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Observatory of Strategic Developments Impacting Urban Logistics (2016 version)

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Deliverable 2.1

CITYLAB Observatory of Strategic Developments Impacting Urban Logistics (2016 version)

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This Deliverable is the first one of three: two more will **update the current version**, one in February 2017, one in February 2018.

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Table of Contents

One page executive summary 7

Full Summary of Findings 9

Initial objectives of Deliverable 2.1 and degree of completion 14
- **Initial objectives** 14
- **Degree of completion of objectives** 15

Introduction 16
- **What and whom is this Observatory for?** 16
- **What is in the Observatory?** 16
- **What is in the 2016 version of the Observatory?** 17

I. Logistics sprawl 18

I.1. What is logistics sprawl? Spatial patterns related to warehouses 18
- **I. 1.1 The development of warehouses in large metropolitan areas** 18
- **I. 1.2 Megaregions and logistics facilities** 19
- **I. 1.3 Logistics sprawl: comparative indicators for several case studies and main findings** 20
  - I. 1.3.1. Case studies and selected indicators 20
  - I. 1.3.2 Presentation of two case studies 22
  - I. 1.3.3 Comparative analysis of indicators 24
- **I. 1.4 Impacts of logistics sprawl on freight vehicle-kms** 27
  - I. 1.4.1 More freight vehicle-kms within a metropolitan area 27
  - I. 1.4.2 Less freight vehicle-kms on a global scale? 27
  - I.1.4.3. Other issues related to impacts of logistics sprawl 28
- **I. 1.5 Would moving logistics facilities "back to the city" bring benefits?** 29
  - I. 1.5.1 A new urban logistics real estate market 29
  - I. 1.5.2 Local policies towards urban logistics terminals: from regulatory obstacles to promotional strategies 31

I. 2. Key conceptual relationships 33
- **I. 2.1 Increase in the number of warehouses** 33
- **I. 2.2 Logistics sprawl** 33

I. 3. Focus: a theoretical exploration of the cost structure of urban logistics 34
- **I. 3.1 A simplified representation of freight transport** 34
- **I. 3.2 The cost structure of the supply chain** 35
- **I. 3.3 Optimal location of the warehouse** 38
- **I. 3.4 Analysis of the cost structure of the supply chain** 40
- **I. 3.5 Conclusion** 41

I.4 Conclusion on logistics sprawl 43

II. E-commerce and urban freight 45

II.1 E-commerce and challenges for urban freight: state of the art 45
- **II.1.1 Definition of e-commerce, structure and actors** 45
  - II.1.1.1 Definition of e-commerce 45
  - II.1.1.2 Actors and structures of e-commerce 47
  - II.1.1.3 E-commerce logistics and delivery 47

II.1.1.4 The specificity of e-grocery 48
II.1.2 E-commerce and urban logistics 48
II.1.2.1 The last mile competition of B2C e-commerce 48
II.1.2.2 The special case of French e-grocery 51
II.1.2.3 The problem of profitability and the development of logistic solutions 52
II.1.3. E-commerce and urban traffic 53
II.1.3.1 E-commerce and urban freight traffic 53
II.1.3.2 E-commerce and customers' shopping trips 54
II.1.4 E-commerce and innovation 55
II.1.5 City logistics: greener and more efficient delivery 56
II.1.6 Same-day deliveries: big players and localized lastmile delivery brokers in urban area 57

