics sector, online shoppers now have the power to demand ever faster, cheaper and more convenient deliveries that, ideally, are traceable from the warehouse to their doorstep. While only a couple of years ago one was satisfied with receiving an online order the same week, next day deliveries have now become the standard instead of a competitive advantage and the 2-hours delivery promise arrived in Europe as well. Studies indicating the opportunities of offering same-day delivery for web shops and logistics players (McKinsey & Company, 2017; 2Flow, 2017) only accelerate this evolution. Ever shorter delivery times are not the only result of the empowerment of the consumer. As many receivers are not at home during delivery hours, logistics players are now obliged to offer a network of pick-up points or parcel lockers to ensure minimal pick-up distances for online shoppers. These new consumer desires have changed the perception of the logistics sector. For example, advertising free shipments may now be more successful than traditional price reductions to clear the last items in stock (Dekker, 2016). As a result, one can say the logistics sector has come to the forefront due to the emergence of e-commerce to the extent that the rise in online shopping has integrated the consumer in logistics processes. .

It are the cities, by generating 80% of total GDP worldwide and hosting an increasing majority of global consumption, that are the focal points of these globally expanding supply chains (The World Bank, 2018; United Nations, 2018). However, because freight cannot vote but passengers do, passenger transport has always received more policy attention compared to logistics. This is certainly expressed in the large discrepancy between the amount of urban mobility and urban logistics plans in cities (Lindholm and Behrends, 2012). The interaction cities-logistics is however rising on research agendas due to the increased consumer driven focus of the sector and resulting impacts of logistics on the livability in urban areas (e.g. 'everybody delivers everywhere' (Browne et al., 2014)). As such Europe's largest innovation and research program, Horizon 2020, puts particular attention on logistics in urban areas while closer to home the research questions presented here were included in the Flemish research project *Urban Logistics & Mobility*.

By definition, the main focus of the logistics sector is to get goods from point A to point B, overcoming the space in between. As a result, *there would be no transportation without geography and there would be no geography without transportation*, as Rodrigue (2013) so nicely states. The academic geographical attention to logistics is nonetheless underdeveloped compared to for example the body of work on freight in engineering or economics (Hesse and Rodrigue, 2004). This because the field of transportation geography, in the footsteps of policy makers, focused mostly on the more fashionable transport of passengers instead of freight. Logistics, as a fragmented sector, was until recently equally low on the regional studies research agenda (Porter, 2003; Rodrigue, 2006b).

The changing role of the sector however justifies dedicated geographical research. Hence, this dissertation focuses on the spatial configuration of the logistics network. In line with the evolution drawn above, it will specifically study how the sector reconfigures its networks due to its new role within the consumer driven economy. The relevance of this research is at least fourfold. First, it extends the academic knowledge on the spatial configuration of the logistics sector by exploring the interface between Transport and Economic geography. Second, the specific quantitative geographical nature of this dissertation can be a source of inspiration for other scholars studying the topic, particularly with the increasing availability of new data sources. Third, as it presents an overview of the current configuration of the sector and a zoom on the challenge e-commerce is posing, this study is a valuable reference document for policy makers at different levels. Especially given their eagerness to identify logistics as a key strategic sector for the development of their region (Vanthillo et al., 2014). Fourth and finally, since each of the following Chapters is strongly data-driven, they provide evidence-based conclusions on the situation and hence result in valuable insights for practitioners in the field. Continuous feedback from the sector during the research enhances its relevance for these actors.

In the remainder of this Chapter the logistics sector is first defined. Afterwards Section 1.2.2 elaborates on the structural changes the sector has gone through over the past decades. In Section 1.3 two key issues which result in the listing of the research questions are highlighted. Finally, this Introduction is concluded with a description of the dissertation's outline.

1.2 The logistics sector

1.2.1 Definition

This dissertation follows the definition of the Council of Supply Chain Management Professionals who summarizes logistics as

> *that part of the supply chain that plans, implements, and controls the efficient, effective forward and reverse flow and storage of goods, services and related information between the point-of-origin and the point-of-consumption in order to meet customers' requirements (CSCMP, 2016).*

The employment share of each of the logistics subclasses in 2015 in Belgium is provided in Figure 1.1. While road transport and postal and courier activities constitute the majority of logistics activity, logistics is clearly more than a mere transport service. Agencies and forwarders, mostly third party logistics (3PLs) and fourth party logistics (4PLs) (for an elaborate discussion on their differences, see Blauwens et al. (2014)) act as intermediaries to ensure the goods are transported from the point-of-origin to the point-of-consumption. Their services can be asset-based (i.e. by using their own infrastructure and vehicles) or non asset-based (further subcontracting all transport and cargo handeling activities) (Selviaridis and Spring, 2007). Background activities, like cargo storage (i.e. warehousing) and handling (e.g. (un)loading container ships in seaports), complement the actual transportation of freight. As one can derive from this concise description, the percentages presented in Figure 1.1 have to be interpret with care. Many companies combine different logistics activities but have to choose one encapsulating industry code, which are used in the statistics presented here. This however demonstrates the heterogeneity of logistics activities, besides the transportation of freight.

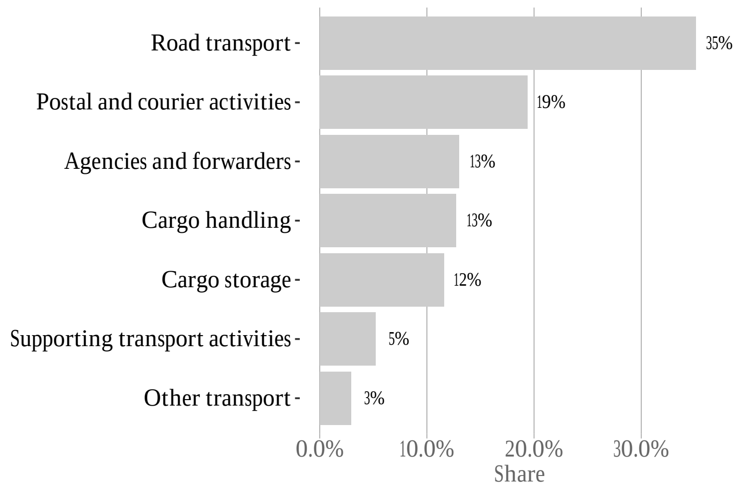

Figure 1.1: Share of direct employment by class in total logistics FTE in Belgium (2015). Source: (NBB, 2017)

1.2.2 From derived to integrated demand

The trigger for freight transport is a need at the point-of-consumption for a product produced at the point-of-production. For example, when goods are sold, the vendor requires replacements, prompting the manufacturer to order a shipment by a transportation company. The demand for transportation and related logistics activities is thus induced by the production and consumption, hence, it is a derived demand (Dicken, 2015). In this context, the customer of the logistics company rarely is the end consumer. Instead it is the one keeping the stock, the manufacturer or vendor, that orders logistics activities.

A simple model of the transport system is presented in Figure 1.2: the demand for transport translates spatially in a set of nodes; the relational aspect of the demand results in freight flows. From a traditional perspective on transport, these nodes represent the points of consumption and production and are the entry and exit points of the transport system. The freight flows are the outcome of

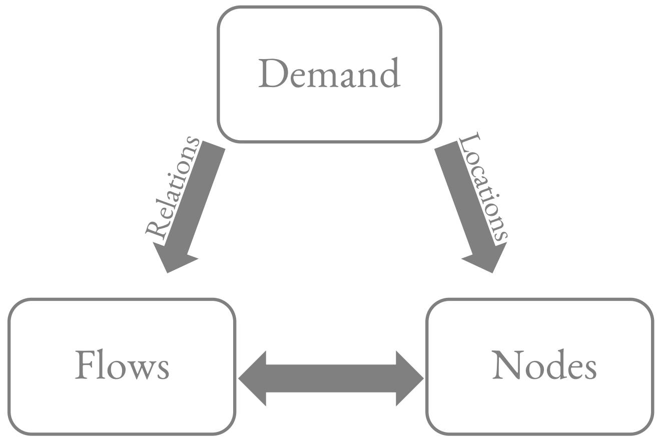

Figure 1.2: The transportation system. Source: own composition based on Rodrigue (2013)

the buyer-supplier interaction and link an origin node to a destination node. Together, the demand, freight flows and nodes are the building blocks of the transport system (Rodrigue, 2013).

The improvement of information and communication technologies together with deregulation and liberalization policies allowed for a truly global economy from the late twentieth century onwards. This global transformation from a 'space of places' to a 'space of flows' with locations being connected beyond physical contiguity, opened the door for global sourcing by large corporations (Castells, 1996; Antràs and Helpman, 2004). The international disintegration of the production process severely complicated the in- and outflow of materials and significantly expanded the operational scale of logistics companies. In parallel, there has been a paradigm shift in the supply-demand relations within the production process. Increasing awareness for the consumer, with a faster delivery of qualitative goods, resulted in a time and quality-based competition (Mentzer et al., 2001). These two evolutions however increased the vulnerability of the production process, especially in a climate of continuous economic and technological changes. This led to a shift in mentality from 'manufacture-to-supply' to 'manufacture-to-order', i.e. from push to pull where supply matches demand and inventories are kept as small as possible (Rodrigue, 2006a). This is similar to the more elaborate principle of lean manufacturing, which focuses on minimizing waste while producing at the pace of the consumer (Shah and Ward, 2003).

The global scope together with a fundamental change in the focus of the production process creates a context where the management of the freight flows necessitates close cooperation between producers, suppliers and distributors and gave rise to a strategy of supply chain management and the advent of contemporary logistics (Figure 1.3) (Mentzer et al., 2001). As a result, logistics, from being a derived external factor, became integrated in the production and distribution system (Hall et al., 2006; Hesse and Rodrigue, 2004; Pedersen, 2001; Rodrigue, 2006a). This integration was two-fold: geographical and functional. On the one hand, the increasing scale of operations and geographical fragmentation of production accentuated the importance of intermediary locations. On the other hand, the complication of the production process resulted in a need for specialized actors to organize the flow of goods within and between production chains. This is demonstrated by the wide variety of specialized agencies and forwarders, and the rise of 3PLs and 4PLs (see Section 1.2.1). Logistics specialization also propagated in related industries, for example in te real estate sector, to better meet the changing demand of distribution activities (Hesse, 2004).

The integration reformed the sector from a derivative of production and consumption to a more structural, independent part of the economy (Hesse, 2007). Consequentially it structurally changed the spatial configuration of logistics networks, with an increasingly important role for distribution centers. The latter can be explained by a couple of reasons. First, instead of holding stocks at different points in the production chain, warehousing activities concentrated in fewer but larger facilities. The trend towards the outsourcing of logistics activities to specialized actors further accelerated this. Second, related to the former point, the specialized logistics players managed economies of scale and scope by organizing these centers as the interface between a convergence on the supply side and a divergence on the demand side (Hesse, 2008; Rodrigue, 2006a). Hence, they became important throughput-oriented nodes. The importance of these nodes together with the expanding responsibilities of the sector resulted in an increased demand for logistics floor space (Holl and Mariotti, 2018).

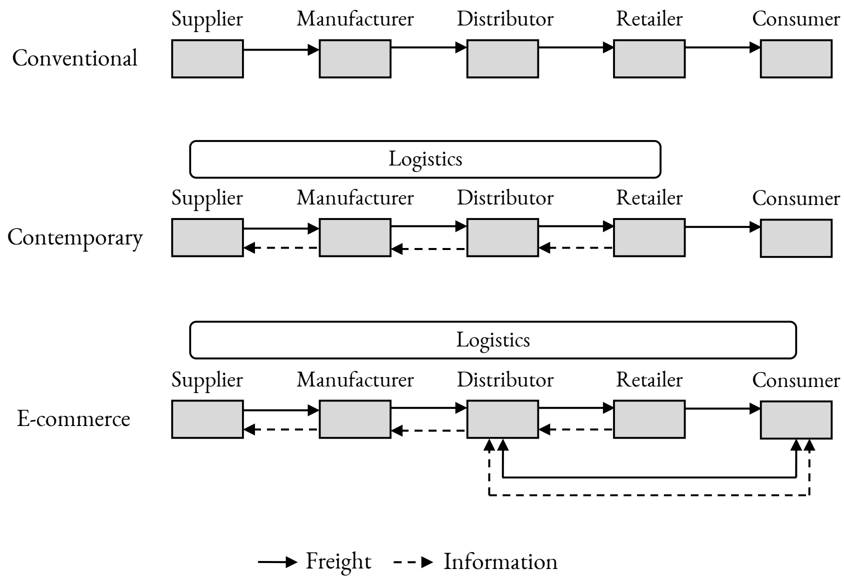

Figure 1.3: The evolution of the logistics sector. Source: own composition based on Dicken (2015); Hesse (2008); Rodrigue (2006a)

The changing role of logistics implied new locational factors for the physical distribution processes. First, due to their role as regulator within the network, good accessibility became imperative (Hesse and Rodrigue, 2004; Holl and Mariotti, 2018). Second, the increasing concentration of flows and goods in these facilities demanded large plots of land (Verhetsel et al., 2015). Traditional warehousing locations, i.e. next to industrial zones in inner cities (Allen et al., 2012), do not fulfill these requirements and hence a suburbanization of logistics facilities was observed (Cidell, 2010; Hesse, 2008). Dablanc and Rakotonarivo (2010) termed this spatial decentralization in metropolitan areas as 'logistics sprawl' and highlighted the negative effects for the environment associated to it. The topic has received much attention through other case studies observing a similar location trend around other cities (Aljohani and Thompson, 2016; Heitz et al., 2018; Woudsma et al., 2016).

1.3 Knowledge gaps

Although logistics has always been low on research agendas, the preceding concise overview demonstrates the body of geographical research on the topic has grown steadily over the past decade, especially since the call by Hesse and Rodrigue (2004). However, the majority of aforementioned geographical research considers only the absolute location of a firm and ignores its spatial interactions. This is surprising, given the authors' recognition of the sector as a key player within the supply chain in particular and the economy in general. As such Hesse (2007) argues that due to this new role for the logistics sector *the location choice of distribution companies cannot be interpreted as simply the response to the presence of specific factors such as infrastructure or access to markets. Rather, it is based on the interactions among an individual company's position within complex value-adding relations, and the spatial and infrastructural configuration of competing locations*. O'Connor (2010) makes a similar remark in his conclusion, predicting a concentration of logistics activities in reference to the 'buzz' created at clusters of service firms. While it is unclear which type of relations - vertical or horizontal - Hesse refers to, O'Connor's 'buzz' is about intense horizontal interactions between companies of the same or related industries, one of the agglomeration advantages linked to the clustering of economic activities (Marshall, 1890; Porter, 2003). Sheffi (2012, 2013) later observed the occurrence of such clusters in the logistics sector, something which previously only had been documented in more traditional economic sectors (Bathelt et al., 2004). Bounie and Blanquart (2016) also recognize the potential of agglomeration advantages in the logistics sector and try to quantify their impact by linking the productivity of a logistics establishment to their location within logistics centers. These studies however highlight the location of businesses and fail to quantify their inter-firm relations. To the author's knowledge, only two publications study explicitly horizontal relationships among co-located logistics firms, both with a qualitative methodology, yet with contrasting findings (Hesse, 2008; van den Heuvel et al., 2014a). It is clear there remains a significant lack of quantitative geographical research on the spatial configuration of the networks within this heavily interconnected sector.

Inter-firm relations are not the only interactions shaping the logistics sector. More and more, the consumer is driving logistics activities. With the popularity of online shopping, an increasing share of the delivery addresses of consumer goods shifts to the end consumer's preferred location instead of a predefined store in the case of offline retail. In addition, the opening of the internet as extra retail channel with home deliveries has resulted in a fragmentation of freight shipments, especially in the last part of the distribution chain, i.e. the last mile (Gevaers et al., 2011; Hesse, 2002). This poses new requirements on logistics operations. First, there is now direct communication between consumers and carriers. Second, new logistics facilities such as collection and delivery points are created to improve the exchange of goods. These new interactions, i.e. both informative as physical, constitutes the consumer as an inherent part of the distribution process. The implications hereof are especially expressed in constrained urban areas (Cárdenas et al., 2017a; Ducret et al., 2016). As a result, the topic is high on the urban logistics research agenda, which is concerned with the organization and impacts of logistics in cities. The majority of urban logistics works, however, focused on public authorities and logistics carriers and ignore the consumer's perspective (Behrends, 2016; Lagorio et al., 2016). While the latter did receive some geographical attention (Anderson et al., 2003; Weltevreden, 2008), very few studies in the field of Economic or Transport Geography link the new role of the consumer to changes in the spatial configuration of supply chains. Hence, a clear gap at the interface of both research fields remains.

1.4 Objectives and Research questions

The aforementioned discussion highlights a lack of research on the spatial interactions within the logistics sector in general. The spatial interactions as defined in both issues significantly differ but find a common ground in their origin: as contacts and movements between places. In their quest for spatial order, early quantitative geographers see these interactions as confined into channels, creating networks that connect places of differing hierarchy (Johnston et al., 2018). In this perspective, the spatial configuration of the network is then the outcome of the contacts and movements, which themselves depend on the spatial context of the people and places. The primary objective of this dissertation is to better understand the drivers of the spatial configuration of the logistics sector. Relating this to the above reasoning leads to the definition of the following research question:

RQ1: What is the relation between spatial interactions and the spatial configuration of *logistics networks within an increasing consumer driven context?*

This dissertation thus focuses on how local spatial interactions shape the overall spatial configuration of the logistics network. This is done at two scales. In Part 1, a meso-level perspective is applied, studying the inter-firm relations between the whole logistics sector at the regional scale. Part 2 adheres a micro-level perspective, concentrating on relations between a subset of the sector and consumers at the urban scale.

1.4.1 Part 1: Inter-firm relations in the logistics network

Part 1 of this dissertation tackles the first key issue highlighted in section 1.3: the lack of quantitative analysis on the inter-firm network structure in the logistics sector. To reduce this gap in the literature, this dissertation attempts to describe the occurrence of horizontal linkages in the sector from a geographical perspective. More specifically, in this Part, the influence of the location of logistics companies on the inter-firm relations between them is studied. This essentially boils down to the question whether agglomeration advantages (i.e. economies of scale and network effects due to co-location) occur within the logistics sector. The first sub-question of this dissertation is therefore:

RQ1.1a: To what extent does co-location in the logistics sector imply the presence of inter-firm relations?

The proposed study to answer this question is novel in the sense that similar questions have been posed only in more traditional economic sectors. Raising this question now for the logistics sector as well demonstrates its recognition as a structural and independent part of the economy.

The study of economic clusters implies an assumption of an uneven geographical distribution of logistics activities. In parallel with the conclusions of other quantitative geographers, this heterogeneity within the network results from nodes of differing hierarchies (Johnston et al., 2018). Hence, the next step in reaching the research objective is the identification of hierarchical structures within the inter-firm network. Resultantly, the second sub-question is:

RQ1.1b: Is there a hierarchical structure present in the inter-firm network of the logistics sector?

Finally, Part 1 further contributes to the existing literature in the field of Economic Geography by applying methods from the field of Network Science. Geographical attention to flows and networks is not new (Castells, 1996; Sassen, 1991) and the *relational turn* in thinking of spaces is already a couple of years behind us (Jones, 2009). Yet, few network analyses exist in the field of Economic Geography and especially the application of complex network analysis in a geographical context is novel. This is certainly the case in quantitative research on agglomeration advantages. Most studies on the topic observe co-location and derive the occurrence of inter-firm relations from that observation, although this is not necessarily the case (Benneworth et al., 2003). Hence, a quantitative network analysis focusing on the inter-firm relations themselves significantly contributes to the existing literature. Because of the size and type of the available data, methodological inspiration is drawn from the field of Network Analysis. The use of such is analysis is critically assessed in this dissertation. Resultantly, a third sub-question concerning the methodology is formulated:

RQ1.1c: What is the added value of complex network analysis in an Economic Geographical research context?

1.4.2 Part 2: Changing consumer demand

In Part 2 this dissertation shifts scales by focusing on the relation between the logistics carrier and the consumer, and its impacts on urban areas. The advent of the internet as a new retail channel with the offer of home deliveries increased the interaction between the end consumer and the logistics sector. This only intensified the consumer-driven focus that started two decades ago. In section 1.3 it is argued that e-commerce settled the consumer as an integral part of the distribution process of consumer goods and hence influenced the spatial configuration of logistics networks. The objective of Part 2 is to support this claim. The first step to reach this objective is to study the online consumer, which results in the following fourth sub-question:

RQ1.2a: What is the geography of the Belgian online shopper?

The understanding of the e-commerce consumer paves the way to study his impacts on logistics operations and resulting changes to the spatial configuration of the logistics network. Resultantly, the fifth and final sub-question of this dissertation is:

RQ1.2b: How is the integration of the consumer within the logistics chain shaping the spatial configuration of the logistics network?

Part 2 of this dissertation conducts a mixed method methodology, combining exploratory spatial data analysis (ESDA) - the quantitative study of location data - with qualitative research methods. Although the application of spatial analysis within the urban logistics community is limited (Ducret et al., 2016), the methodology is slowly gaining popularity (e.g. Morganti et al., 2014a; Motte-baumvol et al., 2017; Rodrigue et al., 2017). The methodology is applied to highlight the role of the consumer and hence fill the gap created by his absence in most urban logistics research (cf. 1.3). Hence, the major contribution of Part 2 is the application of an integrative approach that pays more attention to the role of the end consumer.

1.5 Reader's guide

The crucial role of logistics within our welfare-economic system was sketched in the preceding Sections. This is especially the case in Belgium, the study area of this dissertation, with its central location in the heart of Western Europe and connected to all major road, rail and water transportation axes. With an estimated share of 7.6% of total Belgian GDP for the sector's activities and in-house logistics (i.e. logistics activities in companies not included in the definition in Section 1.2.1), the sector contributes slightly more to the national economy compared to the European average (7.08%) (European Commission, 2015). The international importance is reflected in the country's third place on the Worldbank's Logistics Performance Indicator due to its overall good performance on the six indicators: customs, infrastructure, international shipments, timeliness, logistics competence and tracking & tracing (The World Bank, 2018). Moreover, the northern part of the country is one of the 44 global city logistics regions that handled half of the worldwide air freight and two thirds of total sea freight in 2006 (O'Connor, 2010). Hence, the country is a key player in international logistics chains.

Yet, like everywhere, the Belgian logistics system is equally confronted with the evolutions drawn in this introductory Chapter. The outlook of further (urban) population growth and freight fragmentation demands effective actions to achieve a sustainable logistics system that remains competitive in the future. Especially given that currently already 83% of the population lives in urban or urbanized areas (Dijkstra and Poelman, 2014; Statistics Belgium, 2014) and Belgian's nebular structure is suffering increasingly from traffic congestion (TomTom, 2017).

By answering the research questions described in the previous Section, this dissertation aspires to provide novel insights on spatial interactions in the logistics sector. These insights should support the stakeholders involved to prepare for the upcoming challenges. As mentioned before this is done by studying the sector at two different scales. This dissertation starts by focusing on inter-firm relations at the national level. Chapter 2 discusses the occurrence of these relations within logistics clusters in Belgium, by studying them together with co-location. Co-location is measured by means of traditional indicators of concentration on the employment in the sector. The inter-firm relations are captured by a large microeconomic dataset of buyers-supplier linkages, provided by the National Bank of Belgium. Due to their complexity, methodological inspiration is drawn from the network science literature. More specifically, a community detection algorithm, i.e. the *Louvain* method, is applied. The combination of quantitative analyses on both co-location and inter-firm relations serves well to identify the *spikiness* of the logistics landscape in the country. The results show that geography also matters in this spatially scattered sector. In addition, the study of spatial interactions demonstrate how logistics centers can be a dynamo for the wider economic system, ands hence provides an answer to sub-question 1.1a.

Chapter 2 highlights that geography matters in the Belgian logistics system, i.e. that this system is not just homogeneously distributed over the country. Yet the analysis focuses on the role of the most important nodes and ignores the majority of the underlying variety. Chapter 3 dives deeper into the inter-firm network to explore this variety in more detail. The same community detection algorithm as in the first case study is now iterated at three levels to uncover the hierarchical structure in the network. An additional parameter, i.e. the *damping value* as proposed in Grauwin et al. (2017), is calculated to understand the role of each node individually in the overall network. This Chapter addresses sub-question 1.1b.

The choice for network methodologies stems from the complexity of the dataset of inter-firm relations. The application of such methods within the presented geographical research allows this dissertation to formulate a substantiated answer to sub-question 1.1c. By doing so, it makes a significant contribution to the quantitative geographical research field. Even when the ambiguity of some of the outcomes may prevent widespread use within similar studies.

Part 1 highlights specific regions, mostly cities, as important nodes within the Belgian logistics network. Given the increased concerns on the future livability of urban areas, Part 2 shifts scales to understand what is going on inside these important nodes. This is a triple shift, i.e. in terms of the geographical focus, the type of interactions and the companies taken into consideration. First, instead of studying how a national dataset of interactions shapes the configuration of the logistics network at the scale of the country, the focus now lies on how interactions are influencing the organization of logistics infrastructures within a city. Second, while inter-firm relations were the topic of Part 1, Part 2 considers the relations between the sector and the end consumer. Because the end consumer is often not the customer of the logistics sector (recall Section 1.2.1), these linkages are inherently different from the ones studied in Chapters 2 and 3. Third, the shift in scales reflects the rise in online parcel deliveries that is currently challenging a specific subset of the logistics sector: the courier, express and parcel (CEP) sector. This subsector forms the topic of Part 2 in contrast to the whole logistics sector in Part 1.

To understand how the consumer is interacting with the logistics sector, one first has to understand him or her. Chapter 4 therefore studies the socio-economic and geographical characteristics of this consumer and hence answers sub-question 1.2a. The socio-economic characteristics are analyzed by means of a yearly survey conducted by the Belgian retail federation Comeos on the online shopper. These results are then translated geographically to assess how certain locations generate a different demand for e-commerce goods compared to others. The spatial unit of this Chapter is the statistical sector, which is the most detailed administrative unit in Belgium. The choice for this unit was based on the observation of neighborhood-level variations in parcel deliveries.

After understanding the consumers, Chapter 5 sketches how they are impacting the geographical configuration of logistics networks in cities. The Chapter starts with summarizing the wide variety of urban logistics spaces that are necessary to fulfill the demand for online orders. The case of the proliferation of collection-and-delivery points in and around cities is used to demonstrate the impact of this evolution. In contrast to the other Chapters, Chapter 5 applies a qualitative methodology and summarizes the findings of four years of interviews, presentations and workshops.

Chapter 6 finally provides an overall conclusion of the work conducted in this dissertation. This conclusion relates to the research questions posed in Section 1.4. It will further highlight the implications of this work, not only for academics but for public and private sector stakeholders as well. In addition, Chapter 6 draws perspectives for further research.

Geography is central in each of the Parts, yet from different perspectives (Figure 1.4). The questions raised in Chapters 2 and 3 are situated at the interface of Economic Geography and Transport Geography. The former is focused on the location of economic activities, the latter is concerned about the organization of movements of people, goods and information. As mentioned, methodological inspiration is drawn from the network science literature to study the rich dataset of buyer-supplier linkages within the logistics sector.

The inspiration for the last two Chapters comes from the field of Urban Logistics. As has been mentioned above, this field of study is concerned with the sustainable organization of logistics activities in urban areas. In this context, the increase in online shopping and resulting fragmentation of urban shipments is receiving particular attention. Yet, an integrated geographical approach has been missing up to now. By discussing the findings on online shopping behavior from a transport perspective, Chapter 4 situates itself at the intersection of the fields of Retail and Transport Geography. Finally,

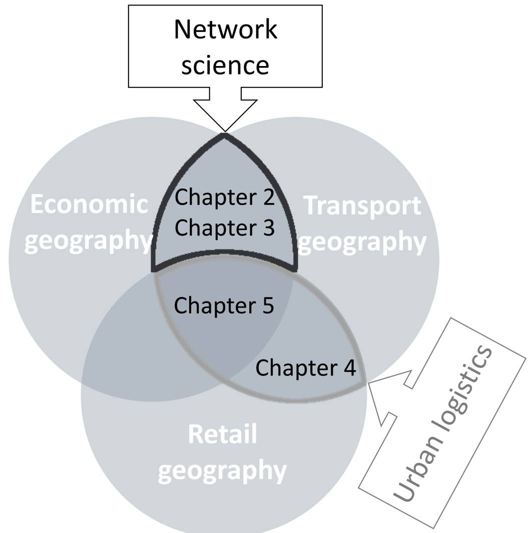

Figure 1.4: Thesis outline

Chapter 5 integrates all different perspectives applied in this dissertation.

2

Logistics clusters, including inter-firm relations through community detection

This Chapter studies clusters in the logistics sector. Like traditional cluster research, indicators of concentration to detect co-location of employment are calculated. However, this approach is enhanced by including a quantitative analysis of the inter-firm relations between logistics companies through the use of a community detection algorithm on a microeconomic dataset of buyer-supplier relations.*

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2.1 Introduction

Inter-firm relations and proximity are central topics in the economic geography literature (Giuliani, 2010). The geographical clustering of firms in the same or related industries is explained using the concepts of localization and urbanization economies. The presence of a dedicated infrastructure, a specialized labour market, easy communication and knowledge exchanges and a network of buyers and suppliers at their doorstep provide agglomeration advantages (Marshall, 1890). Academic scholars and policy makers promote these clusters as the ideal spatial organization of economic activity due to these agglomeration effects (Martin and Sunley, 2003). Well documented examples of economic clusters are the information and communications technology hub in Silicon Valley (Bresnahan and Gambardella, 2004), the engineering cluster in Baden-Württemberg, Öresund medical cluster (Lundequist and Power, 2002), and the Aerospace Valley in Toulouse (Levy and Talbot, 2015). However, most of the cluster literature up till now uses a qualitative methodology. When a quantitative approach is used, the focus is mostly limited to measuring co-location of firms. Although Benneworth et al. (2003) already note that the presence of one cluster characteristic (e.g. co-location) does not imply the existence of another (e.g. inter-firm relations), most of the cluster studies do not measure linkages when discussing the network's structure but limit themselves to analyzing geographical concentrations of employment. While this can be explained by a lack of data, it remains imprudent to derive the existence of relations from the presence of spatial concentration (Benneworth et al., 2003; van den Heuvel et al., 2014a). The objective of this Chapter is to study co-location as well as inter-firm linkages in the Belgian logistics industry. This by identifying concentrations of employment as well as by analyzing the geographical patterns of buyer-supplier linkages. There has been strong criticism on the lack of clarity of the term cluster (Martin and Sunley, 2003). The lack of clear sectoral and geographical boundaries and the confusing use of different terms like agglomeration, concentration, industrial district and cluster for similar concepts underlines the problem. This Chapter will stick to the concepts as presented in Figure 2.1.

The study of logistics clusters is relevant given the argument the sector drives economic growth in the region (Hesse, 2008; Rivera and Sheffi, 2016; Sheffi, 2012). Despite its key role as facilitator and han-

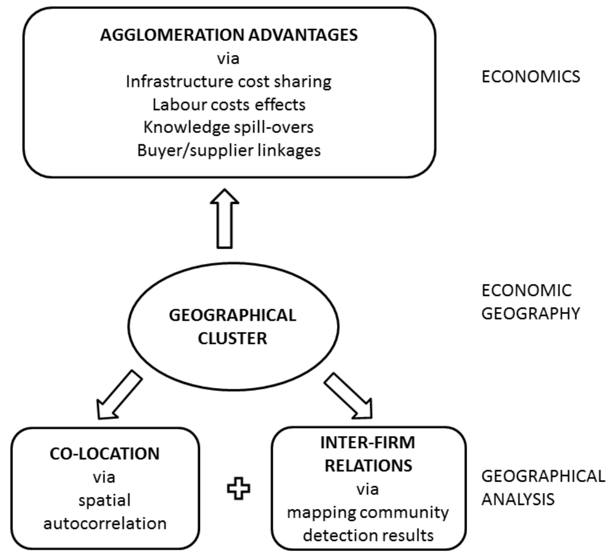


Figure 2.1: Conceptual scheme

dler of goods and related information in different value chains, the influence of globalization processes and a shift towards global standardization in the logistics industry has not ruled out the importance of regional characteristics (Akyelken and Keller, 2014; van den Heuvel et al., 2014a; Verhetsel et al., 2015). Research has put attention on the (uneven) geographical pattern of logistics activities and several studies discuss the importance of agglomeration advantages by demonstrating the existence of logistics clusters. However, a quantitative approach including the analysis of both co-location and inter-firm relations is missing up till now. In addition, a differentiation through cluster characteristics can lead to a more varied typology than a simple cluster/non-cluster division. Logistics companies act as intermediaries that connect all stages of the supply chain. The heterogeneity of logistics firms, however, makes that neither a consistent nor a standardized notion of logistics exists (Verhetsel et al., 2015). For the purpose of the present study, all kind of logistics plants are included: as well those dealing with material flows as those managing the services. This is a quite heterogeneous group of firms ranging from economic activities in peripheral large industrial warehouses to services in inner-city offices.

In the following sections, an overview of the cluster literature from the past 25 years is sketched. The focus lies on the need for a typology of clusters. In Section 2.3, the methodological steps taken in this Chapter are listed: the use of traditional indices of agglomeration and of graph clustering methods. Section 2.4 introduces the available data for Belgium and provides the results in order to study the spatial configuration of the logistic sector. Finally, Section 2.5 provides a typology of logistics concentrations based on the results of the empirical analysis. It constitutes a comparative framework for further research in other regions. The Chapter ends up with concluding remarks and directions for further research.

2.2 Literature on clusters, identifying clusters and logistics clusters

The creation of clusters or regional specialized valleys has become an appealing policy strategy after the re-introduction of the cluster concept by Porter in the 1990s. Besides the more theoretical work on clusters (Bathelt et al., 2004; Martin and Sunley, 2003; Porter, 1998), the strong interest and increasing funds resulted in a flow of both quantitative and qualitative research on the agglomeration of economic activities. Most of these studies limit their focus to the co-location of firms and/or employment, measured by the calculation of an aggregated value. An example is the work of Bertinelli and Decrop (2005) that assesses the concentration of manufacturing plants for several industrial sectors in a range of countries in Europe (Bertinelli and Decrop, 2005; Barrios et al., 2009). Similarly, Duranton and Overman (2005) calculate agglomeration by comparing the spatial pattern of several industries in the UK. Further, many more case studies combine several measures of co-location, all to prove the occurrence of clustering in space (Arbia, 2001; Riguelle et al., 2007; Rivera et al., 2014; van den Heuvel et al., 2012). Yet, while inter-firm relations are a crucial characteristic of clusters leading to the Marshallian externalities, very few cluster research includes the analysis of the inter-firm relations.

Notable exceptions are the work of Bell (2005) who uses social network techniques to analyse inter-firm relations at the management level. Balland et al. (2012) explain the importance of geographical proximity of companies in the gaming industry by pointing to the 'local buzz' and the increasing technological complexity that demands strong inter-firm relations. Others investigate as well co-location patterns as a-spatial input-output datasets to define agglomeration of related industries (Porter, 2003; Ellison et al., 2010; Delgado et al., 2010, 2016). Most often inter-firm relations are supposed to result from co-location without empirical evidence derived from the actual study of inter-firm relations itself. For example, Delgado et al. (2016) state that they derive inter-industry linkages *through the co-location patterns of industries across regions*. Other authors, like Hoffmann et al. (2015), are more cautious and explicitly mention the inability to study the buyer-supplier linkages. The main reason for the omission of inter- and intra-industry trade data in cluster studies is due to their limited availability, especially at subnational spatial units (Hoffmann et al., 2015; Martin and Sunley, 2003).

Although research indicates that economic activities are indeed clustered and that clusters provide at least a part of the advantages expected from agglomeration theory, research on the variety of clusters remains scarce. Markusen (1996) identifies, in addition to the Marshallian agglomeration, three other types of industrial districts, based on the varying roles of firms within the districts, and the orientation of the linkages amongst them: hub and spoke districts, satellite platforms and state-anchored districts. The author does mention several examples for each type, but the research lacks empirical demonstration of the findings. In Sweden Lundequist and Power (2002) classify clusters based on the policy process and vision that has led to their existence.

Although logistics have long been perceived as a consequence of the production process, i.e. as a derived demand (Hesse and Rodrigue, 2004), the actual extent of logistic activities inspire the proposition that logistics clusters, like industrial clusters, enjoy advantages from concentrating activities (Sheffi, 2012). Besides the mentioned agglomeration advantages for companies, logistics clusters are also considered as an important generator of employment and stimulus for growth in other economic sectors (Rivera and Sheffi, 2016; Sheffi, 2012). This partly explains why governments promote their country, region, province or municipality as a logistics cluster, in many cases despite the absence of empirical evidence for their claims (Flämig and Hesse, 2011; Hesse, 2015). But in other cases, the assumed opportunities of logistics clusters have led to the application of cluster research on the co-location of logistics activities. van den Heuvel et al. (2014a,b, 2016) calculated the co-location of logistics companies, but because of a lack of data the inter-firm relations are only analyzed with a qualitative approach.

In contrast to previous studies, a microeconomic dataset of buyer-supplier linkages between the Belgian logistics companies was available for this study. This provides the opportunity to not only measure co-location, but to also empirically analyze the inter-firm relations in the logistics sector. This way, the present Chapter identifies economic clusters in a more comprehensive way. The use of a community detection algorithm for this purpose is to our knowledge novel.

2.3 Identifying clusters: integrate both co-location and inter-firm relations

2.3.1 Measuring co-location: indicators of spatial association

There exist a large number of different indicators to measure spatial concentration. These indices can roughly be divided into two categories: a-spatial and distance based (van den Heuvel et al., 2012). First, the a-spatial measures provide a global index of agglomeration for the entire study area under consideration. Examples are the index of Ellison and Glaeser (1997) and the locational Gini coefficient (Krugman, 1991). The latter is here calculated by comparing the employment share in a specific industry with the spatial unit's share of total employment. A value of 0 implies no spatial concentration (total dispersion) while 0.5 points to the opposite. Nevertheless, this category of measures offers no information about concentrations within specific areas. In addition, the estimated concentration score depends on the spatial units (MAUP), making comparisons difficult (Duschl et al., 2015; van den Heuvel et al., 2012).