II.2 E-commerce indicators 59

II.3 Elements for urban planning and public decision-making 60
II.3.1 E-commerce and urbantraffic 61
II.3.1.1 The growth of e-commerce revenue results in higher parcels volume 61
II.3.1.2 The growth ratesof e-commerce sales and of urban freight traffic are different . 62
II.3.1.3 Instant delivery will increase urban freight traffic 63
II.3.1.4 Growth in freight transportation due to e-commerce depends on the return rates and the reverse needs 63
II.3.2 E-commerce, land use patterns and urban freight 63
II.3.2.1 E-commerce use is quite similar in rural and urban areas 63
II.3.2.2 Land use patterns influence urban freight traffic for home deliveries 64
II.3.2.3 Environmental impacts of delivery services are different according to the land use patterns 65
II.3.3 Substitution between shopping trips and deliveries 65
II.3.3.1 Urban traffic due to e-commerce depends on the substitution between personal travels and deliveries 65
II.3.3.2 The shift from personal travel to freight transport depends on the type of goods 65
II.3.3.3 Growth in freight transport due to e-commerce depends on the level and nature of the substitution with shopping trips 65
II.3.3.4 Instant deliveries will reduce shopping trips for e-grocery 65
II. 3.4 Delivery options in urban, suburban and rural areas 66
II.3.4.1 Potential choice of delivery options is the same in urban, suburban and rural areas 66
II.3.4.2 Trends for the development of delivery options depend on the land use 66
II.3.4.3 Preference for delivery options is different according to the land use 66
II.3.4.4 Instant delivery will be more popular in mega cities 67
II.3.4.5 Click-and-collect grow faster than home delivery 67
II.3.4.6 The type of delivery solutions depends on consumers' habit 67
II.3.4.7 More home delivery means higher failed delivery 68
II. 3.5 Logistics facilities for e-commerce 68
II.3.5.1 E-commerce leads to the rise in logistics facilities 68
II.3.5.2 The location of these logistics facilities depends on their size 69
II.3.5.3 The rise in same-day delivery leads to the increase of sortation centres close to customers 70

II.4 Conclusion on e-commerce 71

III. General conclusion and table of impacts 73
III.1 General conclusions applying to logistics sprawl and e-commerce 73
III.2 Impact Table: impacts of new trends on urban freight mobility and city life 75

IV. References **80**
References for logistics sprawl **80**
References for e-commerce **81**

V. Appendices **85**
Appendix 1. Table of logistics sprawl indicators **85**
Appendix 2. Logistics sprawl case studies **88**
I.6.1 Amsterdam, The Netherlands 88
I.6.2 Atlanta, USA 91
I.6.3 Belo Horizonte, Brazil 93
I.6.4 Berlin, Germany 95
I.6.5 Gothenburg metro, Sweden 97
I.6.6 Gothenburg region, Sweden 100
I.6.7 Los Angeles, USA 103
I.6.8 Paris, France - all warehouses 105
I.6.9 Paris, France – parcel and express transport terminals 108
I.6.10 Randstad, The Netherlands 110
I.6.11 Rotterdam, The Netherlands 113
I.6.12 Seattle, USA 116
I.6.13 Tokyo, Japan 118
I.6.14 Toronto, Canada- Greater Toronto Area 120
I.6.15 Toronto, Canada- Greater Golden Horseshoe 123
Appendix 3. Detailed calculations for Section I.3 ..... **125**
Appendix 4. Table of e-commerce indicators **129**

One page executive summary

Urban freight living labs need to operate in full recognition of the **challenges that will shape the mobility of goods in urban areas** in the future. These challenges are several: macro economic, micro-economic, demographic, technological, societal, and legal. To help CITYLAB cities implement their urban freight initiatives, a better understanding of these challenges is necessary. This is what this *Observatory of strategic developments impacting urban logistics* intends to do, by **providing data and analysis** on some of the most important, or less well known, trends that will shape the urban mobility of goods in the future.

This first version (2016) of the Observatory provides data and analyses on 1) **Logistics Sprawl**; and 2) **E-commerce**. Our findings about the **main impacts** of these two trends for cities involved in urban freight living labs are the following:

- **The number of logistics facilities** (in their diversity: warehouses, fulfilment centres, distribution centres, cross-dock terminals) is increasing in cities, especially cities of some logistics importance as large consumer markets and/or logistics hubs processing the flow of goods generated by the global economy. These facilities are generally located in suburban areas, but a new **niche market of urban warehouses** is emerging.
- Both e-commerce and logistics sprawl generate a **rise in freight vehicles in urban areas**, dominated by small vehicles, while medium to large lorries are relatively less important. These vehicles performing delivery operations are visible in neighbourhoods and a times of day when they were not identified before: residential neighbourhoods, residential building blocks, side streets, in the early evening and on week-ends. Emerging **new types of vehicles** (clean delivery vehicles, two and three wheelers) are now visible in urban centres.
- **Innovations in the urban supply chains** include diverse forms of pick-up points and click-and-collect solutions, while the recent but extremely rapid rise in technologies and algorithms supporting **instant deliveries** brings with it a flourish of new companies connecting customers, suppliers and independent messengers.
- The overall impact of these new trends on energy and carbon emission related to urban freight is difficult to assess. Some trends bring **more CO_2 emissions**, such as the relocation of logistics facilities far away in the suburbs, as de-consolidated shipments are delivered to urban consumers and businesses in smaller and more numerous vans. Some trends bring **less CO_2 emissions**, with a rise in cleaner vehicles and innovative solutions such as drop-off/pickup points. Substitution patterns between personal mobility and professional freight mobility can be a good, or a bad, thing for CO_2 emissions, depending on the initial circumstances and the way personal shopping was done before online orders.
- What is certain is that these changes bring **diversity in the urban traffic flow**. Instant messengers are using all sorts of transport modes, including foot, bicycles, electrically assisted cargocycles, motorbikes, and various types of vans and lorries. This can negatively impact **traffic management, road safety and conflicts in road uses, congestion, air pollution**. Also, the trends we have looked at bring **new types of urban jobs**, with many unresolved legal issues and poor working conditions in many instances. New types of logistics buildings bring architectural diversity and innovation in cities, but also complaints about **noise, aesthetics,** as well as congestion and pollution at entrance and exit points.
- These environmental and social impacts have been so far poorly documented and researched. Consumers are the main drivers of the changes we have observed, but they are also the residents or visitors of urban areas, and for that they carry an important share of the **burdens, as well as the benefits, of the new landscape of urban logistics**.