The second category of indices are distance-based agglomeration metrics, offering the opportunity to identify areas of higher concentration within a study area. The most popular is the Moran's I statistic. This measure calculates the spatial autocorrelation in a study area based on a spatial weights matrix that represents the geographical relationships between the spatial units. These weights can be calculated from a pre-defined number of neighbors, from a contiguity measurement that takes all neighbors into account, or by including only the values of spatial units within a threshold distance. Spatial autocorrelation is positive and high if spatially related units have similar values for a variable, e.g. logistics employment. A Moran's I of 1 indicates perfect spatial autocorrelation, -1 is perfect dispersion and 0 is a random distribution of the value of analysis (Arbia, 2001; Ding and Fotheringham, 1992).

The Local Indicator of Spatial Association (LISA) is further computed to analyse the local contributions to the Moran's I statistic (Anselin, 1995). This index calculates spatial agglomeration values for each spatial unit separately. The resulting Moran's I scatterplot consists of four quadrants that correspond to the four types of spatial association: High-High (HH), High-Low (HL), Low-High (LH) and Low-Low (LL) (Anselin, 1995). Values in the HH quadrant thus represent spatial units with high values for the studied variable surrounded by units with similar (high) values, i.e. concentration. LL values correspond to units with low scores for the variable in question, situated in an area characterized by overall low scores. The HH spatial units identify concentrations, i.e. co-location.

2.3.2 Measuring inter-firm relations: community detection within networks

Networks can be described as a series of nodes that are interconnected by links, the strength of a link between two nodes is called the weight. A quantitative approach to networks in social sciences is not new. Already since the 1930's, social network analysis has been an important research strand in the field op sociology (Scott, 2000). Grown as a tool to describe the role of individual nodes in social networks, scholars frequently apply the methodology to study power relations, e.g. through the calculation of centrality measures (Scott, 2010). Similar applications can be found in logistics research, with a particular focus on the organizational structures of supply chains (Carter et al., 2007; de Camargo Junior et al., 2012). In economic clustering research bridges (i.e. important connectors), structural holes and other measures are used to describe the structure and evolution of inter-firm networks (Ahuja, 2000; Gluckler, 2007).

An industry's network consists of a myriad of financial (buyer-supplier), material and information flows, strongly distributed amongst different scales. Such a network is the result of a history of microeconomic behaviors that led to emergent macro structures and adaptive behavior of the stakeholders involved, e.g. public and private actors. As a result, the combination of local, regional, national and international flows complicate the delineation of the network's borders. Given these characteristics, it is fair to approach such network as a complex system (Martin and Sunley, 2003). In a first step of this research, a social network analysis was conducted on the available dataset of over 800,000 inter-firm linkages. Yet, the complexity of these big datasets limits the interpretation and performance of such methodology. Moreover, the aim of this study was not to look at the role of individual nodes, but to look how groups of nodes interact. An appropriate way to investigate such characteristics in complex networks is by using community detection algorithms.

In random networks, nodes and links are homogeneously distributed. Observed networks are almost never random but are characterized by groups of nodes with higher link densities. These groups of nodes are here referred to as 'communities' and are important entities in the complex network (Fortunato, 2010; Newman, 2003). Their influence on the behavior and structure of the encapsulating network has already attracted a fair amount of academic attention. As such, community detection methods are often used to understand and visualize the organization of such complex networks (Lancichinetti and Fortunato, 2009; Newman, 2004; Porter et al., 2009). In this dissertation I apply the 'Louvain method' proposed by Blondel et al. (2008). This algorithm groups the nodes in a network by optimizing the modularity gain. A first reason to recourse to this particular method is its speed. Because the method optimizes the modularity calculation instead of calculating it exactly, it is particularly useful for large datasets. A second reason is its strong performance in a comparative analysis of popular community detection algorithms (Lancichinetti and Fortunato, 2009). The final reason is its widespread application in the literature. Examples include Lancichinetti et al. (2011) who simplified a social network dataset with nearly 20 million nodes and 300 million edges, Blondel et al. (2010) who applied the method on telephone data, Tranos et al. (2015) on migration networks and Croitoru et al. (2014) on social network groups.

The use of the Louvain method also comes with a set of limitations. First, one has to note that the results depend on the order of the input data. This means that several iterations have to be run before robust results can be presented. For all our analyses, 100 iterations were applied. To visualize the summary of the hundred runs, each node is classified in its major community. Areas corresponding to nodes with a membership value of only 50-75% are indicated by dashes on the maps. Second, being a modularity-optimization approach, the detection of communities tend to operate at a coarse levels preventing the formation of small communities (Fortunato and Barthelemy, 2007). An adapted Louvain algorithm to cope with this resolution limit exists, but demands prior knowledge on the network structure (Delvenne et al., 2013). This issue is however tackled in the Chapter 3.

The Louvain method only groups nodes that are strongly linked. In order to obtain a deeper insight into the role of individual nodes in the network, the within-module degree z and the participation coefficient P, defined by Guimerà and Amaral (2005), are computed. The within-module degree z estimates how well connected a node is to the other nodes in its community. A high z value indicates that the node is well embedded in its cluster, i.e. it contains many internal links. The participation coefficient P, in turn, indicates how well-distributed the node's links are across the other communities. Values close to 1 mean that the node's links are uniformly distributed among the other clusters, a value close to 0 indicates that the node's links are almost all within the cluster. The combination of both parameters determine the role of the node in the network, seven types of regions (Table 2.1) are defined by Guimerà and Amaral (2005). Ultra-peripheral and peripheral nodes lie at the periphery of the network, with few connections to other nodes. Non-hub connector nodes are already better embedded in the overall network, however, their relative low z-degree indicates a low importance in the local community. Next non-hub kinless nodes are better connected with nodes outside their community then with nodes within their own community, this can point to a wrong classification of the nodes. Provincial hubs are characterized by a very few external connections combined with a high within-module degree z (i.e very well connected internally). Connector hubs are important nodes in a network, tying nodes in a group together and connecting the group to other communities Finally kinless hubs are almost equally connected to the whole network and thus do not enforce local communities.

In this Chapter the Louvain method is used to detect communities within the buyer-supplier network of logistics firms in Belgium. Subsequently the calculation for all nodes of the within-module degree and the participation coefficient allows the mapping of the node's role in order to grasp the geography of the Belgian logistics buyer-supplier network. Finally, the results of the measurements of the co-location of employment on the hand, and of the tightness of zip codes based on their inter-firm relations on the other are combined in a typology of logistics clusters in Belgium. The spatial scale of

Table 2.1: Parameters of node connectivity in a network (Guimerà and Amaral, 2005)

Node role	Within-module degree z	Participation coefficient P
Ultra-peripheral nodes	<2.5	<0.05
Peripheral nodes	<2.5	0.05<P<0.62
Non-hub connector nodes	<2.5	0.62<P<0.8
Non-hub kinless nodes	<2.5	>0.8
Provincial hubs	>2.5	<0.3
Connector hubs	>2.5	0.3<P<0.75
Kinless hubs	>2.5	>0.75

the clusters is thus not the individual firm level, but that of the spatial units used.

2.4 Logistics clusters in Belgium

2.4.1 Data: employment statistics and buyer-supplier linkages of Belgian logistics companies

This Chapter uses the classification defined by the National Bank of Belgium to identify logistics firms. These firms are not only transportation companies but concern also storage and warehousing and other supporting transport and logistics activities (Lagneaux 2008, cf. Figure 1.1). Two different datasets are used to measure geographical clustering of Belgian logistics. First, in Section 2.4.2, co-location in the logistics sector is calculated using the employment in full time equivalents (FTE) per municipality in 2010 provided by the Balanscentrale (Central Balance Sheet Office) of the National Bank of Belgium (NBB) (https://www.nbb.be/en/central-balance-sheet-office). Second, in Section 2.4.3, a dataset is provided by the NBB of more than 800,000 buyer-supplier linkages in the logistics sector in 2011 to analyze the inter-firm relations. It concerns micro-economic data derived from the invoices between companies where either the buyer and/or the supplier is a logistics company. For reasons of anonymity the linkages are aggregated at the zip code level, of which there are 1155 in Belgium, which allows to conduct a detailed geographical analysis. The average size of a zip code in Belgium is 27km^2. Some zip codes have no interaction, while the highest frequency is observed within Antwerp with over 10,000 buyer-supplier linkages. Besides the linkages that occur between two logistics companies, e.g. an invoice from a transport company to a freight forwarder, the wholesalers and retailers are the largest provider and receiver of services and goods from the logistics sector when comparing the overall industrial groups. When looking at a more refined level, most of the service providers are related to the sales or maintenance of vehicles. Most frequent customers are farmers, construction companies and machinery vendors. One hypothesis for this observation is the specific transport and storage requirements these categories demand because of the exceptional sizes of the items (e.g. tractor, building material).

The use of these heterogeneous buyer-suppliers linkages to measure agglomeration advantages is not straightforward. First, the inclusion of non-logistics buyers and suppliers may blur the image of a logistics cluster. Yet, an economic cluster is not only characterized by a high concentration of activities within the same sector, but also encompasses the presence of related industries. As such, the presence of vehicle services, which are the most prominent non-logistics suppliers in the dataset, near a concentration of logistics activities is a prime example of an agglomeration advantage. Second, despite the significant amount of non-logistics companies in the inter-firm linkages, the majority of the flows do consist of logistics-logistics linkages, ensuring their principal role within the analysis. Because of this reason, a high geographical density of the heterogeneous buyer-supplier linkages is assumed to represent agglomeration advantages and can result in clustering.

The dataset contains only buyer-supplier linkages with their origin and destination within the Belgian territory. This might seem a limitation, but as the main interest is to identify the logistics clusters within Belgium the data are sufficient. It is clear that considering the international linkages could have generated in some places different patterns. This would be the case in places with many international exchanges, such as the big cities and major (air)ports. Another drawback of the data is the allocation of all linkages of a firm to the zip code of the headquarter, this leads to an overestimation in especially urban areas where generally more head offices are located (this is also the case for the employment data). But as nearly 170,000 unique firms in total, of which more than 83,000 unique logistics companies are involved, one can observe that the logistics sector in Belgium still has a lot of small and medium sized companies which have their headquarters on the location of the actual activities. Therefore, the data seem appropriate to calculate co-location and inter-firm relations.

2.4.2 Global indices of logistics employment

The locational Gini coefficient is reported in Table 2.2 and compared to two studies (Guillain and le Gallo, 2010; van den Heuvel et al., 2012) in the same field. With a value of almost 0.3, the Gini coefficient gives a first indication of the concentration of logistics employment in Belgium. This result is comparable with the results found in the province of North Brabant and – to a lesser extent – in Paris and surroundings. However, these comparisons have to be interpreted with caution since there exist spatial differences among the three datasets. First, while Belgium is six times larger than North Brabant, its size is only 40% the size of Ile-de-France and its surroundings. In addition, the average spatial unit size is much larger in Belgium than in both other studies. In the case of local concentrations, a larger size of the units will probably lead to an underestimation of the locational Gini coefficient. It is thus possible to assume that the first index of agglomeration indicates at least a similar level of concentration in the logistics sector in Belgium.

Table 2.2: Locational Gini coefficients

Region	Locational Gini coefficient	Spatial unit	Average spatial unit size (km²)	Size of study area (km²)
Belgium	0.2991	Municipality	52	30,528
Province North Brabant (NL)	0.2984	Zip code	15	4,919
Ile-de-France and surroundings (F)	0.3797	Municipality	10	77,976

Source: own calculations and van den Heuvel et al. (2012); Guillain and le Gallo (2010)

The different Moran's I calculations are given in Table 2.3, these were calculated on the employment density per municipality to partially correct for the effects of the delineation of municipalities. With an average value of 0.4, the Moran I supports the idea of agglomerations of municipalities with higher

Table 2.3: Moran's I for different spatial contexts

Spatial context	Moran's I	p-value
contiguity	0.43	<0.001
nn1	0.42	<0.001
nn3	0.42	<0.001
<15km	0.38	<0.001
<30km	0.32	<0.001

nn1 = municipality plus neighbor with longest common border
nn2 = municipality with the 3 neighbors with longest common border
Source: own calculations with data NBB

densities of logistics employment or co-location of logistics. In addition, the values show that the wider the spatial context, the lower the spatial agglomeration, this is an extra indication of local higher densities of employment.

The LISA is then calculated to disaggregate the Moran's I to the spatial units. The municipalities that are statistically relevant ($p<0.05$) are mapped in Figure 2.2. The map shows the logistics employment density in Belgium. One observes mainly co-location in the northern part of Belgium on the axis Antwerpen-Brussels, in the port areas of Gent and Antwerpen, around Kortrijk and Roeselare and near the Albert canal. In the southern part only in Seraing near Liège co-location is identified, most of the southern region is characterized by low employment per km^2 in the sector.

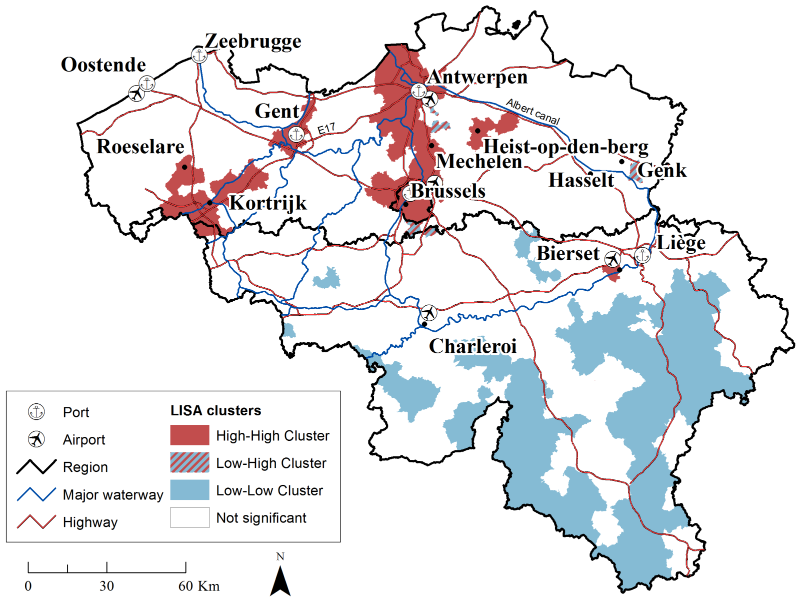


Figure 2.2: LISA map of employment density in logistics (contiguity spatial relation) (2010). Source: own calculations with data NBB.

2.4.3 Community detection in logistics buyer-supplier linkages

In order to find out if the local concentrations of logistics employment also imply more intense inter-firm relations, the buyer-supplier network is now analyzed. A community detection analysis is used to analyze whether some zip codes have more logistics buyer-supplier flows between them compared to other zip codes. Recall a flow between two zip codes is the aggregation of the total number of linkages between individual firms in both zip codes. The total number of linkages between firms in the same zip code, i.e. *internal flows*, are also included in the analysis. Figure 2.3 visualizes the amount of buyer-supplier linkages per zip code, the map shows a higher density of flows in the northern region between Brussels, Hasselt/Genk, Antwerpen and Kortrijk, including links to Liège.

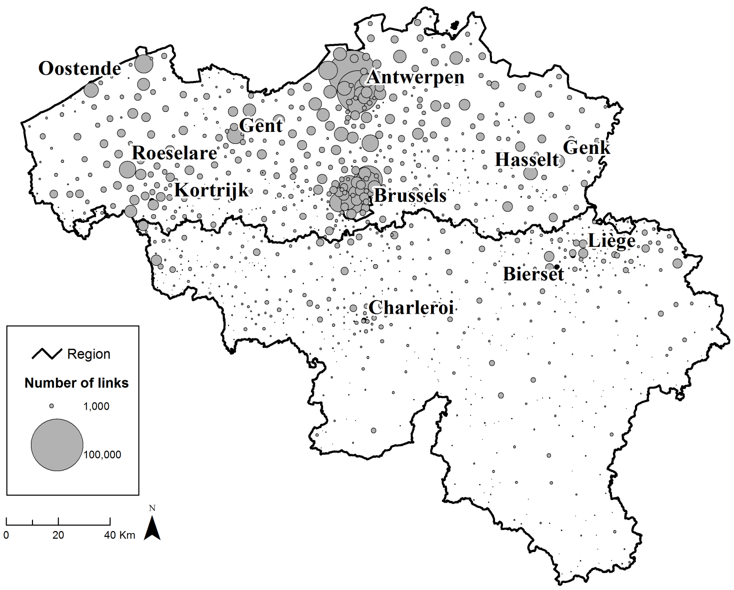


Figure 2.3: Total buyer-supplier linkages per zip code. Source: own calculations with data NBB.

Figure 2.4 maps the communities resulting from the runs of the Louvain-method on the logistics buyer-supplier network, optimizing the modularity of the overall network. Each community consists of a set of zip codes that are tightly connected with each other with buyer-supplier flows. Remark that the network analysis is non-spatial. This means that no spatial relation between the nodes is implied. In total seven major communities are found in Belgium, with an unexpected spatial contiguity (geography/proximity still matters!). Communities are delineated around the capital city Brussels in the central part, around the major cities Antwerpen and Gent that both are port-cities, in the east where the important Albert canal links Antwerpen with Liège, in the province in the west including Kortrijk and the port of Zeebrugge, around Tournai, and finally a stretched-out community in the southern part. The broad area around Charleroi is dashed, indicating there are alternative connections, mainly to the Brussels community. The community detection algorithm provides a delineation of the different communities, which include logistics clusters with their hinterland. The main cities and (air)ports have a major impact on the spatial structure of the communities. The community detection algorithm proves to be a useful tool for analyzing big data on complex networks since the high amount of link-

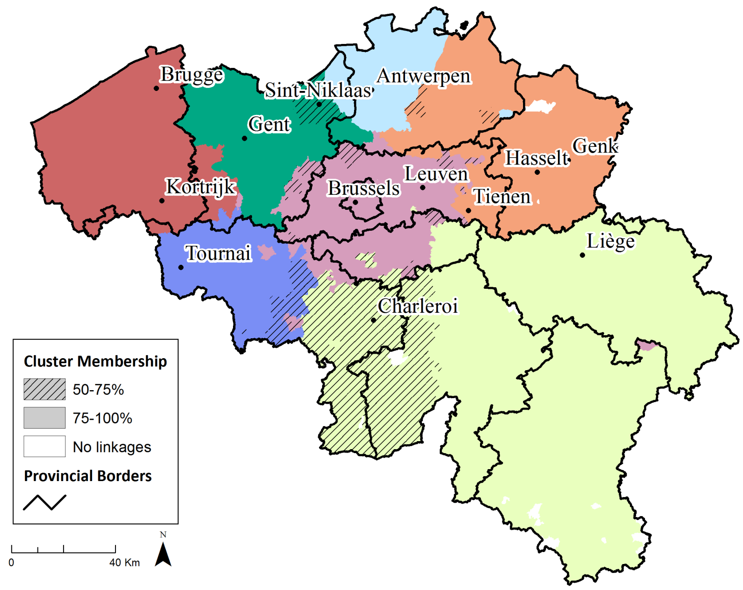


Figure 2.4: Communities in the buyer-supplier network. Source: own calculations with data NBB.

ages made it very hard to detect geographical patterns when analyzing the raw data in a traditional explorative way.

What is lacking is a good understanding of the roles of the different nodes in the various communities. In the final step the coefficients defined by Guimerà and Amaral (2005) are used to analyze the local and overall connectedness of the different nodes in the network. In Figure 2.5 each node is classified according to the z-P parameter space using Table 2.1. Appendix A shows details on the parameters for the nodes classified as connector hub or kinless hub (Table A.1). Especially the connector hubs are important for economic clustering as they tie the nodes together in the community and they make the connection to other communities. The kinless hubs are equally tied to the whole network and as such their role is less geographically localized. Central in the 'Brussels community' four zip codes are kinless hubs including the area around the national airport, the presence of many headquarters explains the many ties with the whole network; two areas in Brussels are connector hubs, these are known as main industrial regions. Other kinless hubs are found in Gent and Tournai. The Antwerpen port area clearly is a logistics center tying together the surrounding community and connecting to the rest of the network with an impressive amount of linkages. The ports of Zeebrugge and Oostende next to Roeselare are the clusters of the community in the west. In the northeast, Hasselt and Genk comprise the logistics cluster, next to two more smaller location with intense relations. Also in and around Liége a series of connector hubs can be found, they are linked to different industrial areas and transport terminals spread over the region. Further most of the nodes have z-vales under 2.5 combined with an average participation coefficient around 0.6, resulting in mostly peripheral and non-hub connector nodes. These nodes belong to the hinterland within the community, but are only loosely connected to the hubs.

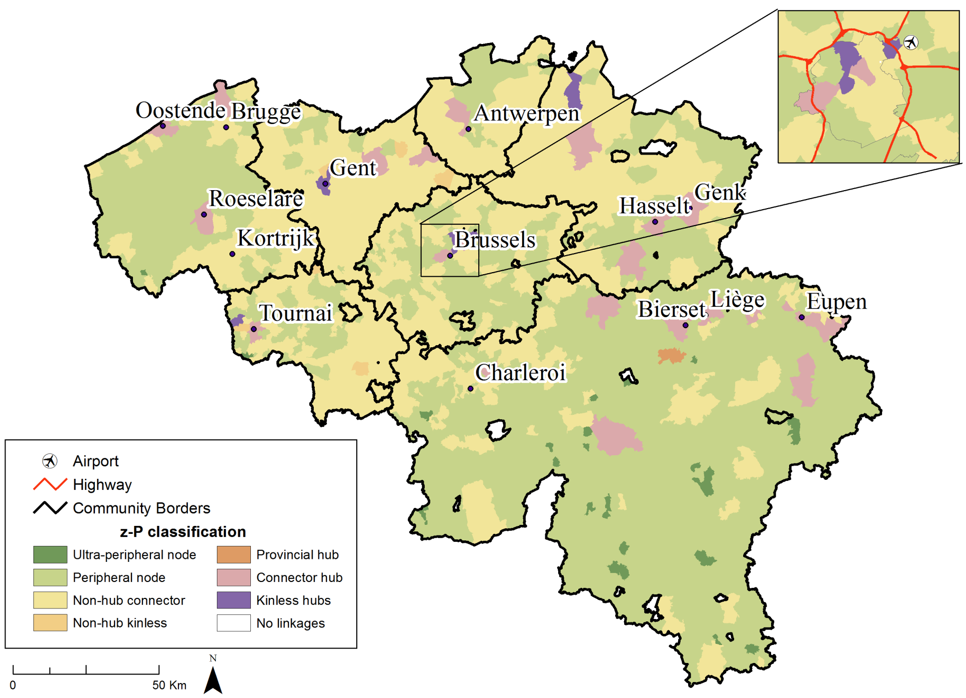
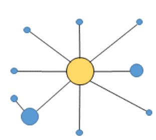
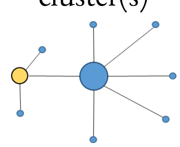
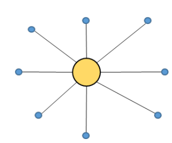


Figure 2.5: z-P parameter space of logistics communities in Figure 2.4. Source: Source: own calculations.

2.5 Discussion

The combination of the various indicators provides a synthesis of the complex network of logistics buyer-supplier relations within Belgium. The analysis of the employment values and buyer-supplier linkages prove that logistics activities are not just scattered over the country: spatial densities of both employment and inter-firm relations can be detected. Despite its labelling as 'dispersing across regions' (Porter, 2003), there remain geographical patterns in the structure of the logistics network (Hesse and Rodrigue, 2004). By using an approach similar to some authors who measure concentration by agglomeration indices (e.g. Guillain and le Gallo, 2010), the results of the LISA would be used to indicate logistics clusters. In that case, places like Kortrijk and Mechelen would be classified as logistics clusters, however these places have a within-module degree under 2.5, indicating a low importance within their community. The combination of traditional agglomeration indices and parameters from complex network analysis (Tables A.2 and A.3 in Appendix A), provides the opportunity to create a typology of logistics concentrations.

Table 2.4: Typology of logistics concentration

Indicators	Cluster	Cluster spillover	Polycentric cluster
LISA	High-High	High-High	High-High/N.S.
Within-module degree z	>2.5	<=2.5	2.5
Participation coefficient P	>0.3	>0.3	>0.3
Network structure	Hub and spoke	Linked to cluster(s)	Multi-point
Network configuration			
Examples	Antwerpen, Brussels, Gent, Roeselare	Mechelen, Kortrijk	Hasselt-Genk Liège-Bierset Oostende-Zeebrugge

Source: own composition

The nodes identified as clusters in Table 2.4 combine employment densities with tight buyer-supplier linkages. These clusters are the logistics clusters that are traditionally identified in studies by Rivera et al. (2014), Sheffi (2012) and van den Heuvel et al. (2012). They are characterized by significant higher concentrations of employment (high-high), strong connections to other nodes in their community (z-score > 2.5) together with a decent amount of links to other communities (P-value > 0.3). Topologically this results in a hub and spoke network with a center of strong employment and many local (i.e. within-community) flows, but well connected to the surrounding areas as well. Examples in Belgium are parts of the major cities Brussels, Antwerpen, Gent but also of the regional city of Roeselare, who serve as connector hubs for their regions in addition to the higher densities of logistics employment.

The economic strength of these clusters may lead to large inequalities between the core and peripheral regions. The strong core with its agglomeration advantages is more attractive to new players looking for a location. When these newcomers settle, the difference in attractiveness between core and periphery enlarges, further reducing the probability of new investments in peripheral regions. This self-enforcing process may lead to large core-peripheral differences. But the aforementioned process may also lead to congestion in the cores. New players may then prefer peripheral locations close to those cores as a reasonable alternative. These are local spill-over logistics clusters focused on the nearby big clusters and hence with weaker local relations. The latter is captured by lower z-values. Examples in Belgium are the region around Mechelen (mainly linked to Brussels) and Kortrijk (linked to Roeselare).

A third type of logistics clusters are the regions with several nearby concentrations, called polycentric clusters. Some of those regions may have significant concentrations of employment, but since the activities are spread over multiple locations the LISA can be non-significant. However, the concentration of logistics companies in those multiple locations serve via their buyer-supplier linkages as connector hubs for the region. Examples in Belgium of these polycentric clusters can be found in Hasselt-Genk, Liège-Bierset and Oostende-Zeebrugge.

While the logistics clusters in Antwerpen, Brussels, Gent and Roeselare would also have been identified using a traditional approach of only agglomeration indices, the methodology would have omitted or overrepresented other clusters. The polycentric clusters would not have been identified, the spill-over clusters like Mechelen and Kortrijk would have been classified like Brussels and Antwerpen. Remarkably, notwithstanding our quantitative geographical approach compared to the qualitative business approach from Markusen (1996), the clusters and spill-over clusters identified in Table 4 resemble very well her hub and spoke and satellite districts. This shows that her business approach can be verified quantitatively.

2.6 Conclusions

The outcome of this Chapter is a typology of logistics clusters resulting from the combination of both agglomeration indices and tools inspired by complex network analysis. The case of logistics in Belgium was studied through both quite accessible employment data and an innovative dataset of buyer-supplier linkages between logistics firms within the country. This provides a unique opportunity to analyze inter-firm relationships in combination with the already well documented co-location approach in order to detect geographical clusters. This chapter demonstrates the value of community detection techniques when working with big relational data in economic geography, mapping the outcomes of community detection provides a valuable tool for analyzing inter-firm linkages. The combination of studying both co-location and inter-firm linkages should give the fuzzy term cluster more depth in future research.

Logistics activities within Belgium are concentrated in some places and they are less relevant in others. Three different types of logistics concentrations are identified, providing a new typology of the logistics sector in Belgium. Concentrations of logistics employment that serve as the center of a large region are identified as clusters as discussed by Sheffi (2012). Related to these centers, spill-over clusters appear in the nearby hinterland. While they are also characterized by higher concentrations of employment, their relationships are mostly directed to a big cluster nearby. Finally, polycentric clusters act as a third type of logistics concentration, although characterized by a less prominent co-location, they do play an important in tying together the firms in the region and connecting them to the overall network. This cluster typology could be helpful in smart specialization strategies in order to detect possible regions for endogenous growth of the logistics sector. Especially since nowadays in Belgium logistics is a popular sector for public investments.

This Chapter demonstrates how inter-firm linkages can be studied in a quantitative way. Adding this information to the results of the co-location analysis brings us closer to the detection of industrial clusters. The spatial contiguity in Figure 2.4 indicates buyer-supplier linkages have a higher probability to occur between companies in each other's vicinity. This is coupled with the presence of a multitude of potential customers and suppliers in the clusters, given that it are mostly the concentrations of employment that form the centers of these communities. This observation demonstrates the presence of both cluster characteristics in the logistics sector in Belgium. Hence it is undeniable some locations exhibit clear locational advantages. The concentration and intense interactions will result in additional economies of scale like labour market pooling, cost advantages and knowledge spillovers. Antwerpen is a good example hereof, where close cooperation between the sector and the university led to specialized academic maritime programs and hence a direct influx in the labour pool. Yet, a more micro-economic analysis of the dataset could help to really quantify some of these Marshallian advantages. As such, it could be tested whether certain relations within the clusters are characterized by lower transaction costs compared to similar relations outside these clusters.

Moreover, little is known of the quality and sustainability of the identified clusters. No differentiation has been made amongst job categories, neither between different inter-industry linkages. This remains a limitation, especially from a cluster life cycle assessment perspective. The challenge therefore remains to link the observed cluster effects to specialization and knowledge spill-overs, which should be the subject of further research. In addition, it would be interesting to apply the proposed methodology to new cases in other economic sectors and regions and to include international relationships to assess their impact on the spatial structure

3

Returning the particular: understanding hierarchies in the Belgian logistics system

Geography clearly still matters in the Belgian logistics system. The spatial contiguity of the communities in Figure 2.4 illustrates the presence of a strong spatial component in logistics buyer-supplier linkages. The same contiguity however creates the illusion of homogeneity. Although the identification of different cluster types partly disentangles this illusion, the analysis of Chapter 2 is limited to the most important nodes. But what about the rest of the network? Are all zip codes in for example the Antwerpen community focused on the one central cluster? And how strong are the borders between these different communities? These questions are tackled in this Chapter.*

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3.1 Introduction

The questions concerning the heterogeneity of the network fit within a broader critique on the academic use of network analysis in geographical research. Like the previous Chapter demonstrated, network theory has become the standard methodology to frame, develop and analyze the newly available big datasets. In line with the critique of Schwanen (2016), it is argued here that initiatives confronting network-based insights with (qualitative) location- and domain-specific insights are necessary in understanding, discussing and advancing the role network analysis can play in geography.

Over the last decade, a long list of big data sources have emerged that give rise to a true data deluge when it comes to capturing spatial economic systems. Recent advances in information technologies now allow for the continuous, positional tracing of a multitude of objects. GPS technologies can equip and trace almost any object, from watches to airplanes, revealing the true extent of worldwide connectedness. Online social networks and smartcard data capture the movement of large-scale populations, credit card transactions enable to follow up on low-level economic transactions within and between territories, and mobile phone data are capable of capturing large-scale communication patterns.

Obviously, the availability of such big data sources has revolutionized the study of movement and interaction in spatial economic systems. A common demeanor in studies integrating these new data sources is their reliance on network theory as both a methodological and conceptual framework. With applications ranging from the mere description of structural network properties to the simulation of complex dynamics, it is more than fair to state that network methodologies have widely advanced the empirical understanding of massive datasets describing spatial economic systems. Advancements, for instance, have been made in understanding the structure of air transportation networks and their potential role in global epidemics (Colizza et al., 2006; Guimerà and Amaral, 2005); in detecting statistical properties of large-scale human mobility and elaborating their use in predictive models (Gonzalez et al., 2008; Simini et al., 2012; Song et al., 2010); or in uncovering the spatial extent of interacting communities, hereby challenging existing delineations of space (Blondel et al., 2010; Ratti et al., 2010;

Sobolevsky et al., 2013; Thiemann et al., 2010).

Despite the progress made, there has been a growing critique on the empiricist, positivist nature of big data and the related use of network analysis in geography (Graham and Shelton, 2013; Kitchin, 2013; Kwan, 2016). With respect to big data and network analysis in Transport Geography, Schwanen (2016) states that: *These methodological developments are to be welcomed because of ... their generative character... . At the same time, caution needs to be exercised for epistemological reasons. There is a risk that generality – regularities, laws, basic principles, ... - comes to trump particularity in the form of place and time specificity, uniqueness, singularity and also local knowledge again* (Schwanen, 2016, p2).

This Chapter deems this critique to be valid. The erasure of heterogeneity between observations by current network methodologies and their push for findings to be considered from a 'network internal perspective' only are discussed here. Although interdisciplinary discussion might be leading recent developments in network analysis to increasingly incorporate aspects of space, context and hierarchy, it is argued that initiatives confronting network-based insights with (qualitative) location- and domain-specific insights, which Miller (2018) terms *mesogeography*, are necessary in understanding, discussing and advancing the role network analysis can play in (transport) geography.

Specifically, this Chapter attempts to demonstrate how fruitful the confrontation between local knowledge and network-based insights can be. Therefore a recently developed network analysis tool as proposed by Grauwin et al. (2017) is applied here. This tool allows, for each node in a network and given a chosen community detection algorithm, the identification of its local, regional and national role and related connectivity. It is shown how the calculation of damping values in this method can be used to facilitate the confrontation with local insights and, by means of a case study on the Antwerpen region, how relevant such knowledge can be for understanding, in this case, logistics systems.

Ultimately, the benefits of establishing clear touching points between network methodologies and the typical local, spatial and qualitative knowledge of (transport) geography is clear. The proposed methodology offers a first step in the development of one such touching point, while pushing the discussion on the applicability of community detection in (transport) geography. It is argued that confrontations like this are beneficial for understanding, discussing, and advancing the role network analysis can play in Antwerpen.

3.2 The popularity of the network paradigm in geographical big data studies

The critique on the empirical and positivist nature of current big data practices, including network approaches, relates to a long history of reflection and debate on quantitative approaches within the geographical discipline (Graham and Shelton, 2013; Kitchin, 2013; Kwan, 2016; Schwanen, 2016), ranging from Haggett's reflection on his own pioneer book 'Locational Analysis in Human Geography' (Johnston and Sidaway, 2015), to numerous debates on the quantitative revolution, positivist approaches and, more recently, the role of GIS and the algorithmic treatment of big data (Goodchild, 1992; Graham and Shelton, 2013; Kwan, 2016). In other words, the rise of big data and the revival of network theory in Transport Geography do not necessarily represent entirely new 'threats'. Rather one can consider them as a next wave of quantitative analyses; this time being fueled by the emergence of new, different and bigger datasets, and the technical and methodological capabilities to treat them.

There is a lot to be said about the way this big data research and network analysis is integrating in current geographic scholarship, ranging from paradigm development to data-access inequality. However, one observation from Schwanen (2016) seems extremely relevant for this Chapter and, more in general, the field of Transport Geography. It is the observation that network science tends to erase heterogeneity and proposes differentiation solely based on characteristics of the network. Although explanations can be *imported from the outside* (for example by linking contextual information with connectivity measures), this approach heavily encourages explanations to be based on the network itself, leaving other perspectives sidelined. As such, the application of network science in Transport Geography is creating a reinforcing system that is *nudging geographers and transport researchers into adopting the internal network perspective* (Schwanen, 2016, p5).

This critique is easily illustrated by two widely used applications of network analysis in transportation geography: the analysis of degree distributions and the application of community detection algorithms, but is similarly relevant for other network applications and big data analytics that can be equally prone to the domination of an internal perspective.

A first illustration of the critique is in the analysis of degree distributions. Many real-world networks, including economic, transport, mobility and communication networks, are found to have power-law like distributions. Their study has allowed the identification of scaling in networks, which in turn implies the presence of a hierarchical structure, i.e. with nodes of different importance (Barabasi and Albert, 1999; Jiang, 2013; Levy and Solomon, 1997; Pumain, 2006). Degrees themselves, however, are merely (aggregated) connectivity measures, or thus structural properties of the network. This means that they possess little to no information about local context, except for the relative one defined in the network. As such, a large part of the heterogeneity amongst nodes is simply not considered which, consequently, makes it hard to approach the prevalence of degrees from another perspective than the network one. Insights from local context and processes, geographical differences, or spatial relations are hence all sidelined in favor of a, both methodological and conceptual, internal network perspective like, for instance, the popular preferential attachment growth model (Barabasi and Albert, 1999).

Second, the use of community detection algorithms forms a second illustration of the critique. Community detection on spatial interaction networks (be it transport, economic, mobility or communication networks) has gained popularity ever since it was shown to allow for empirical regionalization. Although initially surprising, it has now been well established that in many spatial interaction networks communities tend to form spatially homogenous and contiguous groups, highlighting the spatial component of their linkages (Blondel et al., 2010; Nelson and Rae, 2016; Ratti et al., 2010; Thiemann et al., 2010). The implicit erasing of heterogeneity in community detection algorithms, however, lies in the assumption that all links in the networks (often expressed as the aggregated intensity of interaction between locations) are equal, no matter their context of occurrence in real life. Additionally, the primarily retrieved information from community detection exists of which node was classified in which community often revealing little to no information on which roles individual nodes have played in the detection process, which position they take in the entire network, or the attributes that distinguish between them, either in the network or in reality.

It is rather easy to remark that both these elements stimulate false interpretations of homogeneity within detected communities, and of comparability between whatever interactions make up the links in the network. Moreover, and with respect to the typical spatially homogenous communities found in interaction networks, both elements contribute to the imposition of an internal network perspective that promotes the intensity of interaction (or thus the structure of the network) to be the (only) driver of regionalization. This is a very restrictive, even false, perspective as intensity of interaction is simply not the main driver of regionalization, nor is it the reason for the existence of empirically observed communities or does it explain the complex organizations of such communities. Here again, the point is that alternative reasoning is easily excluded from both the methodological and conceptual setup of the network approach.

The question then becomes how, as a Transport Geography research field, to overcome the imposition of an internal network perspective when adhering to network analysis. Two possible ways are distinguished, although more probably exist.

A first way is to stimulate the integration of geographical elements, like space, context and hierarchy in network methodologies. By now, such developments are well underway. To name a few, there is an expanding research field on spatial networks integrating spatial aspects like distance and position in network analysis (Barthelemy, 2010), multilayer, and especially multiplex networks, are allowing to differentiate between nodes and links on several levels instead of only one (Kivelä et al., 2014), and community detection algorithms have been well advanced to allow for overlapping communities and hierarchical structures (Fortunato and Hric, 2016). Somehow, however, it remains an open question whether these developments are influenced by interdisciplinary discussion between (transport) geography and network science, or rather from a next step in advancement of the latter. In other words, it remains to be seen to which degree the methodological developments in network science allow for enough depth to be applied to research questions and themes in Transport Geography.

A second way is for the field of Transport Geography to strive to confront, assess, reconcile and eventually appropriate elements of network analysis in its knowledge production. Appropriation done this way offers possibilities to critically asses network methodologies, challenge the hegemony of the internal network perspective and direct insights to themes that are of explicit interest in Transport Geography; all of which would advance the discussion on the role of network analysis in Transport Geography. To allow for confrontation in the first place, however, clear touching points between network methodologies and the typical local, spatial and qualitative knowledge base of Transport Geography need to be established. This requires, currently rare, case studies to be elaborated that embrace the inner workings of network analysis and show how their information can be coupled back to geographical knowledge.

Specifically, the interest in Grauwin et al. (2017) method lies in the possibility to extract information about the relation of all nodes to different hierarchical levels in the network. As such, information on hinterlands, the strength of borders, and the roles and relations with respect to the wider network can be retrieved for all individual locations. It is a huge opportunity to confront such information with (qualitative) location and domain-specific knowledge and elaborate the point made here based on a case study of a logistics buyer-supplier network in Belgium, with a focus on Antwerpen.

3.3 Methodology

Recently, Grauwin et al. (2017) proposed a network methodology to improve spatial interaction models, like the well-known gravity or radiation models. Their improvement exists in the replacement of continuous distance with a discrete distance denoting only the transgression of *hierarchical borders*. The prediction of flows between locations hence depends on the number of transgressions that needs to be made between two locations with each transgression diminishing the predicted amount of interactions. Interestingly, in their framework the rate at which each transgression diminishes the predicted interaction, or thus the strength of each border, is a network-based measure called “damping value” that is unique for each location. In other words, Grauwin et al. (2017) show how, at least for communication networks in different countries, a spatial interaction model that is based on a discrete, yet location dependent description of distance, outperforms standard interaction models.

Relating to the description of two possible ways to overcome the internal network perspective in previous sections, Grauwin et al. (2017)'s work clearly classify under developments in network methodologies that incorporate elements of geography, in this case being the heterogeneous experience of distance by different locations. Although the construction of damping values and their proof of usability in spatial interaction models is a remarkable feat, this Chapter goes beyond a mere replication of the methodology to another case. Rather, the interest lies in the way damping values, and their network-based calculation of individual locations, can be confronted with local geographical knowledge in order to stimulate discussion on their interpretational value. As such, this Chapter classifies under the second possible way described earlier; in which confrontation of insights is facilitated.

3.3.1 Calculating damping values

To calculate hierarchical borders, Grauwin et al. (2017) iterate a standard community detection algorithm on a given network. As each iteration groups tightly connected nodes in communities, the classification of a node in one community installs a border with all nodes classified in other communities. As such, in a first iteration, L_3-communities are defined based on the entire network. Next, a second iteration of the community detection algorithm is run, this time within each of the previously defined L_3-communities, resulting in a set of L_2-communities. Finally, a third iteration of the community detection algorithm is performed on the network of each of the created L_2-communities, resulting in a set of L_1-communities. In other words, the iterative community detection provides for a multi-level spatial delineation of the given network resulting in a set of L_1, L_2, L_3-community borders specific to each node in the network that are called here 'hierarchical borders'. Having defined the hierarchical borders of a network, the importance of each hierarchical border for each node is assessed. To do so, Grauwin et al. (2017) propose a measure called damping value:

$$q_i^h = \frac{T_i^{h+1}}{W_i^{h+1}} \frac{W_i^h}{T_i^h} \tag{3.1}$$

with h representing the set of nodes that are at a hierarchical distance h of node i. The hierarchical distance between two nodes h is 1 if both nodes are located in the same L_1 region, 2 if they are in different

L_1 regions but the same L_2 region, 3 if they are in different L_2 regions but the same L_3 and 4 if they are located in different L_3 regions. T_i^h are the total amount of linkages from node i to all zip codes at distance h and W_i^h the total amount of linkages from nodes within hierarchical distance h from node i (Grauwin et al., 2017). Interested readers may have noticed the terminology of the levels is flipped compared to the original authors. This mainly to ease understanding but also because it allows for more flexibility and comparability in case more than three levels will be identified in another study.

The interpretation of the calculation of the damping value q_i^h is rather straightforward. As each node is located in a specific L_1, L_2 and L_3 community, the importance of each hierarchical border (for each node) can be easily characterized by comparing the relative strength of a node in a certain hierarchy level, i.e. T_i^h/W_i^h, with its relative importance one level up the hierarchy, i.e. T_i^{h+1}/W_i^{h+1}. As a consequence, a low q_i^h value indicates a strong border between two hierarchical levels, meaning that a change from hierarchical level h to the next $h+1$ is, for the investigated location i, a relevant change in its importance. Viewed from the hinterland perspective, low q_i^h values hence indicate that the investigated location is relatively more important in the hinterland at level h compared to the hinterland at level $h+1$. Consequently, a high q_i^h value implies the contrary indicating a gain in importance of the investigated location i when transgressing to the next hierarchical level. The different levels and damping values are summarized for an example zip code in Figure 3.2.

Remark that the definition of low and high damping values is a relative concept. Logically, damping values are expected to be below 1 as transgressing to a next hierarchical level implies a growing number of other localities (or in the hinterland metaphor, an extension of the hinterland) against which the locality under consideration is compared in order to determine its 'importance'. Currently, Grauwin et al. (2017) is the only research that has calculated damping values and this for large networks of mobile phone communication in different countries. The average damping values they calculated differ slightly from country to country but remain within the 0.10-0.25 range. Most remarkably, however, they found distributions of damping values to be similar for all different hierarchical borders (so for each hierarchical level $h = 1, 2, 3$) within each country.

3.3.2 K-means clustering

To understand the variation in damping values between nodes, a k-means clustering is applied on all nodes using their set of damping values for the three hierarchical levels as attributes. The chosen algorithm does not take the location of the nodes explicitly into account, which makes any resulting geographical image the outcome of the spatiality inherent to the original network. In this case, k is defined in an informal way by plotting the within-group sum of squares for a range of k's choosing the partition that coincides with the bending point in the resulting graph, i.e. where an additional class has less impact on the within-group variation (Everitt and Hothorn, 2010). This approach is similar to the scree-plot used in factor analysis.

3.3.3 Community detection

Remark that in this case, the Louvain method community detection algorithm proposed by Blondel et al. (2008) is applied, contrary to Grauwin et al. (2017) who use the 'Combo' algorithm proposed in Sobolevsky et al. (2014). The 'Louvain method' is preferred because of its widespread application in literature, its strong performance in a comparative analysis Lancichinetti and Fortunato (2009) and because of the familiarity from the previous Chapter. Comparison of the results between Louvain and Combo on the dataset showed little differences in obtained communities for all iterations and, as such, little differences in calculated damping values for both approaches.

Recall the limitation of the resolution limited in Section 2.3.2 when using the Louvain method. This Chapter copes with this issue by detecting various hierarchical levels without privileging one of them, finding smaller communities within larger ones, hereby partly bypassing the resolution problem. Other community detection methods exist to identify the presence of hierarchical structures in complex networks (Adam et al., 2018; Fortunato and Hric, 2016). These however focus on network hierarchies, i.e. how nodes are members of different levels of communities. While this is similar to the reiteration of the community detection algorithm, the calculation of the damping values allows for a bottom-up description of the hierarchical structure, i.e. from each spatial unit individually. Hence it is used to analyze the geographical hierarchy in addition to the network one.

Ultimately, one can wonder why an iterative application of a standard community detection algorithm is preferred over hierarchical community detection algorithms and/or methods that allow for overlapping communities (Fortunato and Hric, 2016). The first reason is that the goal is to identify geographical hierarchy, which, as the results show, is inherently different and thus independent from the network hierarchy that emerges from the latter algorithms. The second reason is that neither application and interpretation of these methods is trivial, thus requiring a more methodological discussion which is outside the scope of this Chapter. It remains, however, future work to investigate the definition of, and differences between, damping values based on these approaches.

3.4 Case study: logistics network in Antwerpen, Belgium

For the case study, the same dataset of micro-economic buyer-supplier linkages in Belgium outlined in the previous Chapter is used. Recall this dataset aggregated all buyer-supplier linkages from individual companies to the zip code they reside. Each node in the network thus represents a zip code. Each link between two nodes represents the total frequency of buyer-supplier linkages between them. Although the previous Chapter attempted to find the drivers of the community delineation by calculating the within-module degrees and participation coefficients, the rich variety (both in size as in geography) of the node degrees, i.e. the total frequency of linkages leaving or arriving at the zip code observed in Figure 3.1, is neglected in the community detection.

The comparison of Figures 2.4 and 3.1 illustrates the limitations of two commonly used network approaches, as already mentioned in the introduction. Community detection, although rendering spatially homogenous communities, does not provide information on the local level, and as such, stimulates false interpretations of homogeneity within communities, as has been seen in other work. Second, the degree characteristics provide information on the variety of the nodes in the network, but ignore the spatial relations. The Antwerpen community in blue for example has a strong internal heterogeneity with the port as the major economic hub but is surrounded by locations with different logistics importance. In addition, despite being classified in different communities, companies in the Antwerpen community have many buyers and suppliers around the country. This information is im-

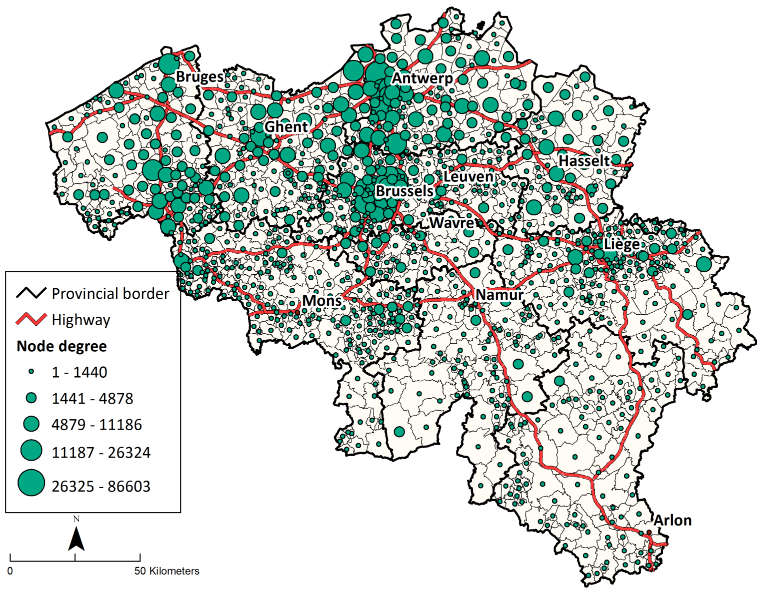


Figure 3.1: Node degree of the logistics buyer-supplier linkages. The node degree is the total frequency of linkages leaving or arriving at a zip code. Source: NBB.

portant since the goal is to understand the buyer-supplier hierarchical structure within the country, but is addressed in neither of the two maps.

In what follows the methodology described in Section 3.3 is applied on the logistics buyer-supplier system in Belgium. First the results of the iterative runs of the community detection algorithm are displayed after which the focus lies on the communities and damping values of the Antwerpen case. The focus on the Antwerp community results from its importance within the Belgian logistics system, reflected in the high number of linkages leaving and arriving there (Figure 2.3). It is also an easy choice given its rather isolated location in the north of the country, with no other strong economic poles in its immediate vicinity. Hence this will facilitate the interpretation of the results. The discussion elaborates on the factors that contribute to the geographical and hierarchical variance of the damping value. The different levels and damping values explained above, are summarized for the example zip code in Figure 3.2 (city of Lier).

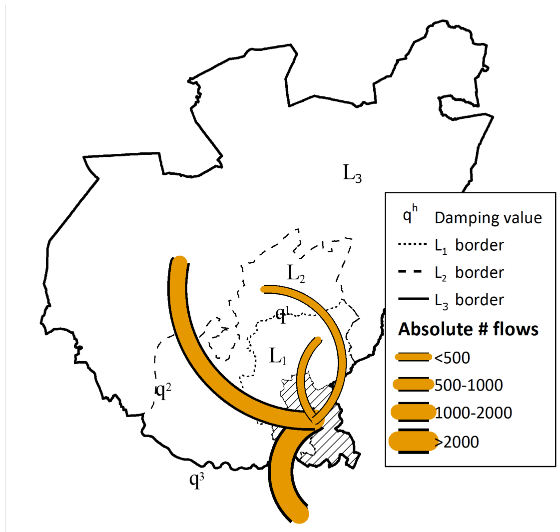
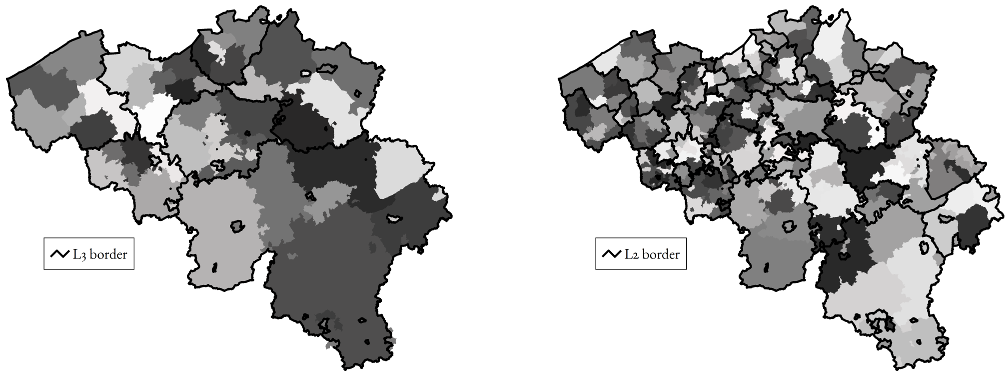


Figure 3.2: Hierarchical levels and corresponding damping values q^h. Source: NBB.

3.5 Results

Applying iterative community detection to the buyer-supplier network of Belgian logistics renders L_1 and L_2 communities as displayed in Figure 3.3 (the L_3 communities are shown in Figure 2.4). A total of 1155 zip-codes were attributed to 7 L_3-communities, 40 L_2-communities and 81 L_1 communities, rendering three hierarchical borders for each individual zip code. Remark that almost all defined communities are spatially contiguous, even though no explicit spatial criterion was introduced by the community detection algorithm. This interesting property aligns with findings in literature based on mobile phone and commuting data (Blondel et al., 2010; Grauwin et al., 2017; Ratti et al., 2010; Sobolevsky et al., 2013; Vanhoof et al., 2015) and suggests that geography matters, also in logistics buyer-supplier systems. From the point of view of each individual node iterative community detection on the network thus results in a spatial pattern where its closest hinterland is defined by its L_1-community, extending into a wider hinterland defined by its according L_2-community and a widest hinterland made up by its L_3-community before entering the scope of the entire spatial network. This can also be observed in Figure 3.2.



(a) L_2 communities **(b)** L_1 communities

Figure 3.3: Lower level communities in Belgium. Greyscale is used to differentiate the communities. Source: own calculations with data NBB

The distributions of the damping values for the hierarchical borders at level 1, 2 and 3 for all zip codes is given in Figure 3.4. Distributions are more or less normally shaped but apparently hierarchical borders at different levels have different strengths in the Belgian logistics system with average damping values being 0.32 for the L_1 level, 0.55 for the L_2 level and 0.21 for the L_3 level. This contrasts with findings by Grauwin et al. (2017) where for mobile phone networks in different countries, damping values tended to have similar distributions for the different hierarchical levels.

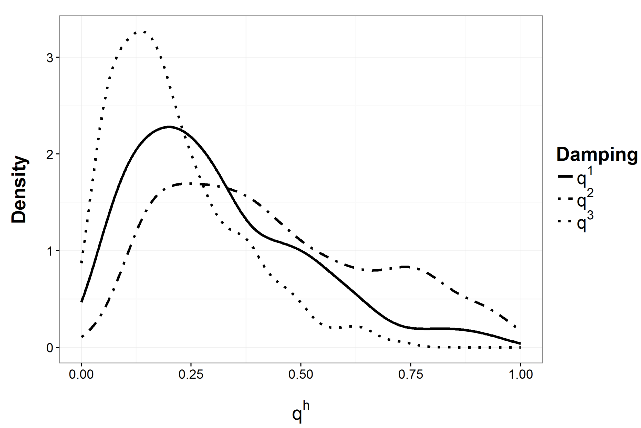


Figure 3.4: Distribution of different damping values. Source: own calculations.

In order to understand how the definition of damping values at different hierarchical levels can lead to an increased interpretation of the particular context of individual zip codes the focus lies on the case of one L_3 community, the Antwerpen community. The Antwerpen community results from the first iteration of the community detection algorithm on the buyer-suppliers network. Figure 3.5 provides a zoom on the Antwerpen L_3 community which corresponds to the blue area in Figure 2.4. The core of the community is the city of Antwerpen of which the center is indicated with a star. The city is surrounded by a ring road and has a large port (purple) located north along both banks of the river Scheldt. Most economic activities outside the city are situated to the south, following the E19 and A12 highways towards Brussels, along the Albert canal towards the east and on the left bank in the west where one finds the most recent developed port areas. The northeastern part of the community is more suburban and even rural. A more detailed description of the location of logistics activities in Antwerpen can be found in Verhetsel et al. (2015). In total, the community consists of 55 zip codes or thus 55 nodes in the analyzed logistics buyer-supplier network.

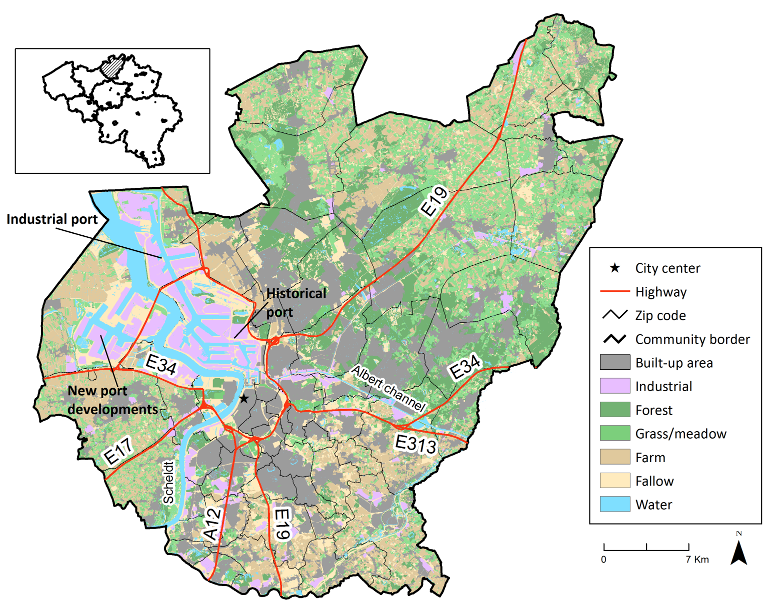
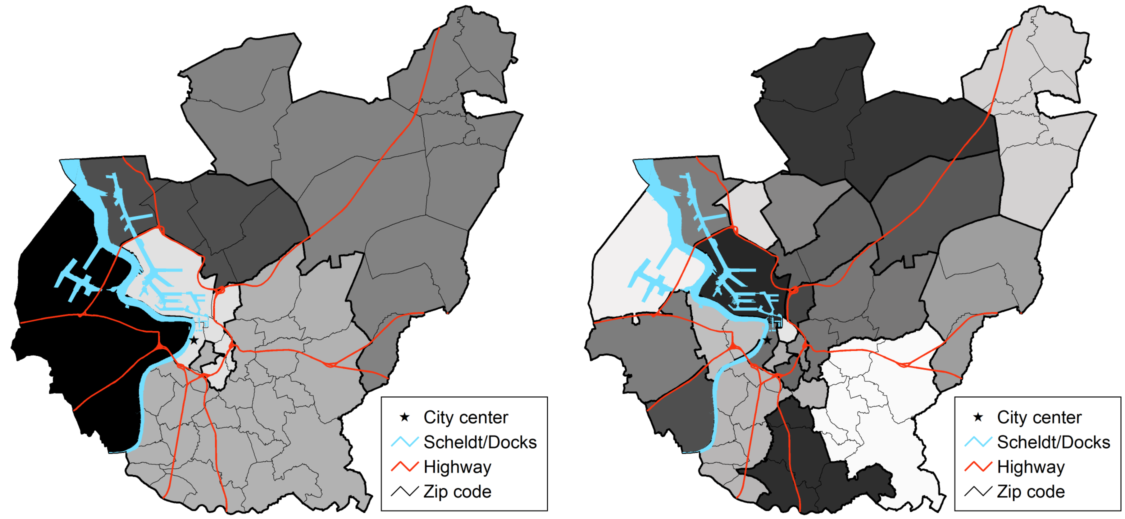


Figure 3.5: Situating the case of Antwerpen. Source: own composition with data Open Street Map.



(a) L_2 communities

(b) L_1 communities

Figure 3.6: Lower level communities for Antwerpen L_3 Community (Figure 2.4). Greyscale is used to differentiate the communities. Source: own calculations with data NBB.

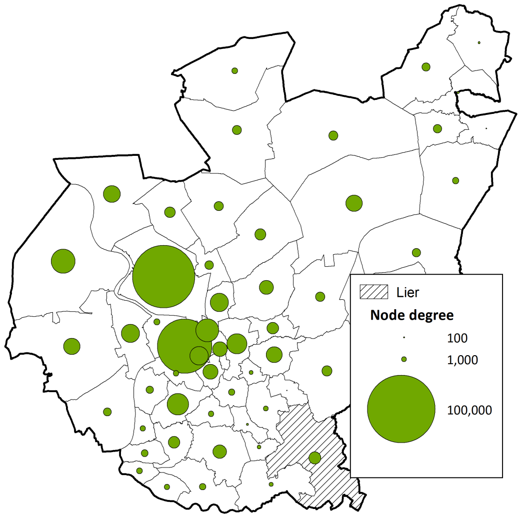
The L_2 and L_1 communities relating to the L_3 Antwerpen community are mapped in Figure 3.6. At the L_2 level one can recognize the central city with the old port to its north. The industrial port with its chemical cluster northwest of the city at the fringe of the L_3 community, and the newest port developments on the left bank show up as individual L_2 communities as well. Further the community detection iteration identifies the southern metropolitan area and the more residential/rural northeast. While all detected L_2 communities contain at least two different zip codes, some zip codes form a community of their own at the L_1 level. This is due to strong internal loops in the concerned zip codes, meaning that buyer-supplier linkages within the own zip code are prominent.

Apart from observing spatially contiguous communities, the question arises to what extent an hierarchical structure is present within these communities. In other words, what exactly are the damping values related to these hierarchical borders, what kind of spatial patterns appears and what do they tell us about the role of individual zip codes?

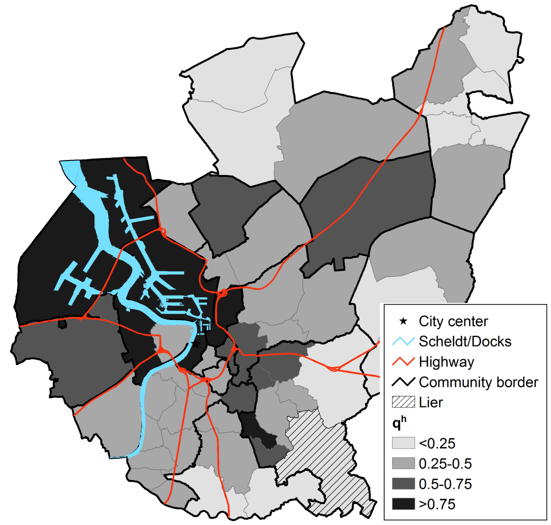
Figure 3.7 plots the q^1, q^2, q^3 values for all zip codes in the Antwerpen community. These values represent the strength of the L_1, L_2, and L_3 borders respectively. Overall the damping values show strong geographical variance at each level as well as over the different levels. Although the damping values are normally distributed around an average, Figure 3.7 clearly shows that summarizing this information in one damping value for all levels over the entire study area as proposed by Grauwin et al. (2017) in his search for a universal model, comes with a neglect of their spatial variance.

The variance of damping values points out the unique positions that each zip code holds in the overall network, depicting different relations to different borders at different levels. For example, the high damping values for the L_1 level obtained for the Antwerpen port area (see Figure 3.7b) indicate a smaller importance of this level for those zip-codes. Likewise, in Figure 3.7c a group of zip codes in the southeast show significantly higher damping values at the L_2 border compared to the L_1 and L_3 ones, suggesting the relative insignificance of their L_2 level. Remark that, given their definition, the construction of damping values for a zip code is independent from its absolute number of buyer-supplier linkages as can be observed by comparing the spatial pattern of node degrees in Figure 3.7a with the spatial patterns of the damping values in Figure 3.7b, 3.7c, 3.7d.

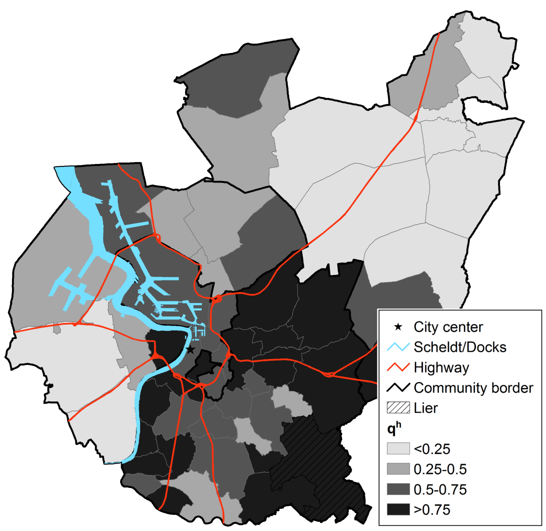
Clearly, the analysis of damping values counters the suggestion of similarity between zip codes that is implied by the discrete, spatially homogenous result of community detection. Indeed, each zip code has its own characteristics when it comes to positioning in the proposed L_1, L_2 and L_3 communities and resultantly, a richer geography is detected. Still, some spatial grouping seems to emerge from Figure 3.7, with adjoining zip codes depicting similar damping values over different hierarchy levels.



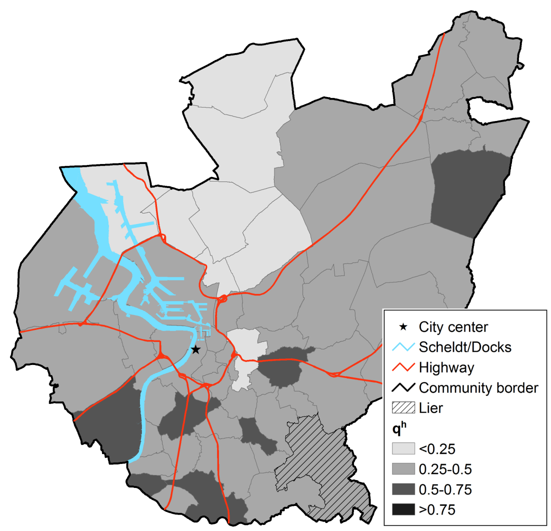
(a) Node degrees



(b) Damping values L_1



(c) Damping values L_2



(d) Damping values L_3

Figure 3.7: Node degrees and damping values for the Antwerpen community. Source: own calculations.

To more formally investigate such similarities and the related spatial pattern, a k-means clustering of the damping values is applied. Figure 3.8 indicates three clusters as the ideal solution, which are mapped in Figure 3.9 and, they too, are spatially quite contiguous but differ rather strongly from the presented L_2 or L_1 communities in Figure 3.6, meaning that a different kind of characterization took place compared to standard community detection. In other words, compared to the network hierarchy resulting from the iterative community detection, the geographical hierarchy within the region is now observed. The applied k-means clustering yields three different classes of zip codes. Their average damping values for the different hierarchical borders are shown in Figure 3.9a, together with the average damping values for all zip codes in Belgium.

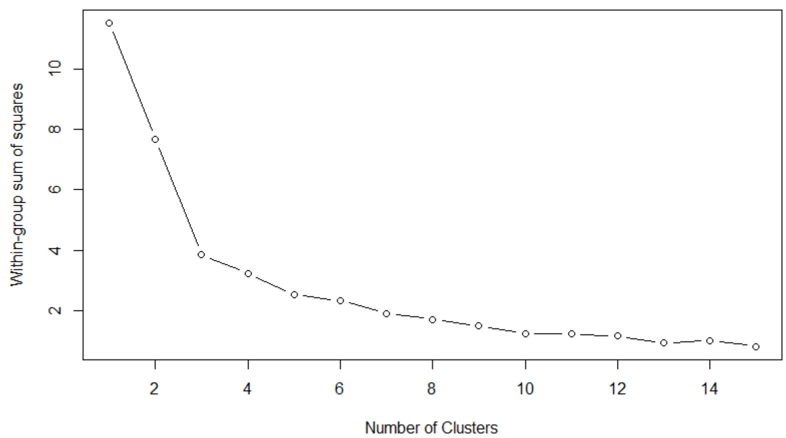
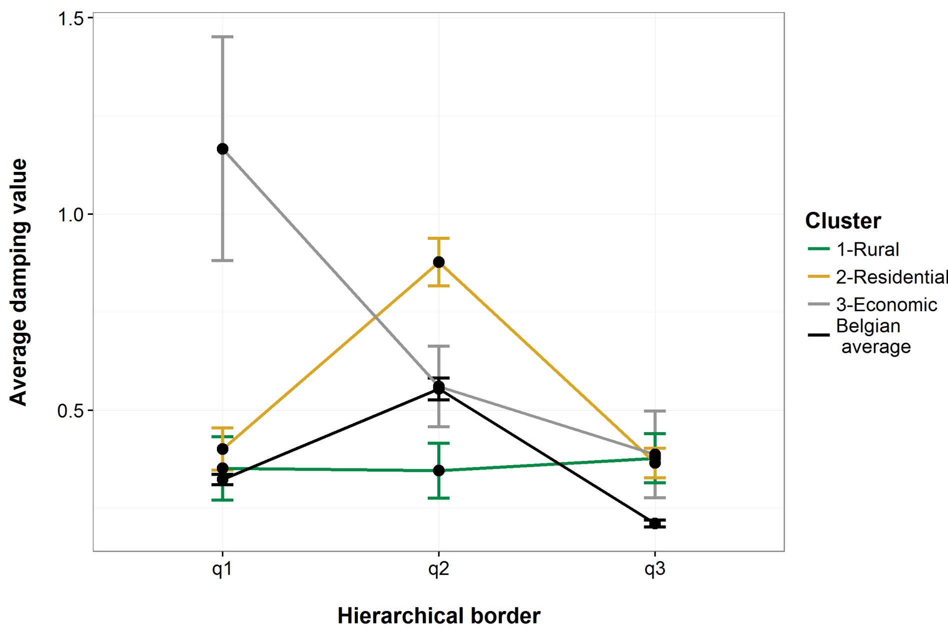


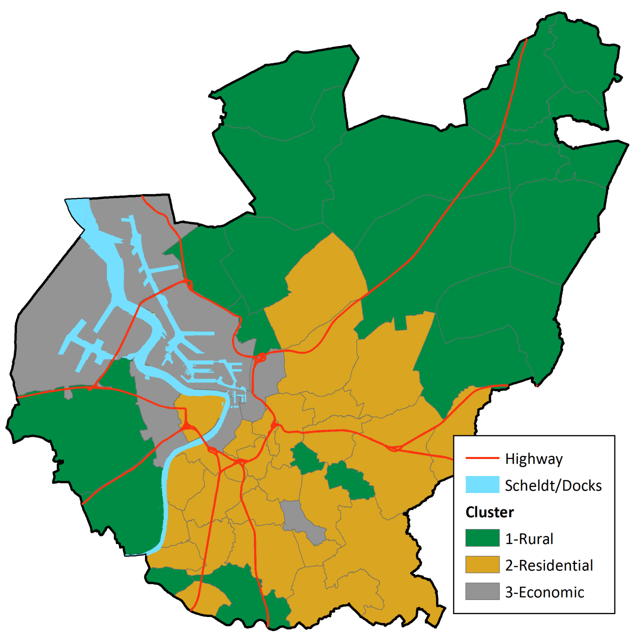
Figure 3.8: Within-cluster sum of squares for different number of clusters. Source: own calculations.

Several insights can be derived from the properties of the k-means clustering based on damping values as shown in Figure 3.7. Firstly the damping values obtained for the L_3 community borders are not differentiating the different clusters. Interestingly, compared to the Belgian average, q^3 damping values of the zip codes in the Antwerpen community are significantly higher, demonstrating the importance of the nodes in the Antwerpen community for the entire Belgian logistic system.

Secondly, it shows that zip codes attributed to clusters 1 and 2 (Figure 3.9a) do not differentiate amongst themselves with relation to damping values for the q^1 and q^3 borders. Rather, it is the q^2 border that separates their profiles from each other. A rather high damping value at the L_2 border for zip codes in cluster 2 suggests the difference between L_2 and L_3 communities to be less relevant compared to the



(a) Damping profile of each k-means cluster.



(b) Geographical pattern of k-means clusters.

Figure 3.9: K-means cluster results. Source: own calculations.

other zip codes in the Antwerpen community. The zip codes attributed to cluster 1 show extremely low damping values, indicating their peripheral role in the wider logistics network. Crosschecking Figures 3.9 and 3.5 reveals the division between clusters 1 and 2 results from the distinct geography in both regions. Cluster 1 comprises the most rural zip codes while cluster 2 consists mostly of small cities and residential areas within Antwerpen. In the remainder of this Chapter these are called rural and residential clusters respectively.

Thirdly, it is clear that the lowest hierarchical border, q^1, is differentiating zip codes attributed to cluster 3 in the k-means algorithm. The zip codes in cluster 3 include the economic areas in the port and city center and will be called economic cluster from here on. Despite their large amount of internal linkages (some of them form an L_1 community on their own), their relative importance is significantly higher at their L_2 community level compared to their L_1 level. Interestingly, for these zip codes, the distinction between L_2 and L_3 communities is similar to the average Belgian zip code, indicating the relevance of this second hierarchical level (Figure 3.6a), even for these important nodes. Since these second level communities correspond to the different port areas, the strong q^2 indicates the relative important difference between the left bank, the old port and the industrial port. While in the previous Chapter they were classified in one Antwerpen logistics cluster, the existence of the sub clusters is now observed, proving the presence of an important geographical hierarchy in the network.

3.6 Discussion

In this Chapter a geographical perspective is applied on Grauwin et al. (2017)'s methodology to delineate hierarchical levels and define the strength of their borders in large networks. This approach provides an empirical way to include the role of each individual location while assessing their relationships, a combination which has been overlooked in recent network applications in (transport) geography.

When applying the approach to a network of logistics buyer-supplier linkages in Belgium, the results clearly show that nodes located in the same community can exhibit strongly differing relations with different hierarchical levels. This is due to a strong geographical and hierarchical variation of the distributions of links in space for different nodes.

The methodology presented here shows how one can capture such geographical and hierarchical variation for each node individually by calculating its damping values. One of the main findings is a high diversity among damping values calculated for buyer-supplier linkages, both between nodes and between hierarchical levels (Figure 3.4). This in contrast to the findings for mobile phone communication networks where damping values show similar distributions at different hierarchical levels (Grauwin et al., 2017). This variation indicates the need for better insights both on the local context of individual nodes as on the existence of hierarchies when interpreting or even modeling linkages.

A second important finding is that despite their high variety, damping values for logistics buyer-supplier linkages show spatial patterns at the regional level (Figure 3.7). A simple k-means cluster algorithm based on the calculated damping values helps to describe the underlying geography of the Antwerpen community (Figure 3.9). The algorithm yields clusters based on the relation of individual nodes over the different hierarchical levels in the network. These clusters can then be interpret by combining expert, i.e. geographical, knowledge and a detailed study of the damping value profiles. This differences between these clusters lead to a renewed insight in the regional differences now based on the relation of individual nodes over hierarchical levels. It hereby unveils a *geographical* hierarchy of the Antwerp community, different from the *network* one which is solely based on the (iterative) community detection.

The analysis of the different cluster profiles in Figure 3.9 allows us to understand how hierarchical levels are experienced differently for each cluster. Given its rather complex definition, the disadvantage of damping values in this perspective is that their interpretation is not always trivial.

Concerning the low q^1 damping values for the rural and residential clusters, for example, it is worthwhile to understand that the main driver is the expansion of the set of considered zip codes. Indeed, when climbing an hierarchical level and given that the added zip codes show similar network characteristics, the W in the definition of damping values will increase, triggering a decrease of the damping

Table 3.1: Absolute flows and damping value over each hierarchy for one zip code per cluster

Level	T^h	W^h	q^h
L_1	460	19,253	0.24
L_2	437	75,959	0.97
L_3	1,715	306,934	0.41
Belgium	3,088	1,332,829	

Source: own calculations with data NBB

values.

An example of a zip code attributed to the residential cluster (city of Lier, zip code 2500, see Figure 3.7) is taken for demonstration. The low damping value for the q^1 border results out of $T^1_{2500} \approx T^2_{2500}$ while $W^2_{2500} \gg W^1_{2500}$ (Table 3.1). The diminishing importance of this zip code at the L_2 level is due to the L_2 level being a merge of several zip codes with similar node degree (size of logistics activities) and linkages distribution (diversity of its network). In the L_1 community each zip code has a share amongst 4 to 10 similar zip codes and in the L_2 community they are joined by more or less 20 other similar zip codes, decreasing the relative importance of a single zip code, like Lier, which translates in an important damping between the two levels.

If, when scaling up, added zip codes do not show similar characteristics, the observed damping values become the result of a complex interplay of relative gains in importance and connectivity at the higher hierarchical level, despite the enlargement of the set of considered zip codes. This is the case for the residential cluster where transferring from L_2 to L_3 means adding zip codes that are either very important (port areas) or less significant (northeastern rural areas), resulting in a more complex construction of damping values and thus a less trivial interpretation. The q^2 for the city of Lier in the residential cluster is a good example. Adding the port area at the L_3 level results in a higher W^3_{2500} due to the many buyer-supplier linkages at the port. In the meantime the port is an important buyer and supplier for the city as well, increasing T^3_{2500}. The extend of this connectivity, enforced by the lower connectivity of the zip codes from the northeastern rural areas that were also added at the L_3 level results in a rather high damping value for the city, even though W^3_{2500} went significantly up by adding highly connected zip codes like the port area to the equation.

In summary, the profiles of the rural and residential clusters demonstrate the mechanics that are behind the calculation of damping values and that make their interpretation non-trivial. The main premise, however, stands: the absolute damping value depends on how important a node is within its L_h community compared to the joining communities at L_{h+1}. The more important it is (in terms of flows and connectivity) the lower your damping value will be.

An understanding of these mechanics allows for an interpretation of the different obtained clusters. Clearly, the rural and residential clusters are locally well embedded with their zip codes having a higher importance at lower scale levels. For the former, this loss of importance is constant when transgressing all hierarchical levels meaning that increasing hierarchy implicates decreasing importance for the involved zip codes. This is not surprising given the rural nature of the involved zip codes.

The residential cluster, on the other hand, does not display constant damping values for all hierarchical levels and has a remarkable high damping value for q^2. The clear gain of importance in the L_3 level is due to two factors. First, the L_3 level introduces a strong relation between the central zip codes of the residential cluster and the port area. Secondly, at the L_1 level, the central zip codes contrast with the less important zip codes from the rural cluster, both of which add to the importance of the residential one at the level of the Antwerpen community. All of this yields an interpretation of the residential cluster being a set of zip codes that have similar characteristics and are rather locally focused, but as a group play an important role at the level of the Antwerpen community.

Finally, the economic cluster is the most interesting case. The extremely high q^1 value indicates the high within-community links at the L_2 hierarchical level (which are the three different parts of the port) compared to the L_1 level (which are the different zip codes of the port individually). In addition, the value for q^2 similar to that of the Belgian average implicates the zip codes in the economic cluster are well linked within the L_3 level too. This pattern is indicative for the zip codes in the economic cluster being the glue of the Antwerpen community. They can be perceived as economic hubs at the center of their region, which is not difficult to imagine when one evaluates their location within the central business district and the port area. The higher than average q^3 indicates their relative importance within Belgium as well.

Even without assessing the absolute number of buyer-supplier linkages it is easy to understand that, in traditional community detection algorithms (like deployed to arrive at the L_3 level) it are the zip codes of the economic cluster that are most important in delineating the Antwerpen community. However, as the zip codes in the two other clusters constitute the largest share of the overall network, it becomes clear how typical applications of community detection do not tap into a significant part of the available information that emergent large datasets provide.

3.7 Conclusions and future research

This Chapter applies three iterations of the Louvain community detection algorithm to uncover the hierarchical structure in the logistics buyer-supplier network in Belgium. By applying the methodology proposed by Grauwin et al. (2017), second and third level communities are received within the ones previously defined for the whole Belgium scale (Chapter 2). Similarly to the high level communities and community delineations in other studies (Blondel et al., 2010; Kung et al., 2014; Nelson and Rae, 2016; Ratti et al., 2010; Vanhoof et al., 2015), the second and first level communities exhibit a strong spatial contiguity. Next, like Grauwin and his colleagues, three damping values are calculated for each node in the network, providing information on the strength of the borders between each hierarchical level. This strength represents the in- or decrease of the relative importance of a node amongst its peers when transitioning a level. To better understand the spatial patterns of damping values in the case study, a simple k-means clustering is applied, which yields three distinct regions and allows for a better understanding of the forces behind the community delineations.

The creation of spatial patterns from hierarchical characteristics in networks has not yet been performed in previous work. The applied approach therefore could enhance studies like Ratti et al. (2010) or Nelson and Rae (2016) that try to redraw the map of the UK or recreate the US economic geography by one-level community detection algorithms only. The problem this approach solves is that, as is discussed for the Antwerpen community, high-level communities delineated by using one iteration of community detection are mostly based on the delineation of the strongest nodes hereby concealing the influence and relations of less important nodes. Given that less important nodes often constitute a considerable share of the overall network, many of the community detection applications overlook a significant part of their data hereby grasping only a small portion of the overwhelming potential the new big datasets provide. A critique that has also been posed by Schwanen (2016) and Kwan (2016), who notice the lack of attention for the local context in current big data analysis.

Furthermore, another finding is that damping values calculated on the buyer-supplier linkages display a strong geographical and hierarchical variance, highlighting the difference among individual nodes within the dataset. Especially the large hierarchical variance of damping values is in contrast with previous work where findings of constant damping led to a generalizing predictive model of mobile phone communication (Grauwin et al., 2017). It is concluded that for logistics such a model will probably not hold meaning that insights on the local context and existence of hierarchies are necessary to understand the complex relations of buyer-supplier linkages in logistics, rather than generalizing principles.

In the presented case study, the k-means clustering of nodes based on their damping values serves well in relating these values to a local context and facilitated the detection of a geographical hierarchy that contrasts the network hierarchy. While the applied methodology directs attention to the specific nodes in the network, this attempt is merely a first step on one of plausibly multiple pathways that can reconcile network-based insights and more qualitative, localized insights. It has, in other words, not been in the scope of this Chapter to fully integrate localized qualitative insights with damping values. Rather, it is demonstrated that the potential is there. What can be stated, however, is that if we were to fully exploit the potential of network-based big data analysis for Transport Geography, the combination of qualitative insights and quantitative analysis should eventually lead to theorization or relevant input for decision making.

Potential ideas, and thus suggestions for future research, are to link the resulting geographical hierarchy to consecutive steps in a hub-and-spoke structured supply chain, in which case different regions demand different zonal planning, although additional input from logistics stakeholders would be necessary. Or, to elaborate a comparison of the k-means clusters over the country to allow the identification of over- and underperformers from a logistics perspective. Understanding the drivers of the observed differences and the comparison with previously identified key factors influencing the location decision of logistics companies (e.g. (Verhetsel et al., 2015)) could potentially allow for new insights in the latter. Similarly, the application of the used methodology on public transport data may help to identify missing links between some regions and overcapacity on other connections when comparing resulting hierarchical communities with, for example, delineations of daily urban systems. Although in these examples the proposed methodology can lead to more advanced geographical insights, hence aiding in reaching the level of mesogeography Miller (2018) advocates, they all demand that extra step of integrative qualitative analysis that now forms the next step to address.

4

Identifying the geography of online shopping adoption in Belgium

The logistics network is not just heterogeneously scattered at the national scale. Network methodologies were used in the previous two Chapters to uncover its spatial pattern. Also at a more detailed scale interactions are shaping the structure of the sector. As introduced in Chapter 1, the origin of these interactions lies in the increased role of the end consumer, which results from the widespread adoption of the internet as retail channel. To study the impact of these interactions, one thus first has to understand this consumer. This is the topic of the current Chapter.*

*This chapter is originally published as Beckers J, Cárdenas ID, Verhestel A. 2018a. Identifying the geography of online shopping adoption in Belgium. *Journal of Retailing and Consumer Services* 45: 33–41

4.1 Introduction

Twenty-three years after the founding of Amazon, business-to-consumer electronic commerce (B2C e-commerce) keeps rising. Over the last six years, Europe experienced an average annual increase in online sales turnover of 16% (E-commerce Europe, 2016b). Despite persistent growth rates around the EU however, levels of e-commerce adoption vary greatly among different member states. While only 16% of the population of Western Europe never shopped online in 2016, this number rises to 40% for Eastern Europe (Eurostat, 2019)

The popularity of internet shopping provides retailers the opportunity of opening an additional distribution channel. At the same moment however it offers customers a wider market to choose from, hence increasing local competition and consumer power (Boschma and Weltevreden, 2008; Weltevreden and van Rietbergen, 2007). In response, retailers are required to be present online and ideally consider effective integration of their online and offline channels (Rimmer and Kam, 2018). In addition, in order to stand out brand creation and marketing have now become even more important, both for traditional and virtual merchants (Doherty and Ellis-Chadwick, 2010).

In parallel, the demand for home delivery services is growing at similar pace, resulting in a fragmentation of the goods distribution flows to the extent of a single item per delivery (Gevaers et al., 2011; Hesse, 2002). In consequence, recent literature estimates that up to 75% of the delivery costs originate from the last part of the distribution chain, i.e. the last mile (Gevaers et al., 2014). This not only puts pressure on traditional delivery models but threatens the livability of some urban areas, due to the increase in light good vehicles delivering parcels associated with the growth in online sales (Anderson and Leinbach, 2007; Browne, 2001; Cherrett et al., 2012).

Resultantly, local administrators are facing pressure to accommodate sustainable growth in online shipments while simultaneously attempting to prevent the disintegration of retail areas within their jurisdiction (Browne and Allen, 1999). The former has resulted in an increased awareness for freight planning within cities' administrations, a topic which up to now has always been overshadowed by the focus on passenger transport (Kiba-Janiak, 2017; Lindholm and Behrends, 2012). Furthermore, attempts are taken to improve the shopping experience within retail areas to limit the substitution of traditional purchases by online orders. Examples include investments in cycle hubs to store purchased goods or facility areas with pick-up points in main shopping streets as to attract online shoppers in nearby stores (Gómez et al., 2017).

As has been proven in multiple studies over the past two decades, the continuing relevance of geography for all stakeholders involved should not be underestimated (Anderson et al., 2003; Boschma and Weltevreden, 2008; Couclelis, 2004). Besides international differences, socio-economic and geographical factors do differentiate the online shopping behaviour within a single country (Clarke et al., 2015; Farag et al., 2006b). Whether these regional differences in online shopping are due to accessibility issues or varying openness to innovation remains under study (Motte-baumvol et al., 2017).

While there is agreement that knowledge on regional variations in online shopping holds great marketing value, these also imply that the demand for e-commerce goods can change from one neighborhood to another. Given the forecast of continuing e-commerce growth, knowledge concerning the e-shopper's profile and his related delivery preferences or failed delivery rates may help the courier, express and parcel (CEP) industry to balance cost efficiency and environmental sustainability in the last mile of e-commerce. In addition, it may provide local authorities the possibility to more efficiently implement sustainable urban logistics planning initiatives or e-resilience measures. Finally, it can support retailers to further improve their offline and online integration.

Given the value of understanding the geography of the online shopper, the spatial pattern of e-commerce demand is analyzed here using data on Belgium. With nearly 60% of the population buying online (Eurostat, 2019) and growth rates of over 10% for the business-to-consumer (B2C) online turnover (E-commerce Europe, 2016a), currently observed impacts will be fast growing in the coming years. As a result, there is an urge for more efficient and environmental friendly logistic solutions, for conscious local authorities and for well-informed retailers that take into account the geography of the demand of e-commerce.

This motivation leads to the construction of two research questions. After the introduction of the methodology, Section 4.4.1 tests whether previous findings of socio-economic factors impacting online shopping behavior currently hold in Belgium. In other words: *who is the Belgian e-shopper?* Second, the current literature on the topic is advanced, knowing the characteristics of the Belgian e-shopper and given the socio-economic profiles of each Belgian neighborhood, by answering the question: *where does the e-shopper live?* The answers to these research questions should help to identify the extent to which the specific geography of e-commerce matters for the stakeholders involved. This Chapter is concluded in Section 4.6 with suggested paths for further research.

4.2 Literature review

Already at the end of the nineties, at the height of the dot-com bubble, researchers in the field of marketing were studying the relation between socio-economic characteristics and the demand for e-commerce. The main goal of these studies was to predict the chances of online shopping based on behavioral characteristics. Early publications identified the better-educated males from 26 to 35 year old with high incomes as the earliest cybershoppers (Donthu and Garcia, 1999; Kau et al., 2003; Sim and Koi, 2002; Vrechopoulos et al., 2001). These findings were later confirmed by similar studies in the field of economic geography. First by Farag et al. (2006b) in their study of e-shopping in the Netherlands, who found a nonlinear relationship between age and buying online: up to the age of 33, the likelihood of buying increases after which it decreases again. Nine years later Clarke et al. (2015) came to similar conclusions for e-shoppers in the UK, although the maximum frequency of online shopping fell in the age category 35-39. Like the previous studies, also in the UK a strong positive correlation seemed to exist between household income and online shopping frequency.

Later, researchers adopted spatial components like urban-rural differences in similar studies starting with Anderson et al. (2003). He formulated two possible but opposite hypotheses concerning the spatial diffusion of e-commerce adoption. First, the efficiency hypothesis states a fast penetration of online shopping can be expected in more remote areas where e-commerce improves retail accessibility. Contrary the innovation-diffusion hypothesis expects early e-shopping to be limited to urban areas because new technologies are assumed to start in these centers of innovation, after which they diffuse to other regions.

Despite their contrasting nature, both hypotheses proved not to be mutually exclusive. Studies in various countries indeed find shoppers in metropolitan areas to be more prone to use the online channel and also observe the diffusion of online shopping to more rural areas over time, supporting Anderson's innovation-diffusion (Clarke et al., 2015; Farag et al., 2006b,a; Kirby-Hawkins et al., 2018; Motte-baumvol et al., 2017; Zhou and Wang, 2014). However, others did find proof for the efficiency hypothesis as well, with higher frequencies for the online shoppers in less accessible areas and the identification of accessibility issues as a major driver for e-commerce (Cao et al., 2013; Farag et al., 2006b; Kirby-Hawkins et al., 2018; Motte-baumvol et al., 2017).

The work on the socio-economic and spatial characteristics of the online shopper implies that the e-commerce demand is not uniformly distributed over the population. As mentioned before, this has been acknowledged by various authors already. Examples include amongst others the assessment of infrastructure decisions in an e-commerce context. As such, in an attempt to improve the efficiency of the last mile of urban goods flows, Ducret et al. (2016) use population density and income figures to list recommendations for logistics infrastructure. This way the authors highlight the value of spatial data for urban freight modeling. In other works authors adopt a retailer perspective and use the socio demographic aspects of online revenue data to asses online and offline strategies (Birkin et al., 2017; Kirby-Hawkins et al., 2018).

The wider city logistics literature on the contrary, concerned with the trade-off between efficient and sustainable distribution in and around the city has paid little to none attention to the importance of geographical variables when studying (the distribution of) e-commerce. With the exception of a small set of works based on empirical data (e.g. Ducret et al., 2016; Weltevreden and van Rietbergen, 2007; Zhou and Wang, 2014), the majority of the B2C city logistics literature assumes the demand is uniformly distributed over the population. Nonetheless, the initial distribution of this demand is the starting point for most of the quantitative analyses, like the assessment of the potential of green transportation vehicles or the reduction of social costs through collaboration among logistics players (Arvidsson and Pazirandeh, 2017; Gonzalez-Feliu et al., 2012; Lin et al., 2016; McLeod et al., 2006; Park et al., 2016). This may imply significant differences, especially when working with detailed data.

This Chapter tests whether previous findings concerning the role of socio-economic and spatial variables in the variability of e-commerce demand also hold in Belgium. This is done by identifying the relevant explaining variables of the probability a Belgian internet user shops online. In a second step, the expected number of online purchases for each spatial unit is predicted. Finally, this modeled demand is confronted with the population distribution to better quantify the variation in e-commerce demand. This Chapter is concluded by assessing the value of knowing the spatial variation for the different stakeholders involved.

4.3 Data and methodology

The online shopper is identified by using the *E-commerce in Belgium 2016* questionnaire organized by the Belgian retail federation Comeos. This online survey was conducted from the beginning of March to the end of April 2016 and polls the online shopping frequency of over 1500 Belgians for different categories (e.g. toys, food, ...). The respondents were selected representatively according to the age, gender and regional quota of the country from a database of over 200,000 regular participants (www.futuretalkers.com). Although participation is to be decided by the respondent, response behavior and time was leveled out due to tracking of previous online polling behavior.

In addition to a range of e-commerce questions, the survey collected the socio-economic variables listed in Table 4.1. Further, the morphology (urban/suburban/rural) of the zip code where the individual resides is included as well. The morphology is identified through the work of Luyten and Van Hecke (2007) and serves to test the hypothesis proposed by Anderson et al. (2003) on online differences between urban and rural areas. Despite their careful delineation, one has to remain prudent when comparing this morphological subdivision with other countries. Belgium, and especially its northern part, has a particular nebular (sub)urbanized landscape (Van Meeteren et al., 2016). This results from a continuous fragmentation of the countryside by urbanization related processes (Antrop, 2004). As a consequence, rurality in Belgium, with the exception of some areas in the south of the country, is not as remote as it can be in other countries.

Table 4.1: Variable levels in the survey used in the statistical analysis. The representativeness of the survey is indicated between brackets: (% of respondents in that level |% of Belgians in that level)

	Gender	Number of children	Education	Age	Household income (net €/month)
L0 (reference)	Female (51|51)	0 (71|65)	Lower high school (15|40)	18-29 (19|16)	<500 (2|10)
L1	Male (49|49)	1-2 (25|28)	High school (62|32)	30-39 (20|17)	500-1249 (19|17)
L2		3-4 (4|6)	Higher education (20|27)	40-49 (22|19)	1250-1749 (30|17)
L3		4+ (0.2|0.2)	Post-master (2|0.6)	50-59 (22|17)	1750-2499 (26|19)
L4				60-69 (17|13)	2499-3249 (14|12)
L5				70+ (0.7|17)	3250-4249 (7|9)
L6					>4250 (2|15)

Source: own calculations with data Comeos and Statistics Belgium (2014)

The sample of respondents ranges from 18 to 70-year-olds, has an equal gender balance and is representative of Belgium's language structure (60/40 ratio Dutch/French speaking). However, there is an overrepresentation of childless households, individuals holding only a high school diploma and mid-level incomes (Table 4.1). The higher educated, the eldest and the lowest income households, on the contrary, are underrepresented in the sample. General shopping characteristics of different socio-demographic groups can be found in the yearly e-commerce report of the retail federation (Comeos, 2016). However, a comprehensive analysis that crosschecks the entire sample is missing up to now. In this Chapter, such an analysis is provided by looking for the socio-economic characteristics that have a significant influence on the probability that one shops online.

The questioned online shopping frequency is used to answer the first research question *who is the online shopper*. In the original survey, each respondent could select one of seven categories to answer the question "How frequently do you buy something via the Internet (for personal purposes)?" (i.e. never; less than once a year; every 6 to 12 months; every 3 to 6 months; every 1 to 3 months; monthly: weekly). Of the total sample, 42% never bought online before. Resultantly, any study analyzing shopping frequency or spending would have to work with less than 1000 data points. Since this would restrict the statistical significance too much, the choice was made to calculate the significance of the influence that different socio-economic characteristics have on the probability one shopped at least once online during the last twelve months. Since the dependent variable becomes dichotomous (Yes/No), the use of a logistic regression is advised. To calculate a binary prediction from any type of predicting variable, the logistic regression models the probability p of the occurrence of an event through the logarithm of the odds ratio in a logit function:

$$\text{logit}(p) = \ln \frac{p}{1-p} \tag{4.1}$$

This logit-transformed probability p is a continuous function which can be used to predict parameters β for predictors x_1, x_2... and to test their significance via the following linear regression:

$$\text{logit}(p) = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots \tag{4.2}$$

The odds one bought online at least once during the last twelve months then becomes:

$$\frac{p}{1-p} = e^{\beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots} \tag{4.3}$$

Assume x_1 variable 1 in Table 4.1, equation 4.3 implies the odds a male bought online over the odds a female bought online, increases with e^{β_1}, keeping all other variables constant.

For studying the second research question *where does the online shopper live*, the e-commerce demand is mapped by estimating the potential e-shoppers in each neighborhood (census statistical sector) in the country. The statistical sectors are delineated at detailed geographical level, resulting in almost 20,000 sectors averaging 1.54km^2 (Jamagne, 2001). The geographical extrapolation of the statistical outcome of the first analysis is possible because of the socio-economic information provided by the Census 2011 and the yearly publication of various tax statistics at the same geographical level (Statistics Belgium, 2014, 2018).

Except for the tax statistics, which have to be redistributed, all variable levels are equivalent in both the survey and the statistical sector units, which facilitates the extrapolation. The tax statistics do include the median, the interquartile range and an interquartile coefficient for each statistical sector and the cumulative density function of the income distribution per 1000€ (yearly) for the whole population, which allows the calculation of the shares of each sector's population within the income classes defined in the survey. This permits the prediction of an estimated total amount of potential online shoppers in each neighborhood through the statistical model from the first part, which will be visualized geographically.

Finally, to test the extent to which the e-commerce demand is proportional to the distribution of the population, the number of modeled online shoppers is confronted with an assumed constant penetration rate of online shopping for each sector. The applied rate equals the average amount of buyers resulting from the model to assure the total sum of buyers remains the same during the comparison.

4.4 Results

4.4.1 Who is the online shopper?

According to the results of the Comeos survey, 57% of the Belgian internet users bought online at least once in the period April 2015 – April 2016, which is similar to the value published in the independent Eurostat survey on the Digital economy and society (Eurostat 2019, see Figure 4.1). Compared to its direct neighbors, the overall percentage of Belgian residents with minimum one purchase in the 2015 is quite low.

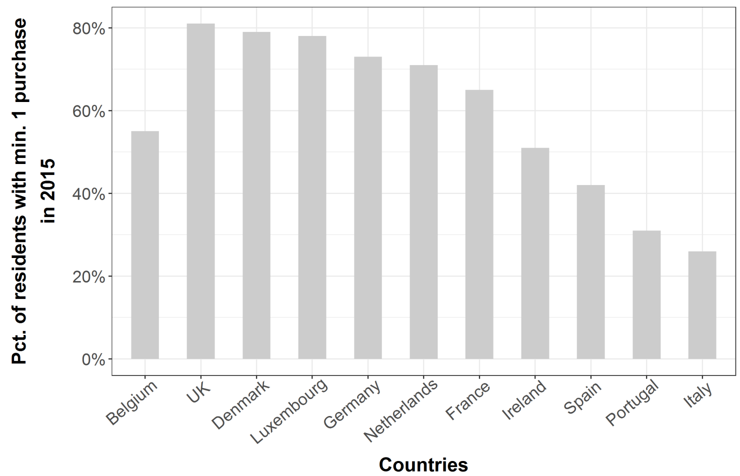


Figure 4.1: Percentage of online shoppers in Belgium compared to its neighboring countries. Source: own composition with data Eurostat (2019)

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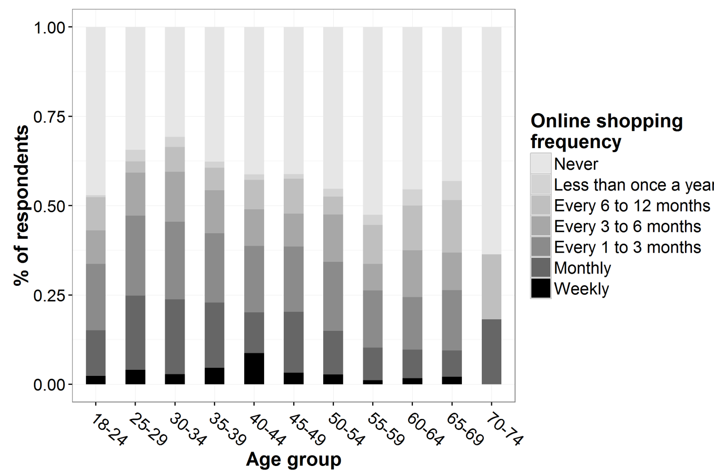
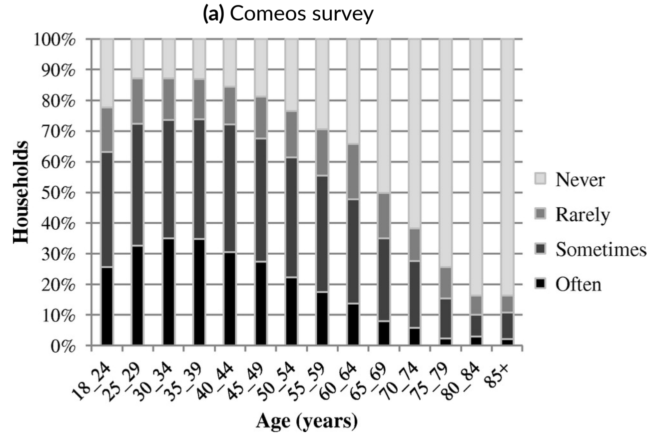
Further, similar to the findings of other academic research, the highest percentages of online shoppers are found in age groups 25 till 40 years old (Figures 4.2a and 4.2b). In comparison to the work of Clarke et al. (2015) in the UK however, online shopping percentages are still lower for each category with exception of the 60-64 interval. Inter-categorical differences are lower in Belgium, shown by the gradual slope of the overall graph, implying an almost homogeneous e-shopping behavior over different age classes. Remark that the eldest age category is absent from Figure 4.2a. If available, the inclusion of this category could potentially influence the rather gradual slope to a steeper one in the end, like in Figure 4.2b.

The first run of the logistic regression includes all variables listed in Table 4.1 since a variance inflation test did not identify any correlation among them. The maximum likelihood test of this regression can be found in Table 4.2. The large decrease in residual deviance given the degrees of freedom proves the significance of the model under the χ^2 distribution. Further, the analysis of variance identifies only the variables income, gender, age and education as significant at the 5% level. This means that the number of children does not seem to have an effect on the probability to buy online. Next, the morphology neither has a significant influence on the online shopping behavior. Urban, suburban and



(a) Comeos survey



(b) Clarke et al. (2015)

Figure 4.2: Online shopping frequency over different age groups. Source: own composition with data Comeos.

Table 4.2: Maximum likelihood test

	Df	Deviance	Resid. Df	Resid. Dev	Pr(>Chi)	
NULL			1585	2159.7		
Income	6	87.456	1579	2072.3	2.2e-16	***
Gender	1	7.478	1578	2064.8	0.00624	***
Age	5	12.898	1573	2051.9	0.0244	**
Number of children	3	8.257	1568	2043.6	0.143	
Education	3	28.146	1565	2015.5	3.385e-06	***
Morphology	2	2.124	1563	2013.4	0.35787	
Note:	$^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$					

Source: own calculations with data Comeos

rural Belgians have similar chances of buying online, which is in line with the results found by Clarke et al. (2015). It is hard to pinpoint the exact origin of this insignificance but assuming accessibility does influence online shopping probability (cf. efficiency hypothesis), a first possible explanation can be the lack of remote rural areas like they exist in countries with really peripheral and low accessible regions. This is due to the historical urban sprawl in Belgium, with a fragmented landscape characterized by a fairly homogeneous distribution of shop density outside the city centers as a consequence (Verhetsel et al., 2010). Resultantly, shop accessibility in many suburban and rural regions is sufficiently high to prevent a turn towards the online retail channel. A second explanation can be found in Anderson's adoption theory, assuming Belgium's progress on the e-commerce adoption timeline is quite advanced. This would mean e-commerce adoption grew beyond the early urban adopters to an almost equal share around the country. Although this conclusion seems doubtful given the country's rather low percentage of online shoppers compared to its neighbors (cf. Figures 4.1 and 4.2), it can only be confirmed through a longitudinal study.

Only the significant variables from Table 4.2 are retained in the second logit model of which the resulting estimates with their standard error are displayed in Table 4.3. The very low intercept indicates the probability of shopping online when $x_1, x_2, \ldots$ in equation 4.2 are zero. This is the case when $\beta_1, \beta_2 \ldots$ are the respective reference levels of the different predictors (cf. Table 4.1). This low value hence indicates low shopping probabilities for lowly educated, low income, young woman with no children. Concerning the individual variables, higher income categories seem to have higher probabilities to shop online compared to the base category of incomes lower than 500€ per month. Given the close relationship between the levels, it makes sense only the higher categories display significance. Besides the income, gender is another important differentiator with the odds of men shopping online being $e^{0.32}$ or 1.4 times higher than for women. The analysis of variance pointed to a lesser significance of the variable age, which returns here with no significant differences among the various levels. Although internet users in their 30ies have higher probabilities of shopping online compared to those in their 20ies, the sign of the estimated coefficient varies among the older age groups. The inconsistency of the age variable was predictable given its distribution in Figure 4.2a, i.e. with small differences between the various categories. Finally, the level of education strongly influences the online shopping odds in a positive direction: the higher the education level, the higher the probability of being an online shopper. One can conclude from the analysis that the well-educated male with good income in his 30ies has the highest odds of shopping online, which makes the Belgian online shopper similar to the profiles identified in earlier works elsewhere.

4.4.2 Where does the online shopper live?

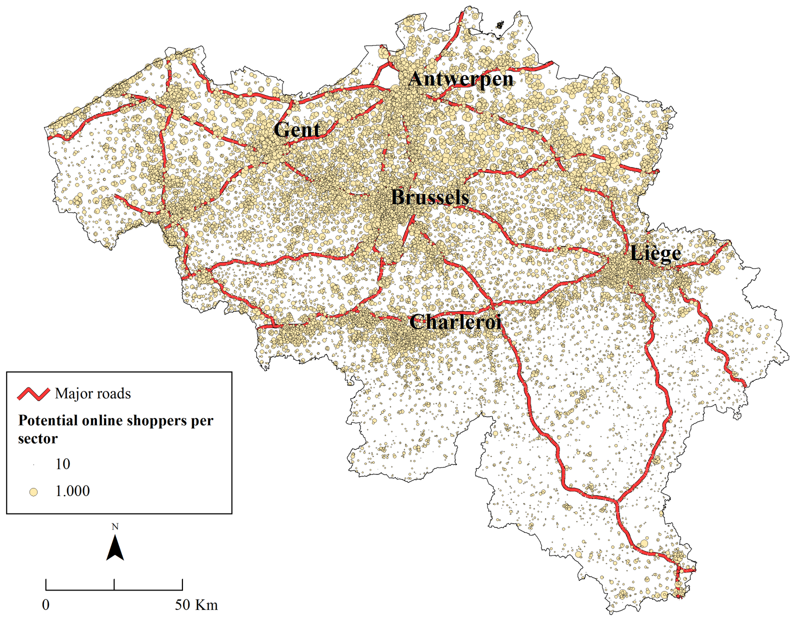
The final model including all variables in Table 4.3 considers all Belgians older than 20 years old and predicts a buying percentage of 50% when estimating the absolute number of online shoppers in each neighborhood. This is lower than the 57% of both the original survey and the Eurostat study. Although no information is present on the Eurostat data, the difference with the retail federation's survey may be explained by the uneven distribution of its target population over the variable levels (Table 4.1). First, since the original survey is conducted through a web platform it only reaches people with internet access. Although the internet penetration in Belgium is high (87%, Eurostat 2019), the online panelist may be more acquitted to internet usage compared to the average Belgian and may thus have a higher probability to shop online. Further, as mentioned in Section 4.3, one can observe a considerable underrepresentation of the eldest age group, of the lowest and highest income groups, and of the lowest educational level in the survey. Except for the highest incomes, the three other classes

Table 4.3: Logit regression results

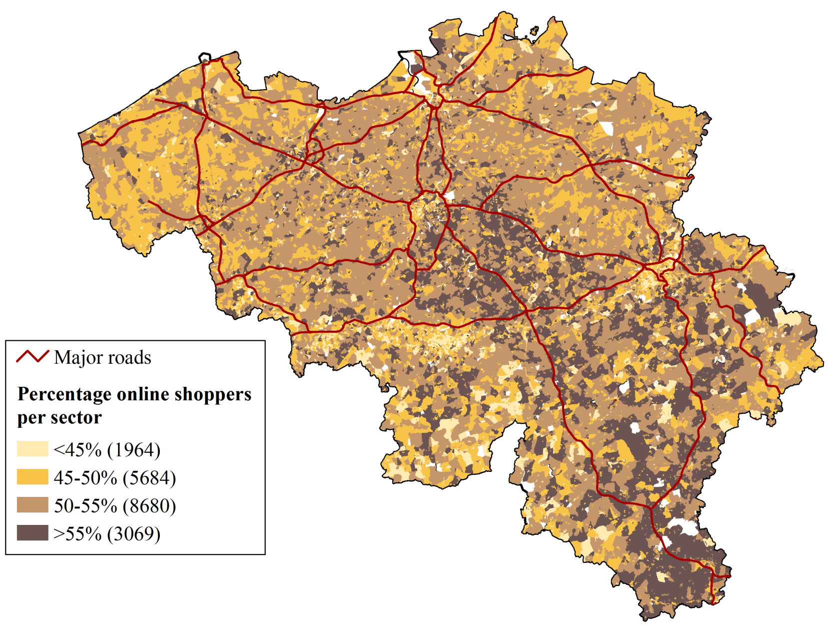
	Dependent variable: Bought online (Y/N)
Income 500-1249	.05
Income 1250-1749	.68
Income 1750-2499	.68
Income 2500-3249	1.25***
Income 3250-4250	1.30***
Income > 4250	.96
Gender male	.32***
Age 30-39	.28
Age 40-49	.05
Age 50-59	−.11
Age 60-69	.08
Age ≥ 70	−.98
High school	.54***
Higher education	.97***
Post-university	1.26**
Intercept	−1.09**
Observations	1,586
Log Likelihood	−1,011.84
Akaike Inf. Crit.	2,055.68
Note:	*p<0.1; **p<0.05; ***p<0.01

Source: own calculations with data Comeos have significantly lower probabilities for online shopping, which means their underrepresentation results in an overestimation of the total online shopping percentage in the survey. From this point of view, one can conclude that the real amount of Belgian shopping online lies somewhere between the model's estimation of 50% and the 57% derived from the survey.

The resulting geographical extrapolation is mapped in Figure 4.3a. The model predicts more buyers in the northern part of the country, in and around the large cities. Further, the traditional axis of industrial cities from Charleroi to Liège appears. Next to the few remaining rural areas in the northern part of Belgium, especially the southern, rural part of the country (the Ardennes) has fewer potential online shoppers. In addition, Figure 4.3b displays the percentage of online shoppers per statistical sector. This map demonstrates the spatial footprint of the interaction between the different impacting socio-economic variables which for example in Brussels results in lower percentages mainly in the low-income neighborhoods in the west of the agglomeration. A more elaborate discussion of these results is presented in the next section.



(a) Potential absolute amount of online shoppers per statistical sector



(b) Percentage of potential online shoppers per statistical sector

Figure 4.3: Extrapolation of the online buyers over Belgium. Source: own calculations.

4.5 Discussion

Because the logistic regression proves various socio-economic variables have a significant impact on the probability one buys online and assuming each online purchase is delivered at the shopper's residence, the demand for e-commerce deliveries is not evenly distributed over the population. For example, demand can vary drastically between two neighborhoods with similar population sizes but with contrasting income levels. Given that in Belgium relatively more lower income neighborhoods can be found in cities that have on average higher population densities, the urban e-commerce demand density might exhibit an inverse relation with the population density.

In other neighborhoods the socio-economic profile may enforce the differences in population density. For example, rich and densely populated areas with a large share of middle-aged highly educated families could yield very high concentrations of potential e-commerce demand. This is observed in the wealthy neighborhoods in and around Brussels and Antwerp. On the contrary rural areas with a poorer, less educated and elder population may show very low demand.

To assess the implication of the significance of some socio-economic parameters, the modeled e-shopper is overlaid with a null model in Figure 4.4. This null model is generated by assuming that 50% of the population in each statistical sector shops online, as predicted in step 2. The homogeneous distribution over the population represents the perspective of many stakeholders on the geographical distribution of the demand. Red areas identify statistical sectors where the full model predicts less than 50% of the population buying online, i.e. where traditional models overestimate the number of buyers. In Belgium, this is in northwest Brussels, around Antwerp, at the coast and in large parts of the Walloon industrial axis. While the large populations there ensure the absolute number of e-shoppers remains high (see Figure 4.3a), the density of e-commerce demand will not reach the levels the population density promises due to the lower socio-economic status of its residents. In some places, dissimilarities of over 50% between both models can be observed.

The light green patches in more suburban areas point to an underestimation of the potential number of e-shoppers in the null model. Although these patches occur frequently, the relative underestimation remains quite low with values between 10 and 25%.

Finally, in some parts of the most rural areas in the west and south of the country, fewer orders occur in the full model compared to the null model. This is also observed in Figure 4.3b with lower shares for these regions. The combination of a sparse population with less than average e-shopping probabilities results in a very low e-commerce demand.

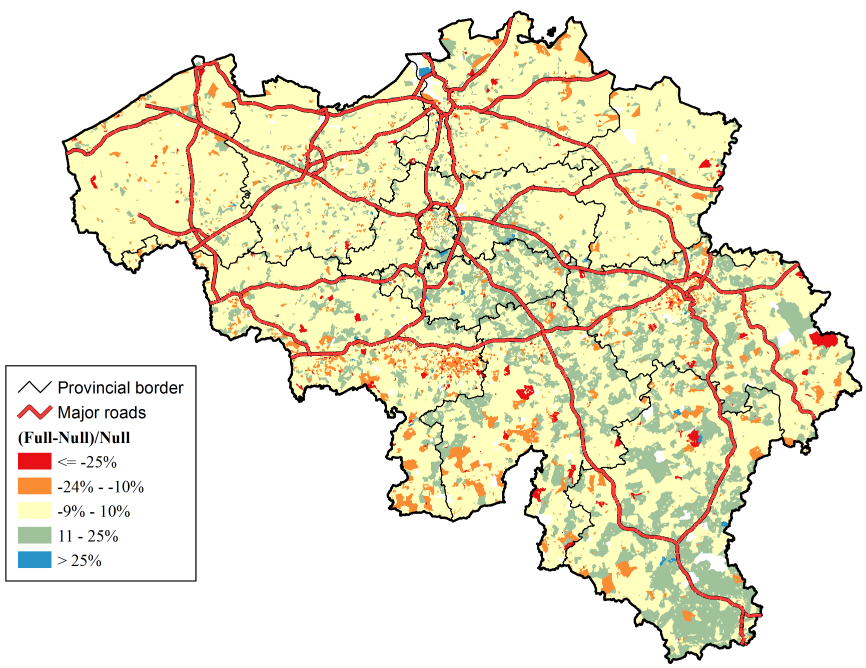


Figure 4.4: Modeled order density vs population density (manual breaks). Source: own calculations.

The differences between the full model and the null model in Figure 4.4 imply that, when distributing the e-shoppers homogeneously over the population, there will be under- and overrepresentations of the real e-commerce demand. These findings have significant value for practitioners and academics working with e-commerce market analyses. For example for logistics carriers concerned with the implementation of collection-and-delivery points (CDP). Originally installed to redirect not-at-home deliveries, these locations evolved to a means to consolidate shipments, hence reducing the delivery costs of the last mile (McLeod et al., 2006; Morganti et al., 2014a; Weltevreden, 2008). In addition, within the current competitive logistics sector, the size of the CDP network now has become an important service factor for logistics companies. Because of this, many carriers prioritize customer service and prefer a network with equal distances to their customers, or with a certain demand within their catchment area. However, since many carriers have difficulties to separate data on business-to-business (B2B) and business-to-consumers deliveries because they are transported and handled together, historical delivery data does not satisfy the requirements for this rather predictive analysis. Hence, carriers are obliged to turn to population statistics when implementing CDPs. Given the under- and overestimations of e-commerce demand depicted in Figure 4.4 however, these statistics may result in suboptimal location choices. While ignorance of the geographical variation in such decision models will not cause the bankruptcy of a carrier, its inclusion may provide a slight competitive advantage in this highly competitive market with very small margins.

A similar example can be provided for city administrators. Concerned with the negative impacts of the large amount of vans delivering freight in the city, a measure to regulate urban freight gaining popularity is the organization of cargo bike deliveries from micro-consolidation centers in the city (Gómez et al., 2017; Janjevic et al., 2013). Given the limited capacity of these bikes however, the key for success for these facilities is the minimization of the distance to the final customer. As numerous examples of bigger urban distribution centers proved however, the financial viability of these projects often turns out to be negative, mostly due to insufficient throughput volumes (Allen et al., 2007; Janjevic and Ndiaye, 2017). In this context, local variances in estimated demand, especially when being of a magnitude close to 50%, can significantly impact the business models of these hubs and may be the difference between an effective measure or a waste of public funding.

The value of information on the socio-economic profile of the e-shopper for retailers has already been mentioned in the first two sections. The knowledge that middle-aged higher income Belgians have a higher probability to shop online can help marketing divisions to better target their efforts. In the discussion of infrastructure investments, Kirby-Hawkins et al. (2018) provide the example of click-and-collect stores, which, similar to the previous two examples, can be better planned when including geographical variability in online shopping.

In this discussion, it is important to remark not all purchases are delivered at the home address of the shopper. For Belgium, it was calculated that 75% of the people prefer home deliveries, which means the remaining 25% choose work locations, drop-off points, pick-up points and brick and mortar stores for their deliveries (Comeos, 2016). Since most stores and offices are located within urban areas, a share of the suburban and rural orders that are delivered to work locations or the brick and mortars, will end up in urban areas. Hence, this implies a slightly larger share of urban deliveries compared to urban purchases and the opposite in rural locations. However, since this shift will be similar for both the modeled shoppers as well as the population, the presented results and discussion remain valid.

4.6 Conclusions

This Chapter seeks to provide insights into the spatial distribution of the demand for B2C e-commerce and its implications for sustainability analyses. Two research questions arise. Who is the online shopper? And where does he or she live? This demonstrates the extent to which the demand for e-commerce is proportional to the distribution of the population, as is often assumed. The case study area is Belgium.

The two research questions are answered by analyzing the dataset resulting from an online survey of over 1500 respondents concerning online shopping conducted by the Belgian retail federation (Comeos, 2016). First, the application of a logit regression allows the identification of the socio-economic variables that have a significant influence on the probability one shops online in Belgium. Similar to other studies in the Netherlands and the UK, the well-educated man in his thirties with a well-paid job has the highest probability to shop online. Whether this profile's shopping probability is due to time constraints, as proposed by Farag et al. (2007), or other incentives remains under study. Further, it appeared the urbanization level of an area does not have a significant impact on the shopping probability. This could be due to the historical lack of urban planning in the country, resulting in relatively high shopping accessibility throughout Belgium, which turns the efficiency hypothesis (Anderson et al., 2003) invalid in this case.

Second, the extrapolation of the statistical model allows the calculation of the number of shoppers in each neighborhood (statistical sector), thereby providing an answer to the second research question. Understandably most e-shoppers can be found in the dense urban areas, but the comparison of the absolute and relative numbers of shoppers displays clear discrepancies. As such, due to on average higher population densities in lower income neighborhoods, and the opposite in higher income urban residential areas, the urban demand density might exhibit an inverse relation with the population density. Yet, while it is the case in this particular study, this hypothesis may not hold in other contexts, for example in world cities with high-end high-rise buildings to accommodate their wealthiest residents in the city centre. In rural areas, where the lowest population densities often point to lower socio-economic classes, the contrary is observed, i.e. with income and education enforcing existing variations in e-commerce demand.

Finally, the confrontation of the extrapolated number of potential buyers with a null model, i.e. where it is assumed that 50% of the population shops online, independent of their socio-economic profile, indicates that the demand for e-commerce goods is not evenly distributed over the population, as many involved stakeholders assume. On the contrary, large variations in e-commerce adoption exist among richer and poorer urban and rural areas. Considering the importance of understanding the geography of the demand for online shopping in both academic and professional environments, one should at least acknowledge the role of geographical variation in this story.

Granted, this Chapter is an attempt to raise awareness on the importance of the customer in e-commerce analyses. Although the sampling used to select respondents ensures validity of the results, the analysis here remains a snapshot of the situation at the moment of the data gathering. This implies it remains difficult to conclude on the hypothesis presented by Anderson et al. in 2003. Since they are in essence related to an evolutionary process, a temporal analysis would be a more appropriate methodology. Even now, with continuous e-commerce growth over the past years, research on the evolution of e-commerce adoption would be relevant. The large international variance in e-commerce adoption rates, even between rather similar countries from a socio-economic perspective (cf. Figure 4.1), show that shopping online is not just dependent on the level of education or income one has. The detection of these other influencers is necessary when we want these findings to have an international value. Moreover, e-commerce is such a broad term. The popularity of the online channel varies greatly from one product to another, as may the predictors when attempting to model this variety. It may be clear that a lot of interesting thought for research remains.

Building on the latter point, another point of concern stems from the lack of differentiation among products bought. Because of this, this study sketches a profile of the general online shopper and equals it to the demand for goods. Nonetheless, the freight volumes and flows eventually depend on the type of good. Hence a more in-depth analysis of this, which could potentially fall in the class of freight trip generation models, would only further enhance demand estimations.

Remark here that any e-commerce transportation model should also take the variety in point-of-origins into account. In Belgium, 42% of the residents purchased at least one product online from abroad in 2018 (Eurostat, 2019). This significantly higher number than neighboring countries like Germany (27%) or France (33%) complicates the estimation of transport flows. Parcels are literally transported into the country from every side, bought on Amazon.de, Amazon.fr, Bol.com and other foreign webshops with distribution centers in their countries of origin.

Furthermore, it is important to note that this study is based on a single dataset concerning one aspect of the e-commerce story. Another interesting path for further research would be a cross-check with retail data, like in the case study of Leeds (Kirby-Hawkins et al., 2018), this would allow a better assessment of the impacts of the growth in e-commerce on traditional retail numbers and could help answering questions like: Does a higher probability of shopping implies a substitution effect in wealthier neighborhoods?

In addition, it would be interesting if follow-up work focuses on quantifying the extent to which differences among customers define home delivery impacts and alternative delivery solutions. This may help to better estimate the size of the absolute error that is made by assuming a homogeneous distribution of the demand in urban freight modeling exercises. The calculation thereof should be able to support the findings in this Chapter.

Finally, the question may arise whether stakeholders need this kind of modeled demand since carriers know where the deliveries are going to. However, as has been mentioned in the discussion section, it is often difficult for these companies to separate B2B and B2C data since these goods are mostly handled and delivered together. While it is true operational models could be built on top of this combined data, carriers often resort to population statistics for B2C market analyses, e.g. when implementing CDP networks. In addition, within this competitive environment data sharing is more exception than rule.

Because of the latter, the work in this Chapter can be of even more use for non-carriers involved in the topic. Given the major role (local) governments play in mitigating the negative impacts of B2C home deliveries, they too should be aware of the importance of socio-economic factors that can result in major demand variation at the neighborhood level. With only 50-57% of the Belgians shopping online, clearly not everybody is enjoying the wide range of opportunities e-commerce offers. Furthermore, as demonstrated in the discussion section, the spatial variations may influence the decision on the implementation of CDPs or the use of greener vehicles. While local policymakers can have a significant influence on the former, through infrastructure and urban planning, the latter too can be influenced by for example the delineation of low emission zones. In addition, coupled with freight trip generation models mentioned above, the analysis presented here can help to better understand traffic flows, potential vehicle types, loading space requirements and other freight parameters and thus provide a useful tool for local infrastructure design and mobility planning.

Hence, this study may help the different stakeholders involved to grasp the geography of the Belgian online shopper and its impact on related freight flows.

5

The proliferation of collection and delivery point networks in Belgium

The demand for e-commerce is scattered in Belgium. In absolute terms however, cities logically host the majority of potential online buyers (Figure 4.3a). With most intense consumer-logistics interactions occurring there, a new range of urban logistics facilities are being installed by the courier, express and parcel industry. This Chapter studies the rise of these facilities, with a particular focus on the proliferation of collection and delivery point networks.

5.1 Introduction

Cities currently host over half of the world population and generate 80% of total global GDP (The World Bank, 2018; United Nations, 2018). Each economic activity demands the transportation of goods, often through densely populated areas in cities that were not planned to accommodate these flows. Freight transport shares the urban infrastructure with pedestrians, cyclists, public transport and private car users and as a result, its social, environmental and economic impacts should not be ignored (Browne et al., 2012; Dablanc, 2007; Lindholm, 2013).

In addition to the growing need of goods in cities due to continuous urbanization and economic growth, changing consumer demand further complicates the organization of urban logistics activities. With the breakthrough of e-commerce, one can with equal effort order goods from web shops all over the world. Due to increased competition, web shops are now regularly offering free deliveries, free returns, time windows and ever shorter lead times (Allen et al., 2017). This customer expectation of fast free home deliveries results in an excessive fragmentation of freight shipments (Gevaers et al., 2011; Hesse, 2002).

As a consequence, the CEP industry faces the challenge to cope with an increasingly complex and expensive last mile of the supply chain, which is especially difficult within the constrained urban areas (Ducret, 2012). To meet the changing consumer demand of home deliveries, on-time deliveries, next-day deliveries, multiple delivery attempts and free return services, the industry is now reinvesting in (urban) logistics locations. Although all parcel carriers face this challenge, there is little cooperation among them, resulting in a highly competitive environment with low profit margins and a notion that '*everyone delivers everywhere*' (Browne et al., 2014).

This is also reflected by the current proliferation of various CDP networks. While originally being the location to drop failed deliveries and a more sustainable delivery alternative for home deliveries, CDPs are becoming an expression of the courier's service level in today's competitive market. Carriers are opening CDPs to increase local presence and improve their delivery options. However, a strategy of quantity over quality may result in questionable decisions regarding location and type of new CDPs. This could lead to economic, environmental, social and spatial impacts that may jeopardize the sustainability promise of these points (Cárdenas and Beckers, 2018). For example, barely prepared local shop owners turned warehouse operators often struggle to accommodate the influx of parcels in small inner-city establishments. Moreover, the lack of proper loading facilities results in similar parking issues as for home deliveries, while the amount of CDPs implies a trade-off between the internal and external costs of the delivery (Cárdenas et al., 2017c). In the meantime, consumers prefer to avoid the hustle of visiting multiple CDPs to collect different shipments by favoring the delivery of parcels at their home address.

Building on previous work describing (parts of) the CDP sector in France (Morganti et al., 2014a), the Netherlands (Weltevreden, 2008) and Brazil (de Oliveira et al., 2017), this Chapter further details the location decision process of CDPs and the resulting impacts, both geographical as operational. This is done by means of a mixed method analysis applied to the case of Belgium. Belgium is an appropriate study area for this problem statement because it is a highly urbanized and economic prosperous country where most international carriers are active. The case study is elaborated by an assessment of all CDP locations in the country, gathered by the Belgian Institute for Postal and Parcel Services (BIPT). This exploratory spatial data analysis is complemented with a qualitative evaluation of current types of CDPs based on a range of interviews with the different carriers operating in Belgium. By outlining the economic, environmental and convenience impacts of different store choices, this Chapter should become a valuable document for stakeholders concerned with the current development of CDP networks.

In Section 5.2, CDPs are discussed in detail, including their increasing presence in urban areas and how they compare to other last mile facilities. The methodology is provided in Section 5.3. Section 5.4 focuses on the current proliferation of these CDP networks in Belgium. This section is subdivided in three parts: the first part describes the origin of the proliferation and lists CDP requirements based on the existing relevant literature and a set of conducted interviews; the second part presents quantitatively the issues found in the Belgian case study using the location data of the BIPT; the third part proposes an assessment of different types of CDPs. Section 5.5 provides theoretical and operational conclusions of this work and gives recommendations for further research.

5.2 The rise of urban logistics spaces

The boom in online sales has altered the spatio-temporal requirements of CEP companies. Addressing the shift towards smaller shipments and shorter lead times, combined with increasing land rents, requires a geographical reconfiguration of the supply chain and a wide variety of e-fulfillment facilities (Dablanc et al., 2017; Durand and Gonzalez-Feliu, 2012; Morganti et al., 2014b; Winkenbach and Janjevic, 2017). Firstly, in contrast to traditional business-to-business purchases, business-to-consumer online orders consist of significantly fewer items, resulting in a fragmentation of shipments (Gevaers et al., 2011; Hesse, 2002). Combined with extensive online catalogues and sufficient online activity, managing the logistics requires dedicated e-fulfilment infrastructure in parallel to existing distribution chains (Durand and Gonzalez-Feliu, 2012). The amount of cross-docking facilities required to minimize transportation costs depends on the parcel volumes, the origin of the goods and the size of the market. Secondly, the inventory scheme is determined by the order lead time, with faster flowing items requiring storage in closer proximity to the market (Durand and Gonzalez-Feliu, 2012; Winkenbach and Janjevic, 2017). The epitome – same-day deliveries – requires products to be locally available. Finally, at a more detailed geographical scale, the logistics location depends on the rent gradient (Verhetsel et al., 2015). High rents in urban areas are pushing logistics activities to peripheral regions, generating a logistics sprawl which results in an increase in vehicle kilometers and associated negative impacts (Dablanc and Rakotonarivo, 2010). While uniformly high rent in metropolitan areas may provide an economic reason to locate larger logistics facilities closer to the city center (Combes, 2016), the sector has to compete with retailers, office space and residential real estate which generate higher returns per square meter.

The delivery scheme(s) a carrier chooses for e-commerce deliveries determines the type of logistics infrastructure needed. Various researchers have proposed different typologies for last-mile distribution schemes and corresponding infrastructure (Boyer et al., 2004; Hayashi et al., 2015; Winkenbach and Janjevic, 2017). Winkenbach and Janjevic (2017) have identified ten different types based on a set of five locational and operational variables: order lead time, place of order preparation, route organization, intermediate transsshipment and product exchange point. However, the chosen setup depends on the local context and changes from one market to another. For example, while it is not uncommon in the US to leave parcels unguarded at suburban porches when the receiver is not at home, this practice would not be accepted by European customers. This required carriers to look for alternatives in these situations. In addition, the continuous exponential growth of online sales forces logistics players to innovate continuously, for example to maintain enough storage close enough to the end consumers. As a result, a wide portfolio of different e-fulfilment facilities are actually developed.

Given the increasing complexity of delivering in urban areas, most innovations take place in cities. On the one hand, the negative impacts of deliveries for purchases made online, including congestion, pollution and noise, are more pronounced in densely populated areas, creating a need for effective mitigation strategies (Cárdenas et al., 2017a). On the other hand, the high urban demand provides more consolidation opportunities and allows for the use of green vehicles that would otherwise suffer from capacity or range problems (e.g., bikes and electric vehicles) (Behrends, 2016). These alternatives, however, typically require specialized infrastructure, sometimes called *urban logistics spaces* (ULS) (Boudouin, 2012; Janjevic et al., 2013; Patier and Toilier, 2017).

Boudouin (2012) coined the term ULS to refer to the variety of urban logistics zones, urban distribution centers, vehicle reception points, goods receptions points and urban logistics boxes that were created to handle the wide range of goods flowing throughout the city (Table 5.1). These spaces are categorized based on their logistics functions and action radius. While the term ULS has been popular in mostly French literature, more recent international work has built on the Boudouin's five categories to describe the increasing variety in urban logistics infrastructure. Janjevic et al. (2013) added three varieties of micro-consolidation centers to the typology that encompass the processes created to downscale the consolidation effort: (1) urban consolidation centers (UCC) closer to the delivery area (i.e., the original micro-consolidation center idea), (2) a suburban depot with transshipment point in the city (in essence a combination of a UCC and vehicle reception point) and (3) a suburban depot with mobile logistics facility. Patier and Toilier (2017) included mobile urban logistics spaces as a sepa-

Table 5.1: Relation of proposed typology with previous ULS typologies

Urban Logistics Space	Boudouin (2012)	Janjevic et al. (2013)	Patier and Toilier (2017)
Urban logistics zone	Urban logistics zone	Urban logistics zone	Urban logistics zone
Urban distribution center	Urban distribution center	Urban consolidation center	Urban distribution center
Micro-consolidation center	/	Micro-consolidation center (types 1 and 3)	Mobile ULS
Express fulfilment facility	/	/	/
Vehicle reception point	Vehicle reception point	Vehicle reception point; Micro-consolidation center (type 2)	Vehicle reception point
Collection and delivery point	Goods reception point; Urban locker box	Goods reception point; Urban locker box	Goods reception point; Urban locker box

Source: own composition

rate category, but failed to position it in the scheme originally proposed by Boudouin (2012). Similar to these three versions of ULS, Table 5.1 summarizes the occurrence of ULS from the focus on the last mile of e-commerce deliveries. Discrepancies from the original typology mainly arise from the specific requirements of business-to-consumer deliveries that require dedicated facilities, e.g. express fulfilment facilities for 2-hour deliveries. Although the original terminology is followed as much as possible, urban locker boxes and goods reception points are grouped under the collection and delivery point umbrella to better connect to the growing body of literature focusing on the delivery of online orders (Allen et al., 2017; Dablanc et al., 2017; Morganti et al., 2014b; Rodrigue, 2015; Winkenbach and Janjevic, 2017). The final typology is presented in Figure 5.1 while its relation to earlier categorizations is outlined in Table 5.1.

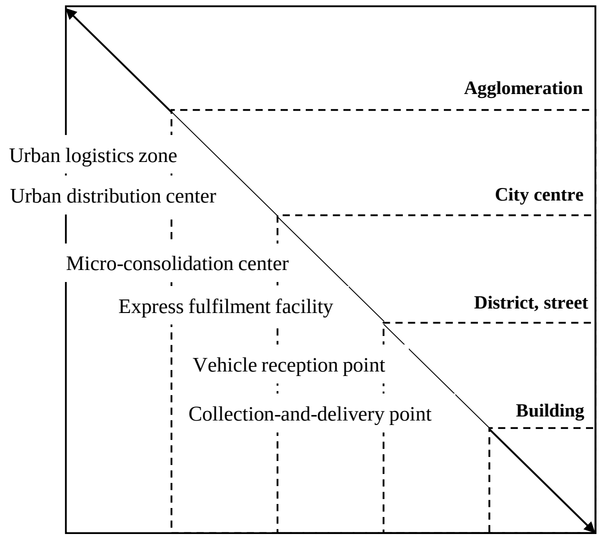


Figure 5.1: Urban logistics spaces. Source: adapted from Boudouin (2012)

The *urban logistics zone* (ULZ) or freight village (McKinnon, 2009) is an intermodal logistics hub that combines modal shift with other logistics services such as warehousing, breaking bulk and others. While this facility may be reserved for urban shipments in large metropolitan areas, it is mostly active on the regional, national and international scale. Due to their size and intermodal requirements, they are located in urban conurbations (Patier and Toilier, 2017). Spatial decentralization of these activities has been observed in many countries , mostly due to increasing land pressure and congestion (i.e., logistics sprawl) (Dablanc and Rakotonarivo, 2010; Strale, 2017; Woudsma et al., 2016). Due to the extra kilometers and externalities associated with this sprawl, these villages should be kept within the city (Boudouin, 2012). Recently, the city of Paris started implementing logistics hotels to cluster logistics facilities within mixed-use multimodal platforms inside the city's boundaries. This should facilitate consolidation among carriers and stimulate the use of greener transport vehicles (Allen et al., 2017; Dablanc et al., 2017). Combining logistics facilities in a mixed-use building is necessary to warrant the large space requirements in expensive urban areas. The Paris Chapelle logistics hotel maximizes its land use by combining a street-level intermodal (railway and road) urban delivery terminal with an underground datacenter, roofing with sports facilities and urban farming, and an attached office block.

At a higher geographical scale, *urban distribution centers* (UDCs) are transshipment points that prevent partially loaded vehicles entering urban areas and allow the use of more sustainable vehicles (e.g. electric) because of their increased proximity to the consumer (Allen et al., 2012). UCCs are classified under the same umbrella. While UDCs are associated with the operations of a single carrier, the term UCC is used more often in a multi-user context. The idea behind the latter, i.e. to consolidate goods of different carriers and distribute them by one clean vehicle from the city's border, has been a popular measure among public authorities already for a long time (McKinnon, 1998). Yet, financial viability and trust remains an issue. Foremost, high investment costs and a minimum throughput are required, which demands external support in the starting phase (Allen et al., 2012; Janjevic and Ndiaye, 2017). Moreover, successful introduction seems to be dependent on accompanying restrictions implemented by local governments, such as restricting vehicles not using the UDC (Allen et al., 2012; Gonzalez-Feliu et al., 2013).

The bundling of goods can also happen much closer to the final destination. In that case the UDC is termed a *micro-consolidation center* (Janjevic et al., 2013). Because of the smaller scale and limited remaining distances which benefit the use of green transport modes, such as cargo bikes or light electric freight vehicles, this solution can be economically sustainable in dense urban areas. The small scale further allows more flexibility, which permits targeting a specific sector instead of hosting all freight flows, which is often the scope in UDCs. For example, this advantage resulted in a successful trial in the case of an office supplies company in London (Browne et al., 2011). In addition, branded vans still enter urban areas because consolidation occurs close to the receiver. While the disappearance of the brand name from inner-cities may prevent carriers to participate in UCC trials, this becomes less of an issue for micro-consolidation centers. Janjevic et al. (2013) propose three different variations of micro-consolidation centers, including the use of a mobile hub which can, for example, be deployed to deliver on summer festivals.

As a result of the increased amount of online ordered goods and the increasing demand for express or same-day deliveries, local stock availability is becoming more and more important (Allen et al., 2017; Dablanc et al., 2017). The term *express fulfilment facilities* is proposed to encompass the infrastructure for this purpose. Two alternatives are frequently discussed in literature: brick-and-mortar shops and infill locations. Brick-and-mortars are regular shops typically located close to consumers in urban areas, which makes them attractive to become part of the e-delivery chain. This applies to both original brick-and-mortars that have a web shop and pure internet players that are considering a physical store (Allen et al., 2017). This has two advantages (Hayashi et al., 2015): on the one hand, the availability of storage space close to the consumer allows for express deliveries; on the other hand, these shops can serve as pick-up points for click-and-collect orders, which also increases the number of shoppers passing by. This way the store, located in prime retail areas, is becoming a multifunctional space as showroom and warehouse (Dablanc et al., 2017). Infill locations (Dablanc et al., 2017) are defined as vacant locations within urban areas that can be re-purposed for logistics activities (Spencer et al., 2016). When stocked with the most popular items they can serve as a mini e-fulfilment center for express deliveries. Due to their preferred location in expensive urban centers, however, their size must be limited. While currently only a few of these facilities exist, e.g. Amazon Prime Now hubs in major American cities, their development may be one of the key evolutions going forward (Dablanc et al., 2017; Prologis, 2016).

Vehicle reception points are defined as spaces facilitating the parking of delivery vehicles (Boudouin, 2012). Patier and Toilier (2017) identify two subclasses: on-street loading bays and road time-sharing spaces. The latter refers to parking spaces dedicated to delivery vehicles, potentially with time windows for shared use with other vehicles. Especially in densely populated areas that are not prepared for high volumes of commercial freight, the lack thereof poses significant congestion problems (Chen et al., 2017). The on-street loading bays are micro-platforms that provide reserved parking space within dense urban areas. They serve as shared drop zones from where the final feet of the delivery is conducted on foot or by (electric) bike (Allen et al., 2007; Gonzalez-Feliu et al., 2013). Various on-street loading bays have been successfully implemented in France under the name espaces de livraison à proximité (ELP) with the help of local authorities (Browne et al., 2012; Ducret, 2014; Gonzalez-Feliu et al., 2013). Other translations of this term include proximity logistics spaces and nearby delivery areas (Allen et al., 2017; Patier and Toilier, 2017).

Finally, the increase of single-item home deliveries comes with the new challenge of failed deliveries. Compared to businesses that are open during delivery hours, the B2C receiver in Belgium is not present in an estimated 8% of the delivery attempts. Failed deliveries result in extra kilometers, costs and externalities for carriers engaging in multiple delivery attempts (Gevaers et al., 2011; McLeod et al., 2006; van Duin et al., 2016). In an attempt to handle these impacts, the CEP sector introduced *collection and delivery points*. CDPs provide an alternative delivery location for (failed) home deliveries. The term CDPs is more commonly used than goods reception points in the urban logistics literature. Further, CDPs encompass goods reception points, here called pick-up points (PPs) and urban locker boxes, which are more widely known as automated parcel systems (APSs) or automated delivery stations (ADSs) (see Table 5.2). PPs are an attended service point for the reception and return of parcels; APSs are an unattended locker box with similar functions (Weltevreden, 2008). Compared to traditional PPs, APSs require less space and are therefore easy to implement in busy commuting areas like train stations (Iwan et al., 2016). However, because the number of lockers in a box is fixed, APSs are more vulnerable to capacity problems, especially in the case of oversized parcels or at peak moments (e.g. Black Friday or Cyber Monday). In addition, the storage of unattended parcels in lockers may pose security issues, e.g. theft of parcels or terrorism (Morganti et al., 2014b; de Oliveira et al., 2017). CDPs allow the consolidation of (failed) parcels into one location with a 100% success rate, significantly reducing the number of delivery van kilometers (Cárdenas et al., 2017b; Edwards et al., 2010; McLeod et al., 2006; Van Oosterhout, 2004). With the increase of home delivered online orders, CDP networks recently expanded exponentially in urban as well as in rural areas. With over 36,000 CDPs in Germany, 18,000 in France in 2014 already and 4,200 unique ones in Belgium, these points are by far the most encountered logistics spaces in the e-delivery chain (Morganti et al., 2014b).

Because this recent expansion occurred rather unplanned, several negative impacts due to problematic store and location choices are now observed. There are multiple CDPs at many locations due to the

Table 5.2: Terminology of collection and delivery points

	Collection and delivery points	
Service	Attended	Unattended
Terminology	• Pick-up point (PP) • Goods reception points • Service Points	• Locker box • Automated parcel system (APS) • Automated delivery station (ADS)

Source: own composition

eagerness of carriers to be present at the same location but their unwillingness to share the same store. Moreover, many CDPs do not have the necessary storage and unloading capacity to handle the stream of parcels. The handful of works on the geographical distribution of urban CDPs (Morganti et al., 2014a; Weltevreden, 2008) mainly focused on the potential to reduce freight in urban areas and did not consider the aforementioned negative consequences of proliferation of CDPs. In the remainder of this Chapter, the focus lies on the origin, observation and mitigation of these consequences.

5.3 Methodology

This Chapter applies a mixed-method methodology to study the location decision process of CDPs and the resulting geographical and operational impacts. The qualitative results are obtained from (1) a combination of interviews with retailers, local governments, and couriers, (2) key note lectures and discussions on urban logistics conferences and workshops, and (3) reviewing recent relevant popular and academic literature. Further, five additional semi-structured interviews were conducted with representatives responsible for managing the CDPs in their respective companies (DHL Parcel, DPD, GLS, Kariboo, UPS). Together, their companies manage 60% of all CDPs in Belgium. The interviews consisted of four parts: (1) the evolution of the company's CDP network was assessed by asking for the strategies behind its development, (2) the actual location model used for implementing CDPs was discussed, (3) the operational aspect of the CDPs are reviewed (i.e., how they are delivered), and (4) the potential for cooperation among companies and the possibility for price differentiation between home and CDP deliveries was asked. In addition to this qualitative analysis, the ESDA results presented in Section 5.4 are derived using data provided by the BIPT. The BIPT has gathered data on the location and service levels of the 9 carriers operating CDPs in Belgium (BIPT, 2018).

Section 5.4 consists of three parts. In Section 5.4.1, the different dimensions of CDPs are identified based on the qualitative methodology elaborated above. This is necessary to understand the drivers behind the expansion of CDP networks. The Section concludes with a practical translation of the three dimensions (economic, environmental and convenience) into a set of requirements for CDPs to meet. Section 5.4.2 presents the ESDA of CDPs in Belgium. This geographical analysis allows assessing the spatial impacts of the current network configurations. In Section 5.4.3—, the quality of existing CDPs in Belgium is assessed based on the requirements listed in Section 5.4.1. The assessment incorporates expert knowledge of the author and collaborators and its results are discussed during the five interviews with the carriers. To the best of the author's knowledge, this study is the first in its kind and therefore may serve as a foundation for future research.

Belgium serves well as a case study due to its particular settlement structure. On the one hand, densely populated city centers with pre-modern unstructured street grids and inner-city shopping areas pose serious constraints on urban freight. On the other hand, urban sprawl and peripheral shopping locations along transport axes result in a nebular structure with the Flemish Diamond between Antwerpen, Gent, Brussels and Leuven in the north and the traditional Walloon industrial axis south of Brussels (Van Meeteren et al., 2016). In contrast, the rural south of the country, the Ardennes, is characterized by a dotted landscape of villages. With currently an estimated e-commerce adoption rate of 68%, most Belgian e-shoppers are located in the urban areas. Yet, due to high internet penetration rates and a wealthy suburban population, online shoppers can be found everywhere, implying delivery services must be guaranteed across the country (see Chapter 4). In addition, Belgium's central location in Western Europe ensures the presence of almost all major international carriers.

5.4 The proliferation of CDP networks

5.4.1 The economic, environmental and convenience dimensions of CDPs

CDPs promise a cheap, environmentally-friendly and convenient delivery option for B2C e-commerce purchases (Cárdenas and Beckers, 2018). Hence, their implementation is of interest to all stakeholders involved: logistics carriers, policy makers, consumers and shopkeepers (Table 5.3). In the paragraphs below, the different dimensions of CDPs and their value for the various stakeholders are discussed.

Table 5.3: Stakeholder incentives in the three CDP dimensions

Stakeholder	Economic	Environmental	Convenience
Carrier	X		X
Policy maker		X	
Consumer			X
Shop keeper	X		

Source: own composition

The economic advantages of CDPs for logistics carriers are threefold. First, CDPs offer a 100% delivery success rate while multiple delivery attempts may be needed for home deliveries due to absence of the receiver. This results in an efficiency gain for direct CDP deliveries. Figure 5.2 schematically compares different delivery models. The aforementioned efficiency gain is visible in Figure 5.2 (only 1 trip necessary in model 2 compared to model 1). Second, direct delivery to CDPs allows for consolidating shipments for a certain neighborhood. This increases the drop density and significantly diminishes the total driven kilometers and hence costs per parcel (total carrier distance is smaller in model 2 than in model 1 in Figure 5.2). Third, many carriers organize the return of parcels or the outbound of other mail (mostly C2C) from the CDPs. This allows them to pick up goods after the parcels destined for the CDP have been unloaded. These economies of scope ensure an optimal use of van space. The introduction of CDP activities will also generate additional income for the shopkeeper: both through a fixed tariff per parcel and indirectly through potential extra sales to people picking up their parcel. In order to fully achieve the economic potential of CDPs, carriers require an effortless delivery process. This means the delivery to the CDPs should not pose any new restrictions or difficulties compared to home deliveries. Meanwhile, shopkeepers expect additional shop turnover when becoming a CDP.

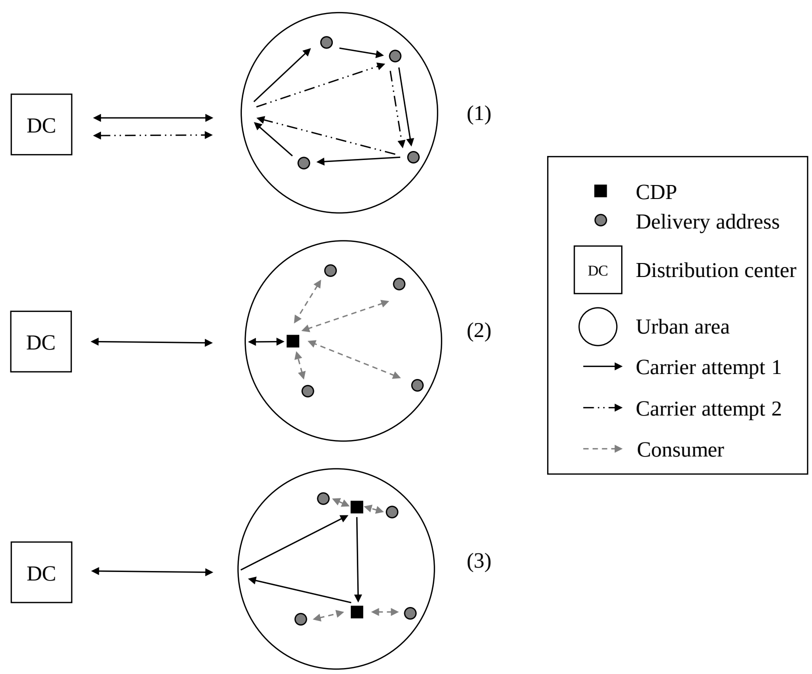


Figure 5.2: Delivery models for (1) multiple home delivery attempts with CDP used for failed deliveries, (2) direct peripheral CDP deliveries, (3) direct central CDP deliveries. Source: own composition.

In addition to the economic advantages, CDPs may allow for a more environmentally-friendly e-delivery process. As has been mentioned above, consolidating several home deliveries into a direct CDP delivery would result in significantly fewer kilometers driven, which would lead to less congestion, fewer emissions, fewer traffic accidents, and a lower impact on the urban livability. Especially when the CDP offers a suitable logistics infrastructure, negative impacts such as incorrectly parked delivery vans should not occur. However, the environmentally-friendly potential strongly depends on the distance of the CDP to the consumers (cf. total consumer distance between models 2 and 3 in Figure 5.2). Assuming that the points are close enough to prevent car-use for the pick-up trip, Edwards et al. (2010) calculated a net reduction in CO_2 emissions when CDPs are used instead of a second delivery attempt. Under the same assumption, Durand and Gonzalez-Feliu (2012) found that in a situation where all parcels are delivered to CDPs, the total kilometers and thus negative impacts per parcel are significantly reduced. When distances between the consumers and the CDP are too large, CDPs can still be a more environmentally-friendly alternative if the pick-up can be combined with another trip (Iwan et al., 2016; Lachapelle et al., 2018). However, when delivery densities are sufficiently high and/or pick-up distances increase and pick-ups are not combined with existing trips, home deliveries may be the lowest carbon scenario (Brown and Guiffrida, 2014; Cárdenas and Beckers, 2018). In conclusion, to achieve its environmentally-friendly potential, the CDP should be equipped for effortless loading and unloading, and allow for green pick-ups.

Finally, CDPs also allow for a convenient delivery. For the consumer, the availability of CDPs provides more flexibility. In case of a failed delivery, there is now the option to pick-up the parcel at a suitable moment. The availability of nearby CDPs even increases consumer's satisfaction (Edwards et al., 2010; Xiao et al., 2017). The interviews indicated that, as observed in France (Morganti et al., 2014a), most operators delivering in Belgium recently expanded their CDP networks in an attempt to assure a homogeneous spread of CDPs among the population. To maintain the service standard of home deliveries, the CDPs must be able to cope with the reception, storage and exchange of parcels and continuous tracking is recommended. However, the size of the CDP network now has become an important selling point for carriers when competing for customers, encouraging a strategy of quantity over quality. As a result, a proliferation of CDPs can be observed, especially in densely populated, hence urban, areas (Cárdenas and Beckers, 2018; Morganti et al., 2014a). In conclusion, to serve as a convenient delivery alternative, CDPs must be accessible for consumers, and reliable for carriers.

To assess the quality of a CDP in relation to the three dimensions (economic, environmental, convenience), a practical translation of these dimensions is necessary. CDPs should meet eight requirements to satisfy all dimensions. These requirements are classified in three groups: location, infrastructure and services. They were identified based on the expectations of the different stakeholders mentioned above. The relation between the dimensions and requirements is provided in Table 5.4.

The location class in Table 5.4 refers to the positioning of the CDP in relation to its surroundings. As discussed above, the CDP should be accessible to both the carrier and the receiver. The former is termed here *upstream* accessibility as proposed by Janjevic et al. (2013). It refers to the proximity of the CDP to a large transportation axis. Good upstream accessibility implies good access from the upper-tier logistics facility located further away from the consumer, or in case of an on-tour drop, easy access between two neighborhoods. The receiver's accessibility is divided in a *downstream* and *commuting* requirement. The downstream accessibility refers to the proximity of the CDP to the final consumer. A closer proximity results in a more frequent use of green transportation for the pick-up trip. In addition, the availability of nearby CDPs increases consumer satisfaction. The commuting requirement refers to the potential to combine a pick-up trip to the CDP with a daily commute. This can be the case for CDPs located next to important transportation corridors, or in public transportation hubs. Hence, these CDPs too may classify for green pick-ups or convenient accessibility.

The infrastructure class groups two essential infrastructure requirements for CDPs: loading bays and storage. This class results from the CDP's role as warehouse, i.e. as an extra tier in the supply chain. The *loading bay* is a parking spot reserved for the delivery vehicle. Similar to the upstream requirement, it is an indispensable feature of a CDP to allow for a smooth delivery process because the driver is not losing time looking for a parking spot. In addition, it prevents illegal parking and associated impacts. *Storage* refers to an area in the store reserved for storing the parcels, required for efficient loading and unloading, and necessary for the reliability of the CDP. Without enough dedicated storage space, the chances for parcels to get lost increase significantly.

Finally, CDPs can be differentiated by the level of services they provide to the consumer (services class in Table 5.4). The opening requirement is linked to the opening time window of the CDP. Longer opening times and weekend openings represent a higher convenience for consumers. The presence

Table 5.4: Requirements for economic efficient, environmentally-friendly and convenient CDPs

		Economic		Environmental		Convenience	
		Effortless delivery	Additional shop turnover	Impactless (un)loading	Green pick up	Accessibility	Reliability
Location	Upstream	X				X	
	Downstream				X	X	
	Commuting				X	X	
Infrastructure	Loading bay	X		X			
	Storage	X					X
Services	Opening					X	
	Attended					X	
	Trip chaining		X		X		

Source: own composition

of a person in the CDP is reflected by the attended requirement. This affects the convenience for consumers, especially for sending of parcels, as was brought up during the interviews with the carriers. Finally, the potential of the CDP to allow combining different trips is captured by the trip chaining requirement. The interviews with the carriers and previous conversations with retailers indicated most pick-ups are dedicated trips and hence, the increased profit for shopkeepers is limited. This appears to be especially the case in situations where the store sells periodical (e.g. shoes) or exceptional goods (e.g. electronics). Stores that sell more frequently consumed goods (e.g. groceries) seem to have a higher probability to receive extra income from the pickup trip by the consumer. This discussion also applies to the value of the trip chaining requirement for satisfying the green pickup expectation: there is more potential for combining trips if the CDP is located in a store selling frequently consumed goods.

The evolution where every carrier now seemingly *ís everywhere* seriously hampers the economic, environmental and convenience potential of the CDPs: the more CDPs to be delivered to, the lower the drop ratio per point resulting in less economies of density. In addition, more points imply more kilometers, hereby jeopardizing the environmental potential (cf. total carrier distance between models 2 and 3 of Figure 5.2). Moreover, far from all CDPs satisfy the requirements listed in Table 5.4. The spatial footprint of this proliferation in Belgium is elaborated in the following sections.

5.4.2 The spatial pattern of the CDP landscape in Belgium

The Belgian CEP sector comprises several small and large carriers. In terms of revenue, TNT represents the largest market share (20-25%) in e-commerce parcel deliveries. These include both B2B and B2C deliveries, as carriers typically do not report statistics on the separate streams. TNT is followed by the Belgian Post and UPS (both 15-20%), and DHL International (10-15%). In terms of volume, the Belgian Post holds the largest market share (25-30%) followed by DPD and UPS (both 15-20%) and GLS (10-15%). Of the seventeen major players operating in Belgium, thirteen handled B2C parcels in 2016. Of these thirteen, nine maintain a network of Collection and Delivery points (CDP) (KPMG, 2017).

In June 2018, after aggressively expanding their networks, the nine different players offered combined

Table 5.5: Collection and Delivery points (CDP) and Automated Parcel Systems (APS) comparison of Belgium within Europe

	Belgium	Estonia	France	Germany	The Netherlands	Spain	Sweden
CDP per 10,000	6.6[1]	/	8.7[2]	6.9[2]	5.1[2]	0.9[2]	3.7[2]
APS per 10,000	0.16[1]	2.0[3]	/	0.48[3]	/	0.73[3]	0.07[3]

Source: own calculations with data [1]BIPT; [2]Piepers (2018); [3]Zurel et al. (2018)

a total of 4400 unique CDPs. 2612 of these points receive parcels from different carriers with 78% of these shared points used by two different carriers, 14% by three, and the remaining 8% by at least four. Summing the advertised number of points from the different carriers results in a total of 7864 options. The effort by the BIPT to gather CDP data from the different carriers is unique; information on other countries are collected by consulting the websites of the various logistics players (Piepers, 2018). Although the number of CDPs for Belgium that Piepers (2018) calculated is not an exact match to the number provided by the BIPT, they are some order of magnitude, allowing for comparison among the countries. The findings by Piepers (2018) are used to calculate an approximate CDP density in different European countries (Table 5.5). It was unclear if Piepers (2018) included locker boxes in his CDP data results. The second row in Table 5 presents Automated Parcel Systems (APS) data for a limited number of countries based on a recent publication by the BIPT (Zurel et al., 2018). Although the quality of Piepers (2018) is unknown, it appears the Belgian CDP network is developed averagely compared to other European countries. The locker system in Belgium with only 186 unique points is significantly underdeveloped compared to attended pick-up points. Capacity restrictions appears to be the biggest barrier for development. All lockers, except for two, are managed by the company Cubee, which is integrated with the systems of Bpost, DHL, GLS and DPD. This provides a prime example that cooperation among carriers is possible.

Table 5.6 presents various metrics for the two types of CDPs (PPs and APS) The degree of urbanization is derived by using the definition of the European Commission (Dijkstra and Poelman, 2014).

Based on a 1 km^2 population grid generated from national population statistics and the CORINE land cover map, urban refers to contiguous grid cells with at least 1500inh/km^2 (i.e., the cities), urbanized to less densely populated suburban areas and smaller towns (min. population of 5000 and density of 300inh/km^2), and rural to sparsely populated areas. The spatial distribution of the PPs appears to follow that of the population. However, there is a slight underrepresentation of PPs in urban compared to rural areas. This is due to the lower population density in the latter, which requires carriers to install more PPs in order to maintain the service level. In contrast, the majority of APSs are located in urban and urbanized areas. The lockers can mostly be found in train stations, post offices, super markets and gas stations.

The low population density in rural areas is reflected by the low share of rural population within a 1km radius of a CDP. The radius threshold is set 1 km because for distances more than 1 km, the car is the preferred transportation mode (Declercq et al., 2017). The majority of households within a 1km radius are assumed to walk or bike to the CDP, hereby fulfilling the condition for the CDP to be an environmentally-friendly alternative to home deliveries. The potential to consolidate parcels in the CDP is indicated by the average population within 1km (column 7 of Table 5.6). Urban CDPs are more efficient than those in urbanized and rural areas due to a higher total and density of population. On average, urban CDPs catch 60% more people within a 1 km radius than urbanized CDPs and more than three times more people than rural CDPs.

The CDP networks in Belgium are considered fairly well developed because 94% of the urban population lives within 1 km from a CDP, and 99% of the whole country lives within five kilometers of a CDP. Whether or not the ultimate goal for society is a full 100% of the population within walking distance remains open for debate (Cárdenas et al., 2017c). An increase in CDPs involves more stops for delivery vans and, especially in remote areas, a decrease in the average population within their catchment area.

Although an increase in coverage in urbanized areas is possible, with already 69% of the Belgian population living within walking distance of a CDP, the current CDP network offers the potential for

Table 5.6: Pickup points in Belgium

	Total PPs	Total APSs	Share of Population	Share of PPs	Share of APSs	CDP per capita	Avg population within 1km	Share of population within 1km	Share of population within 5km
Urban	944	69	28%	25%	37%	3.3 per 10,000	2,804	94%	100%
Urbanized	2213	107	55%	53%	58%	3.8 per 10,000	1,718	65%	100%
Rural	1057	10	17%	22%	5%	5.7 per 10,000	746	42%	98%
Belgium	4214	186	100%	100%	100%	4.0 per 10,000	1,732	69%	99%

Source: own calculations with data BIPT (2018); Statistics Belgium (2014) high environmentally-friendly deliveries. However, because only 58% of these points are shared by at least two carriers, the population share within walking distance decreases significantly when considering individual networks (see Figure 5.3). Only the Belgian national post (and DHL Parcel given that they make use of the same network) catches more than 50% of the population within walking distance of their CDP network. Because online shoppers typically cannot choose the carrier, the majority of the CDP deliveries are dropped further than 1 km from the home address, jeopardizing the environmentally-friendly potential.

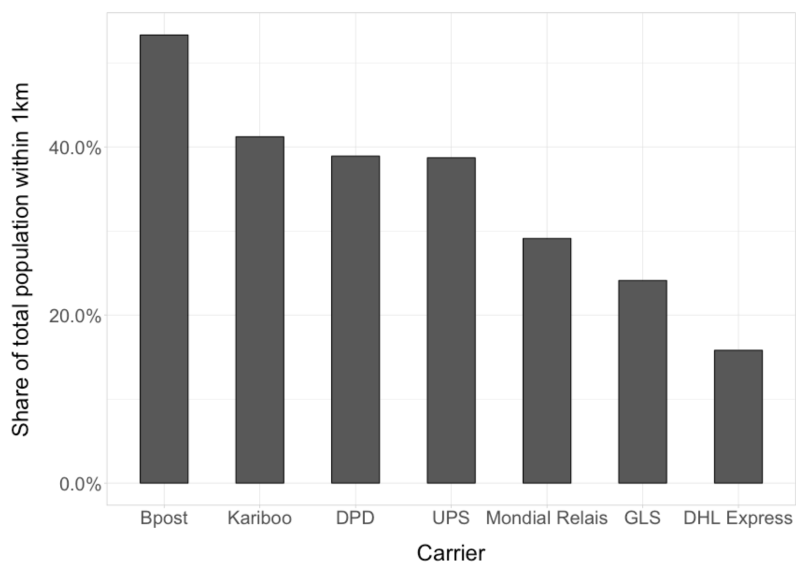


Figure 5.3: Share of total population within 1km of each PP network. DHL Parcel and PostNL are not included because their networks are identical to the networks of Bpost and Kariboo, respectively. Source: own composition with data BIPT (2018).

Individual behavior and different strategies among the carriers causes the inefficiency that 75% of all unique 4300 1 km catchment areas overlap. This means 75% of the population living within 1 km of one CDP also has at least one other CDP within 1 km. The total overlap for each CDP is mapped in Figure 5.4. A red dot indicates 100% of that CDP's catchment area falls within the catchment area(s) of one or more other CDP. CDPs colored yellow do not share any of their catchment areas with other CDPs. Overlap occurs mostly in urban areas due to a high density of CDPs. However, also in many urbanized and rural areas dark spots are present, indicating overlap percentages of 75% or more. This results from the desire of most couriers to maximize their presence in small towns and villages, which are the centers of activity in those regions. This high overlap across the whole country demonstrates the proliferation of CDP networks in Belgium.

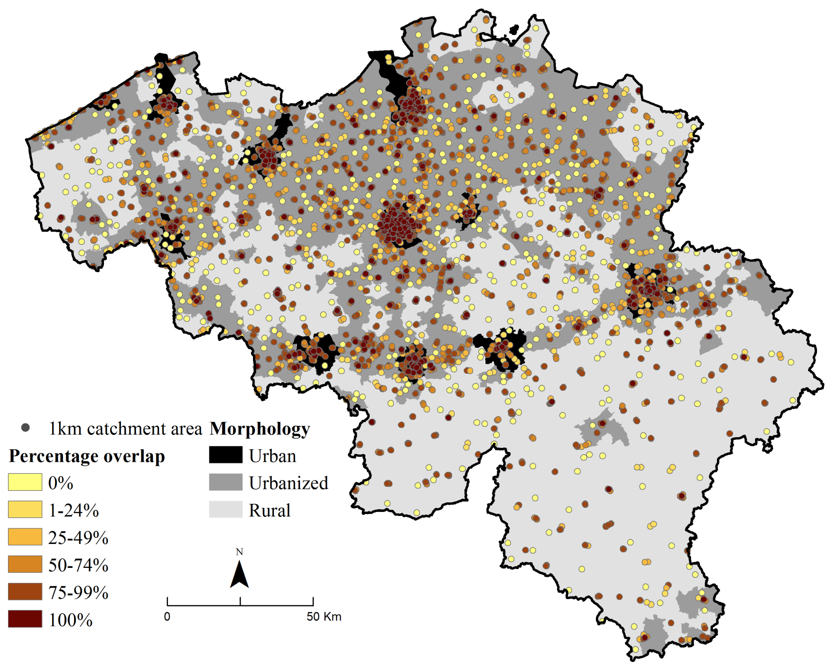


Figure 5.4: 1km catchment areas for the 4214 unique PPs with overlap percentage. Source: own calculations with data BIPT (2018).

Whether the large amount of overlap is a reason for concern is open to discussion. Considering externalities, multiple CDPs for different carriers imply delivery-related impacts (noise, pollution, congestion, safety, livability) in various locations. Measures by local authorities to manage the last mile of the delivery of online orders (e.g., unloading facilities) are not straightforward in these situations. In addition, it results in an increase in pick-up kilometers and a lower service level for consumers, and hence, a multiplication of the pick-up-related external impacts. From an economic point of view, the overlap may seem less of an issue. A carrier may visit his entire network preferably every day, whether the CDPs are shared or not. Operations are likely not impacted by other carriers stopping by the same CDPs. However, by cooperating and sharing the costs, carriers may be able to save on fixed costs associated with the start-up and maintenance of a new CDP, e.g. hard- and software costs and shop keeper training.

The 75% overlap shows there is significant potential for reducing the number of attended delivery points without reducing the service level, even in urbanized and rural areas. On the contrary, 30% of the Belgian population does not live within walking distance of a CDP and this number further drops when considering individual networks. Moreover, some CDPs already suffer greatly from capacity issues. Limiting the number of points without increasing storage space may only increase this burden. Calculating or specifying an *optimal* amount and distribution of CDPs may not be possible, however, making the current CDP network more efficient and sustainable is certainly possible.

5.4.3 An assessment of established CDP types in Belgium

This Section provides an assessment of five established CDPs in Belgium based on their economic, environmental and convenience level with respect to the requirements developed in Section 5.4.1. The results presented may serve as guidelines for implementing future CDPs. The proliferation of CDPs in Belgium has focused on quantity over quality and therefore various types of CDPs are in existence, often not fulfilling their full economic, environmental and convenience potential. Five frequently encountered types are selected which encompass a wide range of CDPs. Hence, the performance of other types can be derived from the discussion provided. In addition to these five types, a sixth type is added based on the Doddle example in the UK (Type 6).

Type 1 are inner-city supermarkets larger than $400m^2$, which supply urban residents food and other household products on a regular basis. This type contains all supermarkets located in local commercial centers and in or nearby residential areas. Type 2 are supermarkets located along major transportation axes. These peripheral shopping locations gained popularity in the 70's, following the suburbanization of mostly affluent and increasingly mobile families. In addition, because land was cheaper compared to inner-cities, economies of scale and scope could be maximized in these locations. Type 3 are nano-stores located in or nearby residential areas (as Type 1). This type encompasses small convenience stores, newspaper vendors and express supermarkets (<400m²). These are grouped together because they offer a limited product range and target a specific group of customers. Type 4 are gas stations. These are located either at the city border or along transportation axes. Similar as in other countries, many of these stations have a small convenience store attached. Type 5 are parcel lockers located in public transportation nodes. These locker boxes are located in easily accessible locations, such as major railway stations or on park and rides at the cities' borders. Type 6 are attended nano-warehouses of the size of small stores dedicated to the handling of parcels, similar to the Doddle example in the UK. This Type does currently not exist in Belgium but is introduced here as promising well-organized CDP option. Many existing CDPs lack streamlined organization due to a lack of strategic planning of CDP operations and the fast growth of e-commerce deliveries. This has resulted in increased pressure on the employees and often an unorganized storage of parcels behind service desks. Like the Doddle example, these small dedicated warehouses would be located in highly frequented areas, such as railway stations or university campuses.

The performance of each type for the different CDP requirements is scored (high - medium – low) in Table 5.7. Because much variety remains within the different types, the scores are based on the potential of an average store of each type. The characteristics of the average store of each type are assessed based on expert knowledge of the Belgian retail market by the author and collaborators.

Type 1 CDPs have, given their central location close to the consumer, low upstream but high downstream accessibility. Trips for purchases at these CDPs however are often done by car (Declercq et al., 2017; Lachapelle et al., 2018). This is especially so for those Type 1 CDPs located at the periphery of residential neighborhoods or near important access roads in urban areas, targeting the urban commuter. Their regular activities require sufficient amount of storage and loading facilities. However, this space is currently rarely used for handling of parcels. It is not uncommon to see parcels stacked behind the service desk, jeopardizing an effortless delivery and the overall reliability (see Table 5.4). Supermarkets typically have longer opening hours compared to other stores. Further, supermarkets typically have a larger workforce —— especially when compared with independent stores —— resulting in high scores for the attendance requirement. Finally, in Belgium, 83% of the population visits the supermarket on a regular basis, implying a high potential for trip chaining (European Commission, 2014).

Type 2 CDPs score similar to Type 1 CDPs, except for the location requirements. Their location along major road axes results in a high upstream, low downstream, and high commuting accessibility. Compared to Type 1 CDPs, an even larger share of the trips to these locations will be done by car.

Due to their central location, Type 3 CDPs score low on upstream and high on downstream accessibility. Because they are typically even more centrally located within residential areas than Type 1 CDPs, they score lower on the commuting potential. In contrast to supermarkets, these stores have limited storage and are supplied on a daily basis. In most cases, a dedicated loading bay is missing. The majority of these stores, except for express supermarkets, have shorter opening hours in comparison to the large supermarkets. Type 3 scores poorly on the trip chaining requirement due to their limited product range.

Type 4 CDPs score high on upstream and commuting but low on downstream accessibility given that they are typically located close to highway exits or on important transportation axes. They have usually limited storage space but plenty of parking space. Opening hours vary significantly, explaining the medium score for the opening requirement. The score for attendance requirement is medium because these CDPs are usually manned by one person only. Because the average Belgian visits a gas station only once a month ((FOD Mobiliteit en vervoer, 2017), the pick-up trip is generally dedicated to merely picking up the parcel, lowering the potential for trip chaining.

Type 5 CDPs are parcel lockers in public transport nodes. Their location is generally picked to ensure high downstream and relatively good upstream accessibility. By definition, they score high on commuting accessibility. They only score medium for infrastructure requirements: (1) they may suffer from capacity limitations, and (2) they are typically located close to the platform but relatively far away from the loading bay. Type 5 CDPs are open 24/7, however, being unmanned may make con-

Table 5.7: Locational, infrastructure and service requirements of frequently occurring CDPs

		Location			Infrastructure			Services	
	Upstream	Downstream	Commuting	Storage	Loading bay	Opening	Attended	Trip chaining
Type 1	low	high	medium	high	high	medium	high	high
Type 2	high	low	high	high	high	medium	high	high
Type 3	low	high	low	low	low	low	medium	medium
Type 4	high	low	high	low	high	medium	medium	low
Type 5	medium	high	high	medium	medium	high	low	low
Type 6	medium	high	medium	high	high	medium	high	low

Source: own composition

sumers reluctant to use them on a regular basis (due to perceived insecurity), especially for sending parcels. The potential for trip chaining is very low (remark combining commuting with picking up parcels is included in the location requirements).

Type 6 CDPs would be located at or near highly accessible places resulting in medium upstream, and high downstream and commuting accessibility. Due to it being organized as a warehouse, this type scores high on both infrastructure requirements. Opening hours will not be as high as with Type 5, however, dedicated personnel ensures a high score for attendance. Trip chaining is not possible because no goods are sold. Yet, picking a strategic location, e.g. at public transport nodes or shopping streets, may solve this issue. The profitability of Type 6 CDPs is questionable. To limit the increase in transportation costs, the cost per parcel must be low, implying large parcel volumes are needed. In the current market in Belgium, the average parcel volumes are too low, with estimates of only 3 to 5 parcels per CDP per day.

5.5 Discussion and conclusions: how to cope with the current proliferation of CDPs?

The rise in B2C e-commerce puts pressure on traditional distribution chains. The fragmentation of shipments, ever shorter lead times, and increasing rents causes a range of new logistics infrastructure. This is especially visible in densely populated areas: plenty of consolidation opportunities combined with more pronounced negative impacts gave rise to a range of urban logistics spaces, and some type of reversed logistics sprawl (Behrends, 2016; Cárdenas et al., 2017a). The most visible of these spaces, especially in Europe, are the CDPs. Originally installed to leave failed deliveries, the CDP network has now become an expression of the carrier's service level.

While the expansion of CDP networks has increased the accessibility to the points, it simultaneously has resulted in a heterogeneous and spatially scattered portfolio of locations, each with its own strengths and challenges. However, the strategy of quantity over quality may jeopardize the sustainability promise of these points. First, a higher number of CDPs can result in a suboptimal trade-off between the internal and external delivery costs. Second, heavy competition and insular behavior often results in duplication of CDPs, i.e. CDPs from different carriers located independently in the same neighborhood. This results in spatial scattering of negative impacts, including illegal parking, congestion, noise, etc. It also limits the potential for shared infrastructure like loading/unloading bays. Third, consumers may have to travel to various locations across the city to collect parcels delivered by different carriers. This not only discourages the use of CDPs, it also promotes the use of cars to pick-up parcels, and hereby increase the total amount of driven kilometers. Finally, nano-stores (e.g., corner stores or newsstands) becoming CDPs puts pressure on the shopkeepers. The expansion of online orders tests the limits of storage space at these stores and demands a significant amount of retailer's time, turning some of them in logistics workers.

Despite strong competition within the sector, a consensus seems to exist that the current situation may not be sustainable. Integrating a range of carriers, as e.g. done by the automated parcel locker company Cubee, may be more sustainable. The interviews indicated attended points are currently still favored over unattended lockers, mostly due to size constraints and security issues. Yet these APSs can offer a way to lessen the burden on shop keepers and may even be implemented by companies as an extra service to their employees, turning the lobby in a private CDP. Given innovation in terms of security and expandable locker systems, the share of APSs in the total number of CDPs may rise significantly in the coming years.

After reviewing different types of CDPs based on their economic, environmental and convenience potential, supermarkets and dedicated warehouses prove to be the best alternatives, especially if volumes further increase. However, how consumers are allocated to different CDPs is key. For commuters, transport axes and public transport nodes may be ideal pick-up locations. Others may prefer locations closer to home or work. A solution where the consumer can choose their CDP, as currently implemented by the Belgian national post, may be necessary to obtain convenient and sustainable CDPs.

Urban authorities can facilitate this development. A recent increase in hard and soft measures to guide deliveries in urban areas indicates local authorities are aware of the negative impacts associated with urban logistics. Verhetsel (1998) proposes four categories of policy measures. First, the inclusion of urban freight in urban planning is necessary to manage its impacts on the long-term (Fossheim and Andersen, 2017). Scholars advocate for this long term focus through the development of sustainable urban logistics plans (Kiba-Janiak, 2017; Lindholm and Behrends, 2012; Russo and Comi, 2017). In Paris for example, considered an international pioneer in urban freight planning, centrally located areas have been designated to logistics activities (Dablanc et al., 2013; Heitz and Beziat, 2016). Second, on a shorter term, the installation of dedicated infrastructure (e.g. loading bays or nearby delivery areas) has been a more popular measure. Different trials in various cities have shown positive impacts (Russo and Comi, 2012, 2016). Third, legislative enforcements (e.g. time windows or parking regulations) provide a fast option to improve efficiency of urban distribution activities. In addition, they are cheaper to implement compared to infrastructure measures (Allen et al., 2000). Fourth, from an economic perspective it makes sense to let logistics players pay for the externalities associated with freight in urban areas. Congestion pricing or area pricing are two examples to manage freight transport. Yet, implementations specifically aimed at urban freight transport remain limited (Dablanc et al., 2013; Russo and Comi, 2016).

Many initiatives include a combination of measures. For example, in the case of UCCs, city authorities may offer distribution space while simultaneously prohibiting non-participants from entering the city at certain times. However, as has been demonstrated several times by the failure of UCCs, top-down initiatives rarely work. Instead, the focus should be on improving the sustainability of existing implementations that are working within the current distribution networks (Zunder and Ibanez, 2004). A general conclusion in academic reviews of these projects is the importance of collaboration among the various stakeholders. This can improve efficiency of parcel deliveries while reducing their negative externalities on the environment and society (Ballantyne et al., 2013; Cui et al., 2015; European Commission, 2013; Fossheim and Andersen, 2017).

Each of the four measures can help coping with CDP proliferation. The successful Cubee example and the 75% overlap of catchment areas demonstrate the potential for cooperation among CDP networks. Some of these measures can be put in place to enforce this cooperation. Regulations could limit the spread of CDPs or single-carrier CDPs can be fined to stimulate cooperation. Even without government action, sharing CDPs among carriers makes sense given the economic, environmental, and convenience potential, as discussed in Section 5.4. Hence, it may be better if local authorities facilitate this process instead of enforcing it. In the short term, this can be accomplished for example by hosting meetings to facilitate discussions among carriers. In the long term, loading bays can be installed at suitable locations, or strategic locations can be conserved through sustainable urban logistics plans. An interesting ongoing project is in Brisbane, Australia (Lachapelle et al., 2018), where local authorities are exploring the latter option. The list of CDP requirements (Table 5.4) and the scoring of different CDP Types (Table 5.7) presented in this Chapter can be a valuable guidance document during such meetings or for identifying suitable CDP locations.

However, several questions remain unanswered. The largest knowledge gap concerns the consumer. In this Chapter, it is assumed the consumer desires a convenient delivery. However, an in-depth analysis of consumer delivery preferences is required going forward. Current consumer behavior, with the expectation of ever faster free home deliveries, may be more a result of fierce competition rather than a requirement for online shops. As a result, the question remains how and to what extent these expectations can be altered, and whether this is necessary in the first place.

Research on city logistics has raised awareness on the environmental impacts of urban freight and, specifically in recent works, the increase of consumer driven logistics. The general tone of this research is rather pessimistic and investigates alternatives to current delivery streams. A quantification of net impacts of online shopping deliveries is still missing. Is e-commerce generating more vehicle kilometers in addition to existing shopping trips? Or is a substitution effect taking place? In the latter case, should the market just optimize deliveries via routing algorithms? While the value of CDPs has been demonstrated, the net impact on driven kilometers remains an assumption based on a small set of case studies.

Independent of the answer to the last question, this Chapter demonstrates there is room for optimization in current CDP networks. There is need for professionalization in existing points, e.g. through organized storage and shopkeeper training. This issue for example led to the creation of the company Doddle. However, how sustainable will storage space be with expensive rents in urban areas? There are signs that retail real estate is overvalued on prime locations and there are a growing number of vacancies near these prime locations, both observations provide opportunities for locating small warehouses. This applies to all urban logistics spaces mentioned in Section 5.2. Moreover, interviews indicated the increased profit for shopkeepers is minimal when the fee per parcel remains low. This undermines the economic viability of CDPs, especially with the current low volumes per point.

In its conceptualization and assessment of the current CDPs, this Chapter assumed the current state of the B2C e-commerce market and no future trends were considered. An interesting question is how CDPs can play a role in the delivery of growing e-commerce markets, like fresh goods. In addition, similar as with B2C deliveries, the interviews with the parcel carriers pointed out an increasing share of B2B orders is fragmented. One reason may be a decrease in storage space to maximize showroom space in expensive commercial areas. Further, the short lifecycle of products in this sector discourages large stocks. While failed deliveries may not be an issue, a decreasing parcels per stop ratio may encourage the use of CDPs for B2B deliveries. Storage is then subcontracted to a (specialized) location, possibly a small warehouse where B2B and B2C can be combined. This approach may be more sustainable in dense commercial areas, especially when retailers demand frequent shipments that cannot be organized within existing time windows. One remark here is that the observations of the parcel carriers concerning this evolution are in contrast to the findings from an objective diachronic analyses on freight movements conducted in Bordeaux (Bonnafous et al., 2016). Whether or not fragmentation in B2B occurs is a difficult question to answer and strongly depends on the measurement chosen and the sectors considered. Without doubt however, it is interesting to monitor this evolution given its potential impacts on the organization of urban freight flows.

Finally, this Chapter is written from a European perspective. It would be valuable to test the proposed list of requirements and types to CDP networks elsewhere. Another interesting question is why the American delivery market is less fond of CDPs. With lockers finding a way in big cities, it would be interesting to apply the lessons learned in Europe to prevent a similar uncontrolled proliferation.

6 Conclusions

This Chapter concludes the dissertation in relation to the research questions raised in Chapter 1. The next section summarizes the findings of the different case studies. The limitations of the dissertation are discussed in Section 6.2. Section 6.3 presents different perspectives for further academic research. Finally, the last section of this Chapter provides a set of implications and recommendations that follow from this research.

6.1 Summary of findings

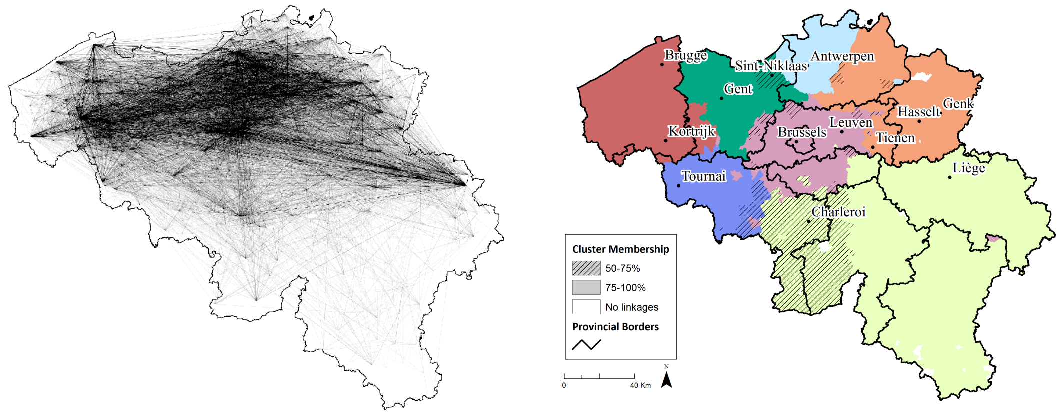
This dissertation started with the observation of the changing role of the logistics sector. First, globalization demanded close cooperation between producers, suppliers and distributors and hence the advent of contemporary logistics. Second, the popularity of e-commerce with the promise of home deliveries integrated the consumer in these global supply chains. While the institution of the sector as a structural part of economic systems did receive academic attention (Hall et al., 2006; Hesse and

Rodrigue, 2004; Rodrigue, 2006a), very little research on how these interactions shape the spatial configuration of the sector exists. This question formed the basis on which this dissertation was built and was studied at two scales. Part 1 tackled this question with an analysis of inter-firm linkages at the national level. In Part 2 the focus lied on the interactions with end consumers at the urban level. The following Sections summarize the conclusions of this dissertation. They are structured along five major findings, each corresponding to one of the sub-questions stated in Section 1.4. Finally, Section 6.1.6 provides an overall conclusion based on to the main research question.

6.1.1 Finding 1: The logistics buyer-supplier network consists of seven spatially contiguous communities

Part 1 of this dissertation made use of a microeconomic dataset of the invoices between companies where either the buyer and/or the supplier is a logistics company. This data was provided by the National Bank of Belgium. Because of the complexity of the dataset, methodological inspiration was drawn from the field of Network Science. In particular, Chapter 2 introduced a community detection algorithm to study the spatial component of these buyer-supplier linkages. The network analysis identified seven spatially contiguous communities (Figure 6.1b). The spatial contiguity of these communities points to the presence of a strong spatial component within the microeconomic dataset. In layman's terms, this means two things. First, buyers of logistics services are more eager to look for logistics suppliers in their vicinity. This implies that even for logistics companies, as connectors between all corners of the country, the presence of potential customers should be an important location factor. Second, similar to the first point logistics companies seem to buy more often from suppliers nearby. Hence these suppliers better locate close to their logistics clients. Although certainly not a prove of clustering, it does hint at the presence of one of the drivers of co-location of associated industries in the logistics sector as well.

This finding may not come as a surprise to those familiar with the application of similar methods in social sciences. Earlier studies (e.g. Adam et al. (2017); Blondel et al. (2010); Nelson and Rae (2016); Ratti et al. (2010)) indeed found a similar spatiality within telephone calls or commuting patterns. However, the logistics sector is perceived as being spatially scattered, being everywhere and nowhere



(a) Network of all flows used in Chapters 2 and 3

(b) The communities inside that network

Figure 6.1: Deriving insights with network analysis. Source: own calculations with data NBB.

at the same time. The observation of such a strong spatial component at different levels should thus not be underestimated.

6.1.2 Finding 2: The logistics network depicts a strong hierarchical structure

The contiguity of the communities however creates an illusion of homogeneity within the overall network. Although near locations show a higher frequency of interactions, the result of the community detection algorithm may leave the impression that within a certain community, all nodes are equal. In addition, maps like in Figure 6.1b hide the presence of cross-community linkages.

These two issues were tackled by complementing the buyer-supplier dataset with employment data in Full Time Equivalents (FTE) per municipality in 2010, and by calculating a range of additional community parameters. First, Chapter 2 combined the community detection results with the calculation of concentration indices on the number of FTE. While it was not possible to quantify explicitly the relation between co-location and inter-firm linkages because of the heterogeneity of the data sources, the study did provide a more comprehensive typology of economic clusters. Hence, it proved that co-location does not by definition imply more intense local inter-firm relations. On the contrary, the latter can occur in many intensities and in different network configurations. The large geographical variety is another indication that the idea of a dispersed logistics sector does not hold. Instead, the sector is structured along a range of clusters, cluster spillovers and polycentric clusters. This structure supports the theory that there is an independent, self-organizing logistics sector that is more than a derivative of other economic activities.

Second, the calculation of additional community parameters allows more insights in the connectedness of the different nodes within and beyond their communities. As such the application of the framework proposed by Guimerà and Amaral (2005) helped to achieve the cluster typology mentioned above. By reiterating the same community detection algorithm two more times, the analysis in Chapter 3 provided a template to uncover the spatial pattern of the rest of the network's hierarchy, outside the actual clusters. The application of the conducted methodology demands a strong quantitative mindset and the interpretation of the results is not always trivial. Yet, the calculation of the so called damping values and its geographical analysis does allow for an understanding of how nodes located in the same community can exhibit strongly differing relations over different hierarchical levels. Similar to the observation of the contiguous communities and the three cluster types, the presence of an hierarchical structure in the logistics network further rejects the idea of a dispersed geographical pattern of the logistics sector.

These conclusions are novel in three ways. First, although the topic recently rose on Economic Geographical research agendas (Bathelt et al., 2004; Martin and Sunley, 2003; Porter, 1998), only a very limited amount of authors (Sheffi, 2012, 2013; van den Heuvel et al., 2013, 2014a, 2016) have paid attention to clustering in the logistics sector. Second, the majority of studies resulting from the revived academic interest focus on the detection of co-location and ignore horizontal relationships. Nonetheless, both dimensions have proven to be crucial when analyzing agglomeration advantages (Marshall, 1890). Third, the development of a framework that allows for the objective comparison of economic clusters is not an easy task given the fluidity of the cluster concept (Martin and Sunley, 2003). The lack of quantitative research further complicates this task. The application of network tools, as conducted in Chapters 2 and 3, allows for a more structural interpretation and helps to specify the concept, given the availability of the required data.

6.1.3 Finding 3: Community detection is useful but needs accompanying measures to retain the particular

The lack of quantitative research on inter-firm relations was tackled in this dissertation by drawing inspiration from the field of Network Science. Chapter 2 introduced the community detection algorithm and the calculation of the network parameters in addition to traditional measures of co-location. Likewise, in Chapter 3 an additional parameter, i.e. the *damping value*, was calculated after multiple iterations of the same algorithm. In both Chapters however, these network tools were used as a way to draw conclusions on (Economic and Transport) geographical questions. It allowed for a deeper understanding of the spatial configuration of the network, e.g. by uncovering present hierarchies and refining the cluster typology (cf. Figure 6.1).

The question may rise whether these complicated methods are the only way towards such deeper geographical understanding. Of course, not even the choice for a quantitative paradigm is imperative for the geographical conclusions in Part 1. The advent of big datasources on all kinds of socio-spatial interactions however opens the door for using such methods in an explorative spatial data analysis framework. While network analysis does not have to be the sole source of methodological inspiration, it provides a wide array of tools that can and should be exploited in a geographical context.

However, this dissertation is also critical towards the application of network methodologies. While the application of community detection algorithms on spatial interaction networks is gaining popularity (Blondel et al., 2010; Nelson and Rae, 2016; Ratti et al., 2010), these studies mostly ignore the underlying heterogeneity within the resulting spatially contiguous communities. The reiteration of the community detection algorithm and the calculation of the damping values as an additional network parameter helped to understand what is going on inside the highest level communities. As such a richer geographical description was achieved. While the above authors may be aware that some prudence is at its place, merely stating that *we must be careful not to assume that an absolute or final structure of regional divisions can be determined* (Nelson and Rae, 2016, p. 21) does not feel sufficient when claiming to describe *The Economic Geography of the US* or to *Redraw the map of Great Britain*. Such studies are an excellent example of Schwanen (2016)'s critique that *there is a risk that generality – regularities, laws, basic principles, ... - comes to trump particularity in the form of place and time specificity*. One has to remain prudent not to revert to an internal network perspective but to reconcile network-based insights and more qualitative, localized insights in order to safeguard particularity.

A similar example of this critique are the claims made in Grauwin et al. (2017)'s development of a universal model for human interactions, which has been critically applied in Chapter 3. In its original publication, the calculated damping values are the foundation of a universal model of human interactions. Although the authors claim to *uncover a systematic decrease of communication induced by borders which we identify as the missing variable in state-of-the-art models* when working on telephone data (Grauwin et al., 2017, p1). The analysis in Chapter 3 demonstrated that the ignorance of the geographical variation of these values clearly does not apply to all types of human interaction.

6.1.4 Finding 4: Socio-economic characteristics have to be taken into account in B2C urban logistics studies

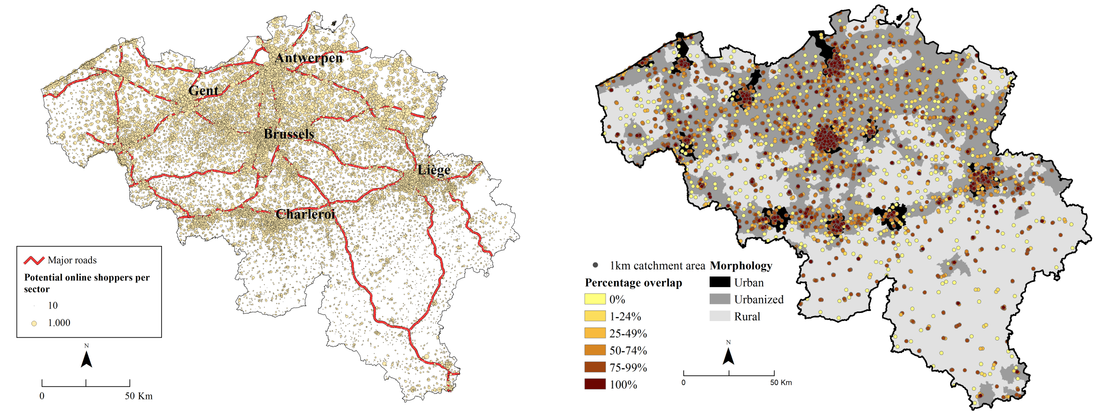
In Part 2 this dissertation shifted scales. Recall this was a triple shift: i.e. in terms of the geographical focus, the type of interactions and the companies taken into consideration. This shift resulted from the claim of an integration of the consumer in modern day supply chains. As has been elaborated during the identification of the research gaps at the introduction of this dissertation, it is the need for physical and information interactions to ensure the delivery of B2C e-commerce parcels that initiated this integration. To understand how this influenced the spatial configuration of the logistics sector, Chapter 4 first attempted to understand the origin of the change, i.e. the consumer shopping online.

Highlighting the importance of the consumer is in itself a contribution to the urban logistics research field, given the lack thereof in the field's recent academic output. One example hereof is the ignorance of this stakeholder in the variety of models that is concerned with modeling the number of vehicle kilometers travelled (VKT) (e.g. Edwards et al. 2010; Gonzalez-Feliu et al. 2012; Park et al. 2016; Perboli et al. 2016). The VKT calculation is a three-step process, with the estimation of the demand as the initializing step. Despite its significance however, the majority of the B2C urban logistics literature assumes the demand is uniformly distributed over the population, in contrast to findings of for example Clarke et al. (2015) and Farag et al. (2006b). Similar to these comparable studies, this dissertation proved that income and education strongly impact the probability of online shopping in our case study. In addition, it showed that gender and age also influence this probability. On the contrary, like in the UK and the Netherlands, the urbanization level of an area does not show a significant relation with the probability one shops online in Belgium. Whether this is due to the historical urban sprawl in the country, or an indication of the universal adoption of online shopping (Anderson et al., 2003) remains food for discussion.

Besides the identification of significant predictors, the geographical translation of the statistical regression is novel and provides additional insights in understanding online shopping adoption. One of the key contributions here is the observation of demand changes at the most detailed spatial unit. The discussion in Chapter 4 dives deeper into this variation, which implies the demand for online goods may change from one neighborhood to another and is in contrast to traditional logistics strategies of providing services proportional to the absolute population in a certain area. As a result, a similar micro-level perspective may be required in the courier express and parcel (CEP) sector.

6.1.5 Finding 5: The rise in online orders results in a new, urban layer in logistics chains

Chapter 5 identified the cities as locations accommodating the majority of potential online buyers, which is unsurprising given higher population numbers. More online buyers imply more deliveries of online orders, which result in a decrease in the delivery costs of these parcels in urban areas. Yet, in return, the challenges these deliveries pose on logistics players are greater there. Ever shorter lead times, absent receivers and single-item orders result in an increased fragmentation of freight flows, prompting the urgent need for solutions to cope with this complexity. Chapter 5 identified the variety of new urban logistics spaces that are created within logistics networks as one of the solutions applied by the CEP sector (cf. Figure 6.2). These nodes, being the extension of logistics chains within the cities, are termed the urban layer of e-commerce deliveries. Because the facilities in this layer have to be small (i.e.



(a) The location of the demand for online goods

(b) The location of CDPs for online deliveries

Figure 6.2: Demand and supply for e-deliveries. Source: own calculations with data Comeos and BIPT.

due to high rents) and nearby (i.e. rapid deliveries), their quantity is large (e.g. >4,400 CDPs in Belgium in 2018). These new facilities increase the amount of logistics jobs in urban areas. Small retailers become warehouse workers; students become part time bike couriers: the power of the consumer has changed the outlook of the sector.

Collection and delivery points, at least in Europe the most common urban logistics facility, have become the materialization of this integration of the consumer in the supply chain. These points offer economic advantages for the carrier, present an environmentally-friendly alternative for home deliveries and allow the consumer a greater flexibility. Despite this integration and increased interaction however, the unsustainable demand for free home deliveries demonstrates that consumers still lack an understanding of logistics processes. Fierce competition within the CEP sector however led to a proliferation of these points in Belgium. Unsurprisingly, bad location choices jeopardize the sustainability of this promising alternative. In an attempt to provide guidance for decision makers, an evaluation of different types of CDPs was provided at the end of Chapter 5.

6.1.6 What is the relation between spatial interactions and the spatial configuration of logistics networks?

By no means this dissertation is a complete overview of the geography of the logistics sector. The four papers, structured in consecutive Chapters, each provide small incremental steps towards tackling the main research question of this dissertation: *What is the relation between spatial interactions and the spatial configuration of logistics networks?* Part 1 demonstrated how the uneven distribution of logistics activities and inter-firm relations is resulting in a spiky logistics network. The calculation of the network parameters in Chapter 2 and the k-means clustering of damping values in Chapter 3 in particular uncover a strong geographical variance in the intensity and distribution of the linkages at the national scale. This variance defines nodes of greater and lesser importance and hence structures the spatial configuration of the logistics network.

The most important nodes in the Belgian logistics network are located close to important economic markets and/or transportation hubs, e.g. Antwerpen, Brussels, Liège-Bierset etc. These centers are hubs where spatial interactions converge, both locally as nationally and hence serve as the focal points in logistics chains. The occurrence of these interactions are a self-enforcing system: the potential for intense inter-firm relations increases the attractiveness of cities, which is enforced when new players with their own set of relations arrive. In Part 2 a similar observation is made at the micro-scale. The interaction consumer-logistics demands a restructuring of the latter's delivery processes. With fierce competition in the CEP sector, players are diversifying delivery options to increase their service levels towards the end consumer. A spatial example hereof is the wide set of pick-up options for consumers. Yet his flexibility gain becomes the new standard in the competitive market, prompting the offer of additional services, further complicating the last mile of e-commerce deliveries, especially in urban areas. In summary, this dissertation observes the relation between cities and logistics companies results in a spiky logistics landscape that is increasingly impacted by individual consumers.

Relating to the popular discussion on logistics sprawl (Dablanc and Rakotonarivo, 2010), the most important logistics centers are mostly on the fringe of the cities. Although not explicitly a prove of logistics sprawl, it provides an indication of a barycenter located at the cities' borders (cf. Dablanc and Rakotonarivo 2010). The emergence of the urban layer due to e-commerce deliveries in contrast, results in an interesting duality in the CEP sector. On the one hand, the installation of urban logistics spaces suggests a potential reversal of logistics sprawl. On the other hand, there is an increasing need for gigantic warehouses to satisfy the e-commerce demand of large metropolitan regions. As a result, even in the CEP sector in absolute square meters the barycenter of logistics activities will probably keep moving away from the geographical center of the city.

What does the future hold? Rimmer and Kam (2018) claim the advent of omnichannel retailing, with the establishment of logistics as a distinct cost component in the consumer purchase equation and a plethora of delivery options, brought along a new logistics wave: *Consumer Logistics 1.0*. The authors' further sketch a future where 3D printing and the Internet of Things are the bearers of the next logistics evolution, which would shift the focus from city logistics (i.e. managing urban freight) to logistics cities (i.e. attract logistics service facilitators and trading companies) (Rimmer and Kam, 2018). Although the breakthrough of 3D printing has been contested on a regular basis over the past decades, the idea of a logistics city is food for thought. The idea can be summarized as the development of a physical internet (Montreuil, 2011) to facilitate a sharing logistics economy. While the authors' view can be perceived as quite futuristic, a future with more consumer participation in logistics chains is not unthinkable. This will undoubtedly further complicate the already complex situation and spatial fragmentation that resulted from the competitive environment in the sector. To cope with such an outlook, an alignment of actions, infrastructures and processes within the logistics sector should be on policy agendas.

6.2 Critical assessment

This dissertation is not without its flaws. The availability of unique datasets resulted in significant quantitative academic contributions. Yet, many assumptions had to be made during the analysis of these datasets, which results in a range of limitations. The main limitations of this dissertation are discussed here.

6.2.1 The buyer-supplier linkages provided by the NBB

It was mentioned in Chapter 2 that the buyer-supplier linkages provided by the National Bank of Belgium are attributed to the headquarters and that international linkages are absent. The impact of the first limitation might be an excessive emphasis on the importance of the economic centers. However, with a strong presence of small and medium sized companies in the dataset, the distortion between headquarter location and actual activities is limited and should not compromise the demands for the analysis. Moreover, the lack of international linkages may diminish the relative importance of some major economic centers in the analysis. This might even balance out some or the error due to the headquarter limitation. Concerning the absence of the international linkages, the relative high number of linkages in the border regions Kortrijk (towards Lille) and Eupen (towards Germany) indicate at least a share of them seems to be captured within the original dataset.

Another limitation stems from the interactions being an expression of the Belgian logistic system in terms of value added, not transported goods. The use of financial flows to study the logistics sector may look counterintuitive. Although this type of flows may also limit the distortion associated to the aggregation of the flows to the headquarter, they might present a more spiky image of the sector, in contrast to the potentially more scattered freight flows. Further, the heterogeneity of the dataset may blur the definition of the logistics clusters, as highlighted in Chapter 2. But not only the variety of industries, also the wide range of logistics facilities included in the dataset distorts the analysis. A similar remark can be made of the second dataset used in Chapter 2, i.e. of FTEs in the logistics sector. A more micro-economic analysis of the concentrations and inter-firm relations would greatly enhance the insights in the observed locational patters, as was done in Heitz et al. (2019). Finally, the data dates back to 2010 which is a long time ago, especially given the changing nature of the sector. Updating the findings with more recent data would not only improve the relevance of this work, it also allows for a diachronic analysis, of which the potential is elaborated in Section 6.3.

6.2.2 The E-commerce in Belgium survey provided by Comeos

The use of the Comeos dataset in Chapter 4 is another point of discussion. First, falling back to the internet to conduct a survey implies non-internet users are left out of the analysis. In Belgium, 87% of the households have internet access (Eurostat, 2019). This means the remaining 13%, except for the ones surfing online at work or in public places, are excluded from the analysis. This is not by definition a limitation when questioning e-commerce characteristics. Deriving average spending or identifying the preferred delivery location for certain types of goods only require answers from online shoppers, who are by definition reachable through online surveys. It is more an issue when predicting the probability of online shopping, as was done in Chapter 4. Because of the chosen medium through which the survey was conducted, the computed probability is actually the e-commerce behavior of Belgian internet users. The extrapolation of this probability to the number of Belgian online shoppers results in an overestimation of the latter due to the absence of non-internet users.

The data provided by Eurostat (2019) allows to assess this error to a certain extent. As such the majority of the households without internet access prove to be member of the lowest two income quartiles (Eurostat, 2019). Hence, the share of online shoppers from the lowest income class has the highest chance to be overestimated in the dataset. In that case, the significant impact of the variable income on the probability may be distorted in a positive sense, i.e. with an overestimation of the coefficient for the lowest levels of this variable. In conclusion, given the potential sampling error due to the use of the online medium, the existing significance of the income variable (i.e. the difference in impacts between the highest and lowest levels) could potentially further increase. A similar conclusion might be made for the education variable, although no data on this was available. The Eurostat survey further indicated little differentiation in internet access for households between different morphological areas (urban/rural) (Eurostat, 2019). Resultantly the impact of the choice for an internet survey on the conclusions made on the hypotheses from Anderson et al. (2003), seem to be limited.

A second limitation is that the survey only gathered 1500 complete responses. One important note is that the 1500 respondents were not gathered randomly. The respondents were sampled from a consumer panel by a specialized company. It was mentioned in Chapter 4 that response behavior was leveled out based on previous polling behavior of the panel. Resultantly a response set representative for Belgium according to age, gender and regional quota was achieved, despite using the internet for surveying. This representativeness was assessed in Table 4.1. Given this, the results of the statistical model are valid for the Belgian internet user. The limited size of the survey may however cause a larger error in the geographical translation of the statistical results, especially since a choice was made to do this translation at the level of the statistical sector. This choice resulted from the experience of working with real delivery data, which showed significant variation at this detailed level (Cárdenas et al., 2016). Another issue concerning the geographical translation is the fact that online orders were equated with online deliveries, which certainly is not always the case. First, 25% of the online orders are not delivered at home. Second, not all purchases result in the same freight flows. Different types of goods can be subject to different delivery preferences, e.g. the desire to have heavy goods delivered at home may be higher than for smaller goods. Fresh goods may be less suited for CDP deliveries and services bought online not even result in physical goods. The size of the error made can only be estimated by comparing the modeled demand with real delivery data. The issue of such datasets however, as mentioned in the discussion in Chapter 4, is the difficulty to split B2B and B2C deliveries. This may be a nonissue when assessing freight flows, but it does matter when attempting to isolate the impact of e-commerce. One potential solution could be to split such delivery dataset based on the destinations. Yet one has to know which address corresponds to a business and which one to a household. Due to the scattering of datasources to compile such a dataset, this is neither a straightforward exercise.

Finally, another improvement could be made by assessing the total frequency of online purchases instead of the probability of the binary variable *buying online* (Yes/No). An issue is that such analyses require more advanced statistical models. This because the occurrence of zeros (i.e. a respondent who bought nothing) can result from two different behaviors. In this survey, these behaviors are *against buying online* or *open to buying online*. The first behavior is the cause of a first type or zeros, i.e. people never buying online. If people are at least open to buy online, the frequency of the purchases is represented by a count process. People open to buy online but who eventually bought nothing are hence the second cause of zeros. While this analyses fell outside of the scope of Chapter 4 because already a lot of assumptions had to be made, it should the be topic of follow-up research because it allows for a better translation of online shopping to actual deliveries.

6.2.3 The qualitative assessment of the CDP network in Belgium

Contrary to the first three case studies, the majority of Chapter 5 uses a qualitative approach. While this is not an issue on itself, it is the nature by which it is applied here that poses limitations on the findings. The development of CDP requirements and their assessment for the Belgian case originate from the experiences gained over the past four years. They stem from formal and informal meetings with representatives of different parcel carriers, from attending a range of workshops and conferences on the topic, from discussing urban freight issues with city administrators and from presenting this work and receiving feedback from different interest groups like Comeos, Unizo (Union of Independent Entrepreneurs) the BIPT and others. This knowledge building grew over time, but lacked a structured preparation. As a result, Tables 5.4 and 5.7 in particular miss a clear methodological framework. This prevents an objective validation and its replication in other studies. To solve this issue, the Tables can serve as the basis for a structural survey to be conducted with the parcel companies and in existing CDPs.

A long list of issues was mentioned here. Nonetheless, limitations are part of conducting research. Especially in relatively new fields such as the application of network methodologies in Economic Geography or the Urban Logistics research field. Given of course a minimum level of academic rigor, limitations are an inherent part of the knowledge building process. The risks taken lead to discussions like this Section, which challenges researchers to look for improvements or other solutions and hence shifts the debate. How these limitations can results in paths for further research is discussed in the next Section.

6.3 Paths for further research

This dissertation touched upon many research fields, hence a variety of topics to be studied in more depth results. First, the concept of logistics clusters remains an interesting path for further research. Chapter 2 and to a lesser extent Chapter 3 extended the growing literature on the topic by including inter-firm relations. Yet a clear definition of economic clusters remains missing. While in this dissertation an attempt was made to construct a quantitative framework for the identification of clusters, one of the major issues was the use of financial transactions from which functional relations were derived. Great potential remains in the use of functional relations to better understand the connections underlying the financial transactions that were studied here. This can help to identify whether or not more economic activities are generated by co-locating logistics companies, which would be a justification for its popularity as an economic development strategy. Another issue was the absence of international linkages in the dataset. Hence quantitative research including an international component can help to further refine the developed framework. Finally, extrapolating the discussion on the network and geographical hierarchy in Chapter 3 to the whole country remains on the agenda. The k-means clustering of the damping values yielded nice results at the level of the Antwerpen community. They should however be validated at the national level as well.

Second, the point made on the potential of a diachronic analysis is another interesting path for further research. Such a temporal analysis could be developed in the Evolutionary Economic Geography (EEG) framework. This paradigm studies the economy as *self-transforming itself from within* which describes its evolutionary and emerging nature (Boschma and Martin, 2010). One of three key concepts within the theory is path dependency theory (Boschma and Frenken, 2011). Summarized, path dependency implies *the explanation to why something exists intimately rests on how it became what it is* (Dosi, 1997, p. 1531). The temporal analysis can offer the opportunity to look for growth or decline factors when assessing the evolution of the different clusters over time. Linking these to endogenous (i.e. path dependent, cf. discussion on self-enforcing system in Section 6.1.6) or exogenous factors would be valuable input in policy debates.

Third, methods developed in the field of Network Science proved to be useful to gain insights in large geographical datasets. Since the latter will only increase in size, quantity and availability, it is paramount to keep drawing inspiration from research fields experienced in the analysis of such datasets. However, it is our role as geographers to evade the internal network perspective when engaging with such methods. As discussed in Chapter 3, this can be done in two ways. On the one hand, we can strive for the development of geographical network methods by including geographical elements, like space, context and hierarchy, in network methodologies. On the other had, we can aim for a *mesogeography* as Miller (2018) terms the confrontation of network-based insights with location- and domain-specific insights, as was attempted in Chapter 3.

Fourth, the increasing fragmentation of logistics flows, both in sizes as in destinations, is clearly impacting the urban logistics and retail landscape. One of the main issues however remains the lack of knowledge on what is going on *exactly*, which is due to the difficulty to conduct data-driven research on the topic. The lack of data not only results from the heavy competition within the sector, but is partially due to the fact that logistics operators do not categorize their cargo based on their typology. B2B and B2C parcels are transported together in trucks and pass the same warehousing processes. This makes it very complicated to analyze specific flows and hence little is known about the exact volumes going in or out urban areas. For example, it seems the popularity of e-commerce increased the use of white vans for deliveries, to the extent that this evolution in car use received its own Dutch term *camionettisering*. Nonetheless it remains to be seen what percentage of these vans are actually used for logistics purposes, let alone for B2C deliveries. Similarly, the actual environmental impacts of e-commerce deliveries remain to be assessed. If a replacement of shopping trips is taking place, the impact of home deliveries may be exaggerated. Finally, a growing share of B2B flows is getting fragmented as well. Will we see a pick-up point delivery for this type of goods too? If so, the issues raised in Chapter 5 will only be aggravated.

To answer these kind of questions however, more research concerning the online and offline consumers at the interface of the fields of Economic, Retail and Transport Geography is necessary. One pathway for this is the development of freight trip models to test different scenarios. Yet B2C freight flows are constantly evolving as consumer behavior changes rapidly, which may make such models outdated very quickly. Nonetheless, given the black box that the city currently is from a freight perspective, any model would still be a valuable source of insights.

6.4 Implications and recommendations

6.4.1 Policy implications

The potential of the structural, integrated logistics sector to generate blue collar employment and foster economic growth makes it an interesting field from a regional development perspective. The cluster idea in particular has been a popular buzzword on policy agendas. Unsurprisingly, policy makers at different governmental levels promote their country, region, province or municipality as a logistics cluster. For example, Hesse (2015) describes the efforts by the Walloon Government in Belgium who, in their Marshall Plan, aim to promote logistics hubs as growth poles for the region (Gouvernement Wallonie, 2012). In the northern part of the country, Vanthillo et al. (2014) questioned the subregional actors and found that each of them mentions logistics as one of the key spearheads for further development of their region. Yet, the lack of evidence for these claims has been described in Chapter 2.

The analysis presented here leads to mixed feelings concerning the eagerness of policy makers to promote the development of logistics clusters. On the one hand, a concentration of logistics activities does seem to be accompanied by a myriad of inter-firm relations more often than not. A large share of these linkages may have a local character, bolstering local economic activities. In addition, the findings of both Chapters 2 and 3 indicate how the logistics sector ensures interregional relations as well. These *global pipelines* are vital to prevent local networks to become *too close, too exclusive and too rigid* (Bathelt et al., 2004, p. 41). Such an over-embeddedness threatens the import of fresh, external ideas and hence hampers the innovation potential and competitiveness of a firm (Uzzi, 1997; Vanthillo, 2017). On the other hand, the analysis also demonstrates strong regional differences in logistics activities and relations. The local concentration of linkages seems to be more pronounced in the major economic centers, while subcenters may be more of a derivative instead of a local independent hub. It is true distances are small in Belgium and the excellent location factors from an international perspective are valid in the whole country, but the attraction of logistics activities in more remote areas would only aggravate logistics sprawl and should thus be prevented.

It is remarkable (or not) that despite this universal policy promotion of logistics, the topic has been absent in the urban transportation or spatial planning departments until recently. As mentioned at the end of the previous section however, it is paramount the transport of freight and its related activities receive at least a share of the attention that is currently given to passenger transport. This is necessary for a couple of reasons. First, in order to organize the different interests of stakeholders within the CEP sector. Second, to guide the potential interaction between passenger and freight transport within a sharing economy. Finally, to ensure the vitality of the urban economy in the future. Especially given the expectation of further economic and population growth in urban areas on the one hand, and the increasing awareness of citizens for the livability of the city and the planet on the other.

This latter remark is even more relevant within the context of e-commerce growth. The home delivery of online orders is a new service that consumers are getting used to. The described fragmentation of shipments however causes a range of negative externalities like pollution, congestion, noise and accidents. These impacts were calculated to cost the society on average 30 cents per parcel (Cárdenas et al., 2017a). The exponential rise of these deliveries caught governments off guard, but slowly policy attention towards these issues is growing. One indispensable requirement to support this growth however is the collection of data on urban freight. This data can come directly from the sector, or through the development of infrastructure, e.g. in a smart city context.

6.4.2 Industry implications

Twelve years ago, Hall et al. (2006) argued the global extension of production and consumption together with the dependence on oil was threatening the distribution system: *this may even trigger a reorganization of production and distribution more in accordance with traditional conceptualizations such as central place theory, in which transport costs were more heavily weighted in the assessment of a spatial structure. After decades of dislocation, economic and transport geographies may be forced to go back to their source* (Hall et al., 2006, p1406). While a return to a traditional reorganization of the logistics sector is probably a bridge too far, the occurrence of logistics clusters indicates the prevalence of geographical factors within a globalized economy. With the outlook of more intense buyer-supplier relations that could stimulate your business, it makes sense for companies to be located in concentrations of logistics activities, even when current transport flows far exceed national boundaries.

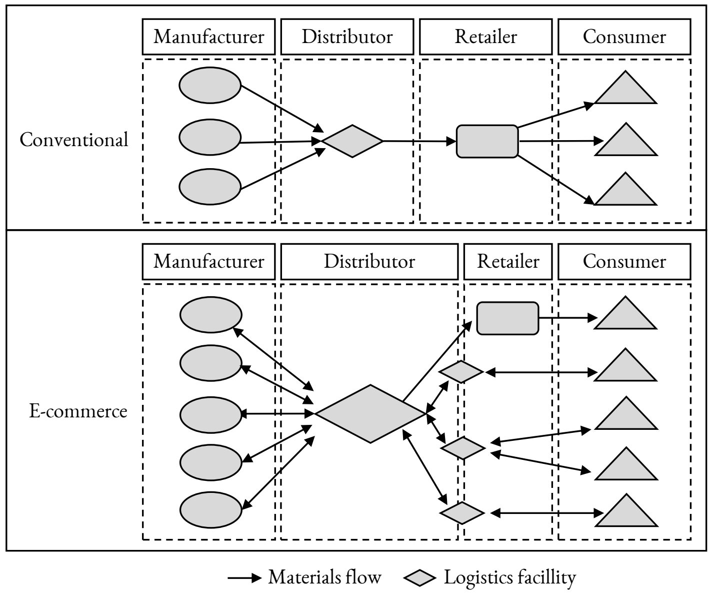


Figure 6.3: Spatial evolution of the logistics sector. Partially based on Hesse (2008).

However, next to this clustering that is indeed in accordance with concepts such as central place theory, the availability of the internet as a retail channel only further fragmented the spatial relation between production and consumption. As mentioned, the increasing share of B2C in total volumes results in a demand for two types of facilities: large scale distribution centers to manage global flows and small urban logistics spaces to satisfy consumer needs (Figure 6.3). Given the requirement of the latter to be close to the consumers, there have to be many of them to ensure a good coverage. This however implies further fragmentation in constrained urban areas with expensive rents and a critical population. This location dilemma demands a new strategical mindset in the CEP sector. Moreover, as a result of a fierce competition within both the retail and the logistics sector, profit margins are very small at the moment. Cooperation therefore seems a requirement instead of an option. This may be accompanied by a return to the core business, and leaving the complicated last mile for a new type of logistics specialists. The parcel locker company Cubee is a successful example of such a logistics specialist as demonstrated in Chapter 5.

Retailers too got confronted with the complexities associated to the last mile of the distribution chain, to the extent that the majority of the current e-delivery chains are in hands of the CEP sector at the moment. However, complaints about the quality of delivery services by subcontractors are common, which motivates retailers to at least think of retaking the delivery in their own hands. Although volumes have to be sufficiently high, they do have a competitive advantage compared to the CEP sector with their existing (retail) infrastructure in urban areas that can be used for logistics purposes. However, an important issue for the retailers remains the strong division between the different consumer channels. A truly omnichannel strategy with centralized stock management could enhance their durability in these difficult times. Finally, it may come as a surprise that this infrastructure is not used for the purpose of picking up parcels bought in other webshops. On the contrary, the majority of the pick-up points are located in gas stations, supermarkets and daily goods stores. Nonetheless, the traditional retailers have the organization to store parcels and maybe are able to sell a matching pair of socks with the shoes that you are picking up.

Finally, the last word of this dissertation should be dedicated to the consumer, who is influencing the spatial configuration of the sector. The role of this consumer forms an interesting topic for discussion. While he/she is the driving factor in the demand for home deliveries, his/her awareness of the resulting impacts cannot be taken for granted, despite regular reports in popular media outlets. Hence, should consumers be held responsible for the externalities their home deliveries are causing, e.g. through congestion pricing? But should consumers be blamed for the capitalist forces that result in the possibility to order parcels ever faster for free at home? If retailers would not offer these options and logistics players would not join the bidding war to realize them, maybe a sustainable solution would surface by itself, without policy intervention to let the consumer pay. This is interesting food for a discussion that should be held now.

A

Table A.1: Zip codes identified as connector or kinless hub in Chapter 2

Zip code	z-p Classification	Total linkages
Antwerpen (2030 Right Bank)	Connector hub	86,603
Antwerpen (2000 centre)	Connector hub	68,025
Brussels (1000 centre)	Kinless hubs	39,609
Zaventem (national airport)	Kinless hubs	35,077
Diegem (national airport)	Kinless hubs	29,006
Brussels (1020 laken)	Kinless hubs	19,519
Brussels (1070 anderlecht)	Connector hub	17,144
Zeebrugge	Connector hub	15,655
Gent	Kinless hubs	14,156
Roeselare	Connector hub	13,452
Brussels (1030 schaarbeek)	Connector hub	10,904
Oostende	Connector hub	10,83
Hasselt	Connector hub	9,913
Genk	Connector hub	8,918
Temse	Connector hub	8,308
Turnhout	Kinless hubs	8,185
Lokeren	Connector hub	7,475
Geel	Connector hub	6,6
Tournai (7522 west)	Kinless hubs	6,16
Sint-Truiden	Connector hub	5,587
Liége (4460 bierset airport)	Connector hub	5,521
Liége(4020 north)	Connector hub	5,267
Eupen	Connector hub	4,937
Liége (4400 flemalle)	Connector hub	4,111
Liége (4040 herstal)	Connector hub	3,826
Welkenraat	Connector hub	3,256
Liége (4000 centre)	Connector hub	2,978
Charleroi	Connector hub	2,941
Hervé	Connector hub	2,437
Hannut	Connector hub	2,297
Tournai (7500 centre)	Connector hub	2,29
Ciney	Connector hub	2,014
Malmedy	Connector hub	1,851

Table A.2: Characteristics of main nodes in Chapter 2

Zip code	LISA	Link frequency	z-value	P-coefficient	Z-p classification
Antwerpen	HH	>50,000	>2.5	0.56-0.69	Connector hub
Mechelen	HH	10-15,000	<2.5	0.77	Non-hub conn.
Brussel	HH	>50,000	>2.5	0.50-0.79	Connector hub
Gent	HH	10-15,000	>2.5	0.77	Kinless hub
Kortrijk	HH	5-10,000	<2.5	0.67	Non-hub conn.
Roeselare	HH	10-15,000	>2.5	0.66	Connector hub
Heist-od-berg	HH	5-10,000	<2.5	0.76	Non-hub conn.
Bierset	HH	<5000	>2.5	0.60	Connector hub
Genk	N.S.	5-10,000	>2.5	0.68	Connector hub
Oostende	N.S.	10-15,000	>=2.5	0.74	Connector hub
Zeebrugge	N.S.	15-20,000	>2.5	0.74	Connector hub
Hasselt	N.S.	5-10,000	>2.5	0.65	Connector hub
Liège	N.S.	5-10,000	>2.5	0.60	Connector hub
Tournai	N.S.	<5000	>2.5	0.60	Connector hub
Eupen	N.S.	<5000	>2.5	0.70	Connector hub
Geel	N.S.	5-10,000	>2.5	0.68	Connector hub
Westerlo	HH	<5000	<2.5	0.70	Non-hub conn.
Lokeren	N.S.	5-10,000	>2.5	0.68	Connector hub
Temse	HH	5-10,000	>=2.5	0.74	Connector hub
Sint-Truiden	N.S.	5-10,000	>=2.5	0.62	Connector hub
Hannut	N.S.	<5000	>=2.5	0.64	Connector hub
Ciney	LL	<5000	>2.5	0.53	Connector hub
Fleurus	N.S.	<5000	>2.5	0.67	Connector hub
Malmedy	N.S.	<5000	>2.5	0.40	Connector hub
Brugge	N.S.	5-10,000	<=2.5	0.24	Non-hub conn.

Table A.3: Typology of main nodes in Chapter 2

Zip code	Typology
Antwerpen	Cluster
Mechelen	Spill-over cluster
Brussel	Cluster
Gent	Cluster
Kortrijk	Spill-over cluster
Roeselare	Cluster
Heist-op-den-berg	Spill-over cluster
Bierset	Polycentric cluster
Genk	Polycentric cluster
Oostende	Polycentric cluster
Zeebrugge	Polycentric cluster
Hasselt	Polycentric cluster
Liège	Polycentric cluster
Tournai	-
Eupen	-
Geel	-
Westerlo	-
Lokeren	-
Temse	Spill-over cluster
Sint-Truiden	-
Hannut	-
Ciney	-
Fleurus	-
Malmedy	-
Brugge	-

References

2Flow. 2017. The on-demand economy: I want it all, and I want it now!
URL https://bit.ly/2E3axWC

Adam A, Delvenne JC, Thomas I. 2017. Cartography of interaction fields in and around Brussels: commuting, moves and telephone calls. *Brussels Studies* .

Adam A, Delvenne JC, Thomas I. 2018. Detecting communities with the multi-scale Louvain method: robustness test on the metropolitan area of Brussels. *Journal of Geographical Systems* 20: 363–386. ISSN 1435-5930.
URL http://link.springer.com/10.1007/s10109-018-0279-0

Ahuja G. 2000. Collaboration Networks, Structural Holes, and Innovation: A Longitudinal Study. *Administrative Science Quarterly* 45: 425. ISSN 00018392.

Akyelken N, Keller H. 2014. Framing the Nexus of Globalisation, Logistics and Manufacturing in Europe. *Transport Reviews* 34: 674–690. ISSN 0144-1647.

Aljohani K, Thompson RG. 2016. Impacts of logistics sprawl on the urban environment and logistics: Taxonomy and review of literature. *Journal of Transport Geography* 57: 255–263. ISSN 09666923.

Allen J, Anderson S, Browne M, Jones P. 2000. A framework for considering policies to encourage sustainable urban freight traffic and goods/service flows: summary report.

Allen J, Browne M, Cherrett T. 2012. Investigating relationships between road freight transport, facility location, logistics management and urban form. *Journal of Transport Geography* 24: 45–57. ISSN 09666923.

Allen J, Piecyk M, Piotrowska M, McLeod F, Cherrett T, Ghali K, Nguyen T, Bektas T, Bates O, Friday A, Wise S, Austwick M. 2017. Understanding the impact of e-commerce on last-mile light goods vehicle activity in urban areas: The case of London. *Transportation Research Part D: Transport and Environment* : 0–1ISSN 13619209.

Allen J, Thorne G, Browne M. 2007. Good practice guide on urban freight transport. URL http://www.bestufs.net

Anderson WP, Chatterjee L, Lakshmanan TR. 2003. E-commerce, transportation, and economic geography. *Growth and Change* 34: 415–432. ISSN 00174815.

Anderson WP, Leinbach TR. 2007. E-commerce, logistics and the future of globalized freight. In Leinbach TR, Capineri C (eds.) *Globalized Freight Transport*. Edward Elgar Publishing, 287.

Anselin L. 1995. Local indicators of spatial association—LISA. *Geographical analysis* 27.

Antràs P, Helpman E. 2004. Global Sourcing. *Journal of Political Economy* 112: 552–580.

Antrop M. 2004. Landscape change and the urbanization process in Europe. *Landscape and Urban Planning* 67: 9–26. ISSN 01692046.

Arbia G. 2001. The role of spatial effects in the empirical analysis of regional concentration. *Journal of Geographical Systems* 3: 271–281.

Arvidsson N, Pazirandeh A. 2017. An ex ante evaluation of mobile depots in cities: A sustainability perspective. *International Journal of Sustainable Transportation* 11: 623–632. ISSN 1556-8318.

Balland PA, De Vaan M, Boschma R. 2012. The dynamics of interfirm networks along the industry life cycle: The case of the global video game industry, 1987-2007. *Journal of Economic Geography* 13: 741–765. ISSN 1468-2702.

Ballantyne EE, Lindholm M, Whiteing A. 2013. A comparative study of urban freight transport planning: Addressing stakeholder needs. *Journal of Transport Geography* 32: 93–101. ISSN 09666923.

Barabasi AL, Albert R. 1999. Emergence of scaling in random networks. *Science* 286: 509–12. ISSN 1095-9203.

Barrios S, Bertinelli L, Strobl E, Teixeira AC. 2009. Spatial Distribution of Manufacturing Activity and its Determinants: A Comparison of Three Small European Countries. *Regional Studies* 43: 721–738. ISSN 0034-3404.

Barthelemy M. 2010. Spatial Networks. *Physics Reports* : 1–86.

Bathelt H, Malmberg A, Maskell P. 2004. Clusters and knowledge: local buzz, global pipelines and the process of knowledge creation. *Progress in Human Geography* 28: 31–56. ISSN 03091325.

Beckers J, Cárdenas ID, Verhestel A. 2018a. Identifying the geography of online shopping adoption in Belgium. *Journal of Retailing and Consumer Services* 45: 33–41.

Beckers J, Thomas I, Vanoutrive T, Verhetsel A. 2018b. Logistics clusters, including inter-firm relations through community detection. *European Journal of Transport and Infrastructure Research* 18: 178–195. ISSN 15677141.

Beckers J, Vanhoof M, Verhetsel A. 2017. Returning the particular: Understanding hierarchies in the Belgian logistics system. *Journal of Transport Geography* In press.

Behrends S. 2016. Recent Developments in Urban Logistics Research - A Review of the Proceedings of the International Conference on City Logistics 2009 - 2013. *Transportation Research Procedia* 12: 278–287. ISSN 23521465.

Bell GG. 2005. Clusters, networks, and firm innovativeness. *Strategic Management Journal* 26: 287–295. ISSN 01432095.

Benneworth P, Danson M, Raines P, Whittam G. 2003. Confusing Clusters? Making Sense of the Cluster Approach in Theory and Practice. *European Planning Studies* 11: 511–520. ISSN 09654313.

Bertinelli L, Decrop J. 2005. Geographical Agglomeration: Ellison and Glaeser's Index Applied to the Case of Belgian Manufacturing Industry. *Regional Studies* 39: 567–583.

BIPT. 2018. Postal points in Belgium.
URL `http://www.bipt.be/en/consumers/post/cartography`

Birkin M, Clarke G, Clarke M. 2017. *Retail Location Planning in an Era of Multi-Channel Growth*. Routledge.

Blauwens G, De Baere P, Van de Voorde E. 2014. *Transport Economics*. Antwerp: De Boeck, 5th edition.

Blondel V, Guillaume Jl, Lambiotte R, Lefebvre E. 2008. Fast unfolding of community hierarchies in large networks. *Journal of Statistical Mechanics: Theory and Experiment* 10: 1–6.

Blondel V, Krings G, Thomas I. 2010. Regions and borders of mobile telephony in Belgium and in the Brussels metropolitan zone. *Brussels Studies* .

Bonnafous A, Patier D, Routhier JL, Toilier F, Serouge M. 2016. French Surveys of the Delivery Approach: From Cross-section to Diachronic Analyses. *Transportation Research Procedia* 12: 181–192. ISSN 23521465.

Boschma R, Frenken K. 2011. The emerging empirics of evolutionary economic geography. *Journal of Economic Geography* 11: 295–307. ISSN 1468-2702.

Boschma R, Martin R (eds.) . 2010. *The Handbook of Evolutionary Economic Geography*. Edward Elgar Publishing.

Boschma RA, Weltevreden JW. 2008. An evolutionary perspective on Internet adoption by retailers in the Netherlands. *Environment and Planning A* 40: 2222–2237. ISSN 0308518X.

Boudouin D. 2012. *Methodological guide: urban logistics spaces*. Paris: La documentation Française.

Bounie N, Blanquart C. 2016. Logistics Centers and Agglomeration Economies: Logistics Clusters or Co-located Logistics Activities? The French Case. *World Conference on Transport Research WCTR* .

Boyer KK, Frohlich M, Hult G. 2004. *Extending the supply chain: How cutting-edge companies bridge the critical last mile into customers' homes*. New York: Amacon.

Bresnahan TF, Gambardella A. 2004. *Building High-Tech Clusters: Silicon Valley and Beyond*. Cambridge University Press. ISBN 0521827221.

Brown JR, Guiffrida AL. 2014. Carbon emissions comparison of last mile delivery versus customer pickup. *International Journal of Logistics Research and Applications* 17.

Browne M. 2001. The impact of e-commerce on transport. In *Joint OECD/ECMT Seminar*. URL https://doaj.org/article/92cf5b03a89e48779ecab0d54de2c824

Browne M, Allen J. 1999. The impact of sustainability policies on urban freight transport and logistics systems. In Meersman H, Van De Voorde E, Winkelmans W (eds.) *World Transport Research, Vol 1: Transport Modes and Systems*. Oxford, elsevier edition, 505–518.

Browne M, Allen J, Leonardi J. 2011. Evaluating the use of an urban consolidation centre and electric vehicles in central London. *IATSS Research* 35: 1–6. ISSN 03861112.

Browne M, Allen J, Nemoto T, Patier D, Visser J. 2012. Reducing Social and Environmental Impacts of Urban Freight Transport: A Review of Some Major Cities. *Procedia - Social and Behavioral Sciences* 39: 19–33. ISSN 18770428.

Browne M, Rizet C, Allen J. 2014. A Comparative Assessment of the Light Goods Vehicle Fleet and the Scope to Reduce its CO 2 Emissions in the UK and France. *Procedia - Social and Behavioral Sciences* 125: 334–344. ISSN 1877-0428.

Cao X, Chen Q, Choos S. 2013. Geographic distribution of e-shopping. *Transportation Research Record: Journal of the Transportation Research Board* : 18–26.

Cárdenas ID, Beckers J. 2018. A location analysis of pick-up points networks in Antwerp, Belgium. *International Journal of Transport Economics* In press.

Cárdenas ID, Beckers J, Vanelslander T. 2017a. E-commerce last-mile in Belgium: Developing an external cost delivery index. *Research in Transportation Business and Management* 24: 123–129. ISSN 22105395.

Cárdenas ID, Beckers J, Vanelslander T, Verhetsel A, Dewulf W. 2016. Spatial characteristics of failed and successful Ecommerce deliveries in Belgian cities. In *ILS 2016 - 6th International Conference on Information Systems, Logistics and Supply Chain*.

Cárdenas ID, Dewulf W, Vanelslander T, Smet C, Beckers J. 2017b. The e-commerce parcel delivery market and the implications of home B2C deliveries vs pick-up points. *International Journal of Transport Economics* 44: 235–256. ISSN 22105395.

Cárdenas ID, Sanchez-Diaz I, Dewulf W. 2017c. Coordination in Delivery Points Networks for the E-commerce Last-mile. *The 10th International Conference on City Logistics* : 148–161.

Carter C, Ellram L, Tate W. 2007. The use of social network analysis in logistics research. *Journal of Business Logistics* 28: 137–169.

Castells M. 1996. *The rise of the network society. The information age: economy, society and culture*. Oxford: Blackwell.

Chen Q, Conway A, Cheng J. 2017. Parking for residential delivery in New York City: Regulations and behavior. *Transport Policy* 54: 53–60. ISSN 0967070X.

Cherrett T, Allen J, McLeod F, Maynard S, Hickford A, Browne M. 2012. Understanding urban freight activity - key issues for freight planning. *Journal of Transport Geography* 24: 22–32. ISSN 09666923.

Cidell J. 2010. Concentration and decentralization: The new geography of freight distribution in US metropolitan areas. *Journal of Transport Geography* 18: 363–371. ISSN 09666923.

Clarke G, Thompson C, Birkin M. 2015. The emerging geography of e-commerce in British retailing. *Regional Studies, Regional Science* 2: 370–390. ISSN 2168-1376.

Colizza V, Barrat A, Barthelemy M, Vespignani A. 2006. The role of the airline transportation network in the prediction and predictability of global epidemics. *Proceedings of the National Academy of Sciences* 103: 2015–2020. ISSN 0027-8424.

Combes F. 2016. A theoretical analysis of the cost structure of urban logistics. *ILS 2016 - 6th International Conference on Information Systems, Logistics and Supply Chain* .

Comeos. 2016. E-commerce Belgium 2016. Technical report.
URL www.comeos.be

Couclelis H. 2004. Pizza over the Internet: e-commerce, the fragmentation of activity and the tyranny of the region. *Entrepreneurship & Regional Development* 16: 41–54. ISSN 0898-5626.

Croitoru A, Wayant N, Crooks A, Radzikowski J, Stefanidis A. 2014. Linking cyber and physical spaces through community detection and clustering in social media feeds. *Computers, Environment and Urban Systems* 53: 47–64. ISSN 01989715.

CSCMP. 2016. Supply Chain Management Definitions.
URL https://cscmp.org/supply-chain-management-definitions

Cui J, Dodson J, Hall PV. 2015. Planning for Urban Freight Transport: An Overview. *Transport Reviews* 35: 583–598. ISSN 14645327.

Dablanc L. 2007. Goods transport in large European cities: Difficult to organize, difficult to modernize. *Transportation Research Part A: Policy and Practice* 41: 280–285. ISSN 09658564.

Dablanc L, Giuliano G, Holliday K, O'Brien T. 2013. Best Practices in Urban Freight Management: Lessons from an International Survey. *Transportation Research Record* : 29–38ISSN 9780309287043.
URL https://hal.archives-ouvertes.fr/hal-00854997/document

Dablanc L, Liu Z, Koning M, Klauenberg J, de Oliveira LK, Blanquart C, Combes F, Coulombel N, Gardrat M, Heitz A. 2017. Observatory of Strategic Developments Impacting Urban Logistics (2017 version).
URL https://hal.archives-ouvertes.fr/hal-01627824/document

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 - Social and Behavioral Sciences* 2: 6087–6096. ISSN 18770428.

de Camargo Junior JB, Neto MS, Pires SRI, da Silva EM, Vivaldini M, Correa DA. 2012. The role of logistics services providers in the supply chain management: the social network perspective. In *Deuxieme Congres Transformare 19-20 mars 2012, Paris*. ISBN 0024-6301. ISSN 00246301, 45.

de Oliveira LK, Morganti E, Dablanc L, de Oliveira RLM. 2017. Analysis of the potential demand of automated delivery stations for e-commerce deliveries in Belo Horizonte, Brazil. *Research in Transportation Economics* 65: 34–43. ISSN 07398859.

Declercq K, Reumers S, Janssens D, Wets G. 2017. Onderzoek verplaatsingsgedrag vlaanderen 5.2 (2016-2017). Technical Report 0, Instituut voor Mobiliteit, Universiteit Hasselt.

Dekker J. 2016. Logistiek als een marketing tool.

Delgado M, Porter ME, Stern S. 2010. Clusters and entrepreneurship. *Journal of Economic Geography* 10: 495–518. ISSN 14682702.

Delgado M, Porter ME, Stern S. 2016. Defining clusters of related industries. *Journal of Economic Geography* 16: 1–38. ISSN 1468-2702.

Delvenne JC, Schaub MT, Yaliraki SN, Barahona M. 2013. The stability of a graph partition: A dynamics-based framework for community detection. *Dynamics On and Of Complex Networks* 2: 221–242.

Dicken P. 2015. *Global shift: Mapping the Changing Contours of the World Economy*. SAGE, 7th edition.

Dijkstra L, Poelman H. 2014. A harmonised definition of cities and rural areas: the new degree of urbanisation. *Regional and Urban Policy* : 28.

Ding Y, Fotheringham A. 1992. The integration of spatial analysis and gis. *Computers, Environment and Urban Systems* 16: 3–19. ISSN 01989715.

Doherty NF, Ellis-Chadwick F. 2010. Internet retailing: the past, the present and the future. *International Journal of Retail & Distribution Management* 38: 943–965. ISSN 0959-0552.

Donthu N, Garcia A. 1999. The internet shoper. *Journal of Advertising Research* 39: 52.

Dosi G. 1997. Opportunities, incentives and the collective patterns of technological change. *The Economic Journal* 107: 1530–1547.

Ducret R. 2012. Livraison de colis et logistique urbaine : quelles recompositions de la messagerie en milieu urbain? *Revue Française de Gestion Industrielle* 31: 29–48.

Ducret R. 2014. Parcel deliveries and urban logistics: Changes and challenges in the courier express and parcel sector in Europe - The French case. *Research in Transportation Business and Management* 11: 15–22. ISSN 22105395.

Ducret R, Lemarié B, Roset A. 2016. Cluster Analysis and Spatial Modeling for Urban Freight. Identifying Homogeneous Urban Zones Based on Urban Form and Logistics Characteristics. *Transportation Research Procedia* 12: 301–313. ISSN 23521465.

Durand B, Gonzalez-Feliu J. 2012. Urban Logistics and E-Grocery: Have Proximity Delivery Services a Positive Impact on Shopping Trips? *Procedia - Social and Behavioral Sciences* 39: 510–520. ISSN 18770428.

Duranton G, Overman HG. 2005. Testing for Localization Using Testing Data Micro-Geographic. *Review of Economic Studies* 72: 1077–1106.

Duschl M, Scholl T, Brenner T, Luxen D, Raschke F. 2015. Industry-Specific Firm Growth and Agglomeration. *Regional Studies* 49: 1822–1839. ISSN 0034-3404.

E-commerce Europe. 2016a. Country Report Belgium 2016. Technical report.
URL https://bit.ly/2RIpgcZ

E-commerce Europe. 2016b. European B2C E-commerce Report 2016. Technical report.
URL https://www.ecommerce-europe.eu/cms/showpage.aspx?id=2049

Edwards J, McKinnon A, Cherrett T, McLeod F, Song L. 2010. Carbon Dioxide Benefits of Using Collection-Delivery Points for Failed Home Deliveries in the United Kingdom. *Transportation Research Record: Journal of the Transportation Research Board* 2191: 136–143. ISSN 0361-1981.

Ellison G, Glaeser EL. 1997. Geographic Concentration in U.S. Manufacturing Industries: A Dartboard Approach. *Journal of Political Economy* 105: 889. ISSN 00223808.

Ellison G, Glaeser EL, Kerr WR. 2010. What Causes Industry Agglomeration ? Evidence from Coagglomeration Patterns. *American Economic Association* 100: 1195–1213.

European Commission. 2013. A concept for sustainable urban mobility plans, Annex to the Communication to the European Parliament, the Council, the European Economic and Social Committee of the Regions. Technical report, European Commission.

European Commission. 2014. Modern retail on the economic impact of choice and innovation in the EU food sector final report. Technical report, European Commission.

European Commission. 2015. Fact-finding Studies in Support of the Development of an EU Strategy for Freight Transport Logistics Lot 1: Analysis of the EU Logistics Sector. Technical report.
URL `https://bit.ly/2tieOip`

Eurostat. 2019. Digital economy and society statistics - households and individuals. Technical report.
URL `https://bit.ly/2UM59wy`

Everitt BS, Hothorn T. 2010. *A handbook of Statistical Analyses Using R*. CRC Pres, 2 edition.

Farag S, Krizek KJ, Dijst M. 2006a. E-Shopping and its Relationship with In-store Shopping: Empirical Evidence from the Netherlands and the USA. *Transport Reviews* 26: 43–61. ISSN 0144-1647.

Farag S, Schwanen T, Dijst M, Faber J. 2007. Shopping online and/or in-store? A structural equation model of the relationships between e-shopping and in-store shopping. *Transportation Research Part A: Policy and Practice* 41: 125–141. ISSN 09658564.

Farag S, Weltevreden JW, van Rietbergen T, Dijst M, van Oort F. 2006b. E-shopping in the Netherlands: Does geography matter? *Environment and Planning B: Planning and Design* 33: 59–74. ISSN 02658135.

Flämig H, Hesse M. 2011. Placing dryports. Port regionalization as a planning challenge - The case of Hamburg, Germany, and the Süderelbe. *Research in Transportation Economics* 33: 42–50. ISSN 07398859.

FOD Mobiliteit en vervoer. 2017. Kilometers afgelegd door Belgische voertuigen. Technical report, FOD Mobiliteit en vervoer.
URL `https://bit.ly/2Sml0V1`

Fortunato S. 2010. Community detection in graphs. *Physics Report* 75: 103.

Fortunato S, Barthelemy M. 2007. Resolution limit in community detection. *PNAS* 104: 36–41. ISSN 0027-8424.

Fortunato S, Hric D. 2016. Community detection in networks: A user guide. *Physics Reports* 659: 1–44. ISSN 0370-1573.

Fossheim K, Andersen J. 2017. Plan for sustainable urban logistics – comparing between Scandinavian and UK practices. *European Transport Research Review* 9: 1–13. ISSN 18668887.

Gevaers R, Van de Voorde E, Vanelslander T. 2011. Characteristics and typology of last-mile logistics from an innovation perspective in an urban context. In *City Distribution and Urban Freight Transport: Multiple Perspectives*. Edward Elgar Publishing, 56–71.

Gevaers R, Van de Voorde E, Vanelslander T. 2014. Cost Modelling and Simulation of Last-mile Characteristics in an Innovative B2C Supply Chain Environment with Implications on Urban Areas and Cities. *Procedia - Social and Behavioral Sciences* 125: 398–411. ISSN 18770428.

Giuliani E. 2010. Clusters, networks and economic development: an evolutionary economics perspective. In Boschma R, Martin R (eds.) *The Handbook of Evolutionary Economic Geography*. Cheltenham: UK: Edward Elgar, 261–279.

Gluckler J. 2007. Economic geography and the evolution of networks. *Journal of Economic Geography* 7: 619–634. ISSN 1468-2702.

Gómez T, Demeyer V, Manville S. 2017. D3.4 Set of Recommendations for follower cities related to infrastructural and regulative measures enabling a step-wise introduction of near zero emissions urban logistics. *Cyclelogistics Ahead – a key step towards zero emission logistics in cities* .
URL `https://bit.ly/2WJPgse`

Gonzalez MC, Hidalgo CA, Barabasi AL. 2008. Understanding individial human mobility patterns. *Nature* 453: 779–782.

Gonzalez-Feliu J, Ambrosini C, Routhier JL. 2012. New trends on urban goods movement : Modelling and simulation of e-commerce distribution. *European Transport* 50: 23p.

Gonzalez-Feliu J, Malhéné N, Morganti E, Trentini A. 2013. Developpement des espaces logistiques urbains. CDU et ELP dans l'europe du sud-ouest. Technical report.
URL https://halshs.archives-ouvertes.fr/halshs-00862009/document

Goodchild MF. 1992. Geographical information science. *International Journal of Geographical Information Systems* 6: 31–45.

Gouvernement Wallonie. 2012. Plan Marshall 2022. Technical report.

Graham M, Shelton T. 2013. Geography and the future of big data, big data and the future of geography. *Dialogues in Human Geography* 3: 255–261. ISSN 2043-8206.

Grauwin S, Szell M, Sobolevsky S, Hövel P, Simini F, Vanhoof M, Smoreda Z, Barabasi AL, Ratti C. 2017. Identifying the structural discontinuities of human interactions. *Scientific Reports* 7.

Guillain R, le Gallo J. 2010. Agglomeration and dispersion of economic activities in and around Paris: An exploratory spatial data analysis. *Environment and Planning B: Planning and Design* 37: 961–981. ISSN 02658135.

Guimerà R, Amaral LAN. 2005. Functional cartography of complex metabolic networks. *Nature* 433: 895–900. ISSN 0028-0836.

Hall P, Hesse M, Rodrigue JP. 2006. Guest editorial: Reexploring the interface between economic and transport geography. *Environment and Planning A* 38: 1401–1408. ISSN 0308518X.

Hayashi K, Nemoto T, Visser J. 2015. E-commerce and City Logistics Solution. In Taniguchi E, Thompson RG (eds.) *City Logistics. Mapping the Future*. Boca Raton, FL: CRC Press, 217.

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. *Transportation Research Procedia* 12: 812–824. ISSN 23521465.

Heitz A, Dablanc L, Olsson J, Sanchez-Diaz I, Woxenius J. 2018. Spatial patterns of logistics facilities in Gothenburg, Sweden. *Journal of Transport Geography* : 0–1ISSN 09666923.

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. *European Transport Research Review* 11: 1–22.

Hesse M. 2002. Shipping news: The implications of electronic commerce for logistics and freight transport. *Resources, Conservation and Recycling* 36: 211–240. ISSN 09213449.

Hesse M. 2004. Regulation of Regional Distribution Complexes. *Tijdschrift voor Economische en Sociale Geografie* 95: 162–173. ISSN 0040747X.

Hesse M. 2007. The System of Flows and the Restructuring of Space Elements of a Geography of Distribution. *Erdkunde* 61: 1–12.

Hesse M. 2008. *The city as a terminal: The urban context of logistics and freight transport.* Burlington, VT: Ashgate Publishing Company.

Hesse M. 2015. Selling the region as hub. In Cidell J, Prytherch D (eds.) *Transport, Mobility, and the Production of Urban Space*. Routledge. ISBN 9788578110796.

Hesse M, Rodrigue JP. 2004. The transport geography of logistics and freight distribution. *Journal of Transport Geography* 12: 171–184. ISSN 09666923.

Hoffmann J, Hirsch S, Simons J. 2015. Identification of spatial agglomerations in the German food processing industry. *Papers in Regional Science* 96: 139–162. ISSN 14355957.

Holl A, Mariotti I. 2018. The Geography of Logistics Firm Location: The Role of Accessibility. *Networks and Spatial Economics* 18: 337–361. ISSN 15729427.

Iwan S, Kijewska K, Lemke J. 2016. Analysis of Parcel Lockers' Efficiency as the Last Mile Delivery Solution - The Results of the Research in Poland. *Transportation Research Procedia* 12: 644–655. ISSN 23521465.

Jamagne P. 2001. Vademecum Statistische sectoren : 1–82.
URL https://bit.ly/2HTPUjx

Janjevic M, Kaminsky P, Ndiaye AB. 2013. Downscaling the consolidation of goods – state of the art and transferability of micro - consolidation initiatives. *European Transport \ Trasporti Europei* 54: 1–23.

Janjevic M, Ndiaye A. 2017. Investigating the financial viability of urban consolidation centre projects. *Research in Transportation Business and Management* 24: 101–113. ISSN 22105395.

Jiang B. 2013. Head/Tail Breaks: A New Classification Scheme for Data with a Heavy-Tailed Distribution. *The Professional Geographer* 65: 482–494. ISSN 0033-0124.

Johnston R, Harris R, Jones K, Manley D, Wang WW, Wolf L. 2018. Quantitative methods I : The world we have lost – or where we started from. *Progress in Human Geography* .

Johnston R, Sidaway J. 2015. *Geography and Geographers: Angelo-American Human Geography Since 1945*. London: Routledge.

Jones M. 2009. Phase space: Geography, relational thinking, and beyond. *Progress in Human Geography* 33: 487–506. ISSN 03091325.

Kau AK, Tang YE, Ghose S. 2003. Typology of online shoppers. *Journal of Consumer Marketing* 20: 139–156. ISSN 0736-3761.

Kiba-Janiak M. 2017. Urban freight transport in city strategic planning. *Research in Transportation Business & Management* 24: 4–16. ISSN 22105395.

Kirby-Hawkins E, Birkin M, Clarke G. 2018. An investigation into the geography of corporate e-commerce sales in the UK grocery market. *Environment and Planning B: Urban Analytics and City Science* ISSN 2399-8083.

Kitchin R. 2013. Big data and human geography: Opportunities, challenges and risks. *Dialogues in Human Geography* 3: 262–267. ISSN 2043-8206.

Kivelä M, Arenas A, Barthelemy M, Gleeson JP, Moreno Y, Porter MA. 2014. Multilayer networks. *Journal of Complex Networks* 2: 203–271. ISSN 20511329.

KPMG. 2017. Studie met betrekking tot de Belgische markt voor de levering van pakketten in het kader van e-commerceactiviteiten. Technical report, Belgian Institute for Postal and Parcel Services (BIPT).

Krugman. 1991. *Geography and Trade*. MIT press.

Kung KS, Greco K, Sobolevsky S, Ratti C. 2014. Exploring universal patterns in human home-work commuting from mobile phone data. *PLoS ONE* 9. ISSN 19326203.

Kwan Mp. 2016. Algorithmic Geographies: Big Data, Algorithmic Uncertainty, and the Production of Geographic Knowledge. *Annals of the American Association of Geographers* 106: 274–282. ISSN 1098-6596.

Lachapelle U, Burke M, Brotherton A, Leung A. 2018. Parcel locker systems in a car dominant city : Location , characterisation and potential impacts on city planning and consumer travel access. *Journal of Transport Geography* 71: 1–14.

Lagneaux F. 2008. Economic Importance of Belgian Transport Logistics.

Lagorio A, Pinto R, Golini R. 2016. Research in urban logistics: a systematic literature review. *International Journal of Physical Distribution and Logistics Management* 46: 908–931. ISSN 09600035.

Lancichinetti A, Fortunato S. 2009. Community detection algorithms: a comparative analysis. *Physical Review E* : 12.

Lancichinetti A, Radicchi F, Ramasco JJ, Fortunato S. 2011. Finding statistically significant communities in networks. *PloS one* 6. ISSN 1932-6203.

Levy M, Solomon S. 1997. New evidence for the power-law distribution of wealth Moshe. *Physica A* 242: 90–94.

Levy R, Talbot D. 2015. Control by proximity: Evidence from the 'Aerospace Valley' Competitiveness Cluster. *Regional Studies* 49: 955–972. ISSN 0034-3404.

Lin J, Chen Q, Kawamura K. 2016. Sustainability SI: Logistics Cost and Environmental Impact Analyses of Urban Delivery Consolidation Strategies. *Networks and Spatial Economics* 16: 227–253. ISSN 15729427.

Lindholm M. 2013. Urban freight transport from a local authority perspective – a literature review. *European Transport \ Trasporti Europei* : 1–37ISSN 1825-3997.

Lindholm M, Behrends S. 2012. Challenges in urban freight transport planning - a review in the Baltic Sea Region. *Journal of Transport Geography* 22: 129–136. ISSN 09666923.

Lundequist P, Power D. 2002. Putting Porter into Practice? Practices of Regional Cluster Building: Evidence from Sweden. *European Planning Studies* 10: 685–704. ISSN 0965-4313.

Luyten S, Van Hecke E. 2007. De Belgische stadsgewesten 2001.
URL `https://bit.ly/2SoRE8z`

Markusen A. 1996. Sticky Places in Slippery Space : A Typology of Industrial Districts. *Economic Geography* 72: 293–313.

Marshall A. 1890. *Principles of Economics.* London: Macmillion.

Martin R, Sunley P. 2003. Deconstructing clusters: chaotic concept or policy panacea? *Journal of Economic Geography* 3: 5–35. ISSN 1468-2702.

McKinnon A. 1998. Urban transhipment: review of previous work in the UK. Technical report, Heriot Watt University, Edinburgh.

McKinnon A. 2009. The present and future land requirements of logistical activities. *Land Use Policy* 26: 293–301. ISSN 02648377.

McKinsey & Company. 2017. The urban delivery bet: USD 5 billion dollar in venture capital at risk? Technical report.

URL https://www.mckinsey.com/industries/travel-transport-and-logistics/our-insights/how-will-same-day-and-on-demand-delivery-evolve-in-urban-markets

McLeod F, Cherrett T, Song L. 2006. Transport impacts of local collection/delivery points. *International Journal of Logistics Research and Applications* 9: 307–317. ISSN 1367-5567.

Mentzer JT, Keebler JS, Nix NW, Smith CD, Zacharia ZG. 2001. Defining Supply Chain Management. *Journal of Business Logistics* 22: 1–25. ISSN 07353766.

Miller HJ. 2018. Geographic information science II: Mesogeography. *Progress in Human Geography* 42: 600–609. ISSN 0309-1325.

Montreuil B. 2011. Toward a Physical Internet: meeting the global logistics sustainability grand challenge. *Logistics Research* 3: 71–87. ISSN 1865-035X.

Morganti E, Dablanc L, Fortin F. 2014a. Final deliveries for online shopping: The deployment of pickup point networks in urban and suburban areas. *Research in Transportation Business and Management* 11: 23–31. ISSN 22105395.

Morganti E, Seidel S, Blanquart C, Dablanc L, Lenz B. 2014b. The impact of e-commerce on final deliveries: alternative parcel delivery services in France and Germany. *International Scientific Conference on Mobility and Transport* 4: 178–190.

Motte-baumvol B, Belton-chevallier L, Dablanc L, Morganti E, Belin-Munier C. 2017. Spatial Dimensions of E-Shopping in France. *Asian Transport Studies* 4: 585–600.

National Bank of Belgium. 2017. Economic importance of the logistics sector in Belgium.

Nelson GD, Rae A. 2016. An Economic Geography of the United States: From Commutes to Megaregions. *Plos One* 11. ISSN 1932-6203.

Newman MEJ. 2003. The structure and function of complex networks. *SIAM review* 45: 167–256.

Newman MEJ. 2004. Fast algorithm for detecting community structure in networks. *Physical Review E* 69. ISSN 1539-3755.

O'Connor K. 2010. Global city regions and the location of logistics activity. *Journal of Transport Geography* 18: 354–362. ISSN 09666923.

Park H, Park D, Jeong IJ. 2016. An effects analysis of logistics collaboration in last-mile networks for CEP delivery services. *Transport Policy* 50: 115–125. ISSN 1879310X.

Patier D, Toilier F. 2017. Urban Logistics Spaces: what models, what uses, and what role for public authorities. *The 10th International Conference on City Logistics* : 319–333.

Pedersen PO. 2001. Freight transport under globalisation and its impact on Africa. *Journal of Transport Geography* 9: 85–99. ISSN 09666923.

Perboli G, Rosano M, Gobbato L. 2016. Parcel delivery in urban areas: opportunities and threats for the mix of traditional and green business models .

Piepers A. 2018. The definitive guide to pick-up points in Europe.
URL `https://www.paazl.com/blog/definitive-guide-pick-up-points-in-europe/`

Porter MA, Onnela J, Mucha P. 2009. Communities in networks. *Notices of the AMS* 56: 1082–1097.

Porter ME. 1998. Clusters and the new economics of competition. *Harvard Business Review* 76: 77–90.

Porter ME. 2003. The Economic Performance of Regions. *Regional Studies* 37: 545–546. ISSN 0034-3404.

Prologis. 2016. The Global E-commerce Revolution: What does its impac on logistics real estate really look like.
URL `https://bit.ly/2vt4vff`

Pumain D. 2006. *Hierarchies in natural and social sciences*. Springer Netherlands, 1 edition.

Ratti C, Sobolevsky S, Calabrese F, Andris C, Reades J, Martino M, Claxton R, Strogatz SH. 2010. Redrawing the map of Great Britain from a network of human interactions. *PLoS ONE* 5. ISSN 19326203.

Riguelle F, Thomas I, Verhetsel A. 2007. Measuring urban polycentrism: A European case study and its implications. *Journal of Economic Geography* 7: 193–215. ISSN 14682702.

Rimmer PJ, Kam BH. 2018. *Consumer Logistics. Surfing the Digital Wave*. Cheltenham, UK: Edward Elgar Publishing.

Rivera L, Sheffi Y. 2016. The benefits of logistics clustering. *International Journal of Physical Distribution & Logistics Management* 46: 242–268. ISSN 0960-0035.

Rivera L, Sheffi Y, Welsch R. 2014. Logistics agglomeration in the US. *Transportation Research Part A: Policy and Practice* 59: 222–238. ISSN 09658564.

Rodrigue JP. 2006a. Challenging the derived transport-demand thesis: Geographical issues in freight distribution. *Environment and Planning A* 38: 1449–1462. ISSN 0308518X.

Rodrigue JP. 2006b. Transport geography should follow the freight. *Journal of Transport Geography* 14: 386–388. ISSN 09666923.

Rodrigue JP. 2013. *The Geography of Transport Systems*. Routledge, 3th edition.

Rodrigue JP. 2015. E-Commerce as a Driver for City Logistics in China Title : E-Commerce as a Driver for City Logistics in China. Technical report, MetroFreight Center of Excellence Dept., New York.

Rodrigue JP, Dablanc L, Giuliano G. 2017. The freight landscape: Convergence and divergence in urban freight distribution. *Journal of Transport and Land Use* 10: 557–572. ISSN 1938-7849.

Russo F, Comi A. 2012. City Characteristics and Urban Goods Movements: A Way to Environmental Transportation System in a Sustainable City. *Procedia - Social and Behavioral Sciences* 39: 61–73. ISSN 18770428.

Russo F, Comi A. 2016. Urban freight transport planning towards green goals: Synthetic environmental evidence from tested results. *Sustainability* 8. ISSN 20711050.

Russo F, Comi A. 2017. From City Logistics Theories to City Logistics Planning. *The 10th International Conference on City Logistics* : 1017–1030.

Sassen S. 1991. *The global city: New York, London, Tokyo*. Princeton: Princeton University Press.

Schwanen T. 2016. Geographies of Transport II : Reconciling the General and the Particular. *Progress in Human Geography* 41: 1–10. ISSN 0309-1325.

Scott J. 2000. *Social Network Analysis: A Handbook*. London: SAGE Publications.

Scott J. 2010. Social network analysis: developments, advances, and prospects. *Social Network Analysis and Mining* 1: 21–26. ISSN 18695450.

Selviaridis K, Spring M. 2007. Third party logistics: A literature review and research agenda. *The International Journal of Logistics Management* 18: 125–150. ISSN 17586550.

Shah R, Ward PT. 2003. Lean manufacturing: Context, practice bundles, and performance. *Journal of Operations Management* 21: 129–149. ISSN 02726963.

Sheffi Y. 2012. *Logistics Clusters*. Cambridge, MA: MIT Press.

Sheffi Y. 2013. Logistics-Intensive Clusters: Global Competitiveness and Regional. In Bookbinder JH (ed.) *Handbook of Global Logistics, International Series in Operations Research & Management Science*, chapter 19. New York: Springer.

Sim LL, Koi SM. 2002. Singapore's internet shoppers and their impact on traditional shopping patterns. *Journal of Retailing and Consumer Services* 9: 115–124. ISSN 09696989.

Simini F, González MC, Maritan A, Barabási AL. 2012. A universal model for mobility and migration patterns. *Nature* 484: 96–100. ISSN 1476-4687.

Sobolevsky S, Campari R, Belyi A, Ratti C. 2014. General optimization technique for high-quality community detection in complex networks. *Physical Review E - Statistical, Nonlinear, and Soft Matter Physics* 90: 1–8. ISSN 15502376.

Sobolevsky S, Szell M, Campari R, Couronné T, Smoreda Z, Ratti C. 2013. Delineating geographical regions with networks of human interactions in an extensive set of countries. *PLoS ONE* 8. ISSN 19326203.

Song C, Koren T, Wang P, Barabási AL. 2010. Modelling the scaling properties of human mobility. *Nature Physics* 6: 818–823. ISSN 1745-2473.

Statistics Belgium. 2014. Census 2011 - België. Technical report, Statistics Belgium.
URL http://census2011.fgov.be/

Statistics Belgium. 2018. Fiscale inkomens. Technical report.
URL https://statbel.fgov.be/nl/themas/huishoudens/fiscale-inkomens/plus

Strale M. 2017. The role of port and logistics activities in Brussels. *Brussels Studies* .

The World Bank. 2018. Urban Development.
URL https://data.worldbank.org/topic/urban-development

Thiemann C, Theis F, Grady D, Brune R, Brockmann D. 2010. The structure of borders in a small world. *PLoS ONE* 5: 1–7. ISSN 19326203.

TomTom. 2017. Traffic Index. Technical report.

Tranos E, Gheasi M, Nijkamp P. 2015. International migration: a global complex network. *Environment and Planning B: Planning and Design* 42: 4–22. ISSN 0265-8135.

United Nations. 2018. World Urbanization Prospects: The 2018 Revision : 2ISSN 1435-9871.
URL https://esa.un.org/unpd/wup/publications/Files/WUP2018-KeyFacts.pdf

Uzzi B. 1997. Social structure and competition in interfirm networks: the paradox of embeddedness. *Science Quarterly* 42: 35–67.

van den Heuvel F, de Langen PW, van Donselaar KH, Fransoo JC. 2012. Identification of Employment Concentration Areas. *European Planning Studies* 22: 204–226. ISSN 0965-4313.

van den Heuvel F, de Langen PW, van Donselaar KH, Fransoo JC. 2014a. Proximity matters: synergies through co-location of logistics establishments. *International Journal of Logistics Research and Applications: A Leading Journal of Supply Chain Management* 17. ISSN 1469848X.

van den Heuvel F, Rivera L, van Donselaar KH, de Jong A, Sheffi Y, de Langen PW, Fransoo JC. 2014b. Relationship between freight accessibility and logistics employment in US counties. *Transportation Research Part A: Policy and Practice* 59: 91–105. ISSN 09658564.

van den Heuvel F, van Donselaar K, de Langen P, Fransoo J. 2016. Co-Location Synergies: Specialised Versus Diverse Logistics Concentration Areas. *Tijdschrift voor economische en sociale geografie* 107: 331–346. ISSN 0040747X.

van den Heuvel FP, de Langen PW, van Donselaar KH, Fransoo JC. 2013. Spatial concentration and location dynamics in logistics: The case of a Dutch province. *Journal of Transport Geography* 28: 39–48. ISSN 09666923.

van Duin J, de Goffau W, Wiegmans B, Tavasszy L, Saes M. 2016. Improving Home Delivery Efficiency by Using Principles of Address Intelligence for B2C Deliveries. *Transportation Research Procedia* 12: 14–25. ISSN 23521465.

Van Meeteren M, Boussauw K, Derudder B, Witlox F. 2016. Flemish Diamond or ABC-Axis. The Spatial Structure of the Belgian metropolitan area. *European Planning Studies* 24: 974–995.

Van Oosterhout M. 2004. Kiala: a new distribution concept for the home shopping market. In *Prediction of Economy Impacts on Transport (POET): Actual Case Studies for Passenger and Freight Transport*. Leiden: RAND Europe.

Vanhoof M, Smoreda Z, Ratti C. 2015. Drawing Boundaries of Social Interacties. *Uses and Value* 52: 2–5.

Vanthillo T. 2017. *Shaping conditions for economic development : the role of regional strategies*. Ph.D. thesis, Universiteit Antwerpen.

Vanthillo T, Verhetsel A, Vanelslander T. 2014. Subregionaal speerpuntbeleid in Vlaanderen. Technical report.

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: 110–121. ISSN 09666923.

Verhetsel A, Thomas I, Beelen M. 2010. Commuting in Belgian metropolitan areas. *Journal of Transport and Land Use* 2: 109–131.

Vrechopoulos AP, Siomkos GJ, Doukidis GI. 2001. Internet shopping adoption by Greek consumers. *European Journal of Innovation Management* 4: 142–153. ISSN 1460-1060.

Weltevreden JW. 2008. B2c e-commerce logistics: the rise of collection-and-delivery points in The Netherlands. *International Journal of Retail & Distribution Management* 36: 638–660. ISSN 0959-0552.

Weltevreden JW, van Rietbergen T. 2007. The Role of Perceived City Centre Attractiveness. *Tijdschrift voor Economische en Sociale Geografie* 98: 68–85. ISSN 0040-747X.

Winkenbach M, Janjevic M. 2017. Classification of last-mile delivery models for e-commerce distribution - a global perspective. *The 10th International Conference on City Logistics* : 162–176.

Woudsma C, Jakubicek P, Dablanc L. 2016. Logistics Sprawl in North America: Methodological Issues and a Case Study in Toronto. *Transportation Research Procedia* 12: 474–488. ISSN 23521465.

Xiao Z, Wang JJ, Lenzer J, Sun Y. 2017. Understanding the diversity of final delivery solutions for online retailing: A case of Shenzhen, China. *Transportation Research Procedia* 25: 985–998. ISSN 23521465.

Zhou Y, Wang XC. 2014. Explore the relationship between online shopping and shopping trips: An analysis with the 2009 NHTS data. *Transportation Research Part A: Policy and Practice* 70: 1–9. ISSN 09658564.

Zunder TH, Ibanez JN. 2004. Urban freight logistics in the European Union. *European Transport / Trasporti Europei* 28: 77–84.

Zurel Ö, Van Hoyweghen L, Braes S, Seghers A. 2018. Parcel lockers, an answer to the pressure on the last mile delivery? In *26th Conference On Postal And Delivery Economics*.