Full Summary of Findings

This first version of CITYLAB's *Observatory of strategic developments impacting urban logistics* provides a first set of **indicators**, shown in Appendices I.1 and II.1, as well as, throughout the document, **analyses** of these indicators and a first attempt at **conclusions** on how observed trends impact the mobility of goods in cities today and in the future.

Urban freight living labs need to operate in full recognition of the **challenges that will shape the mobility of goods in urban areas** in the future. These challenges are several: macro economic, micro-economic, demographic, technological, societal, and legal.

To help CITYLAB cities implement their urban freight initiatives, a better understanding of these challenges is necessary. This is what this Observatory intends to do, by **providing data and analysis** on some of the most important, or less well known, trends that will shape the urban mobility of goods in the future.

We have chosen to focus on the following topics:

- Land use issues and **logistics sprawl**;
- New ways of servicing supply chains (including **e-commerce** and **e-grocery**, recycling and the **circular economy**);
- Growing importance of **service trips**.

As mentioned above, these trends, which are defined below, do not represent the whole range of challenges that will shape urban freight. They represent some of these challenges. The reasons we do not encompass a general overview of the drivers of future urban freight mobility are several, with a first reason being the necessary limitation in time and workforce of our CITYLAB 2.1 team. Another more legitimate reason is that these topics have **not been researched much** insofar as they impact the urban mobility of goods (and the mobility of people carrying goods).

This first deliverable covers land use issues and **logistics sprawl as well as e-commerce and e-grocery** supply chains. The next two versions of the deliverable, due in one and two years, will cover the circular economy and service trips. We have **collected data, compared and analysed** these data, and provided **a list of 'conceptual relationships**' that contribute to the identification of simple relationships between trends (i.e. logistics sprawl and e-commerce) and the urban mobility of goods. We have introduced an **'Impact Table**' identifying impacts on various stakeholders and activities.

Obvious **limitations of this work** are the following. Data on logistics sprawl is emerging, through a growing number of case studies in several world regions. However, these case studies are still limited in number (less than twenty), and not always comparable in terms of methodology and scope. More case studies are on-going and we are hopeful we can enlarge our sources of information for the next versions of the deliverable. In the summer of 2016, a special session about logistics sprawl will take place during the World Conference on Transport research in Shanghai, and hopefully will provide feedbacks for our analysis. Data on e-commerce is now quite widespread, at least for Europe and North America. However, missing are data sources that specifically focus on urban areas. The behaviour of urban residents regarding e-commerce and e-delivery, as compared with the rest of the population, is not well known, and even less examined in terms of impacts on mobility and urban supply chains. Other limitations regard conceptual relationships, for both topics. Some of our propositions are based on assumptions and hypotheses that require further verification, largely because of lack of comparable data. For logistics sprawl, we carried out a more theoretical exercise using modelling techniques, in order to verify theoretically some of our assumptions. This exercise confirmed that the related relationships we suggested were robust, which makes it interesting to develop further this theoretical work in the future.

Our **main findings** are the following.

1) "**Logistics sprawl**" (LS) is the spatial deconcentration of logistics facilities and distribution centres in metropolitan areas. It has been a noticeable spatial pattern for the last decades in large cities around the world, as identified by about twenty case studies covering mostly European and North American cities, with Tokyo, Belo Horizonte and Bogota in addition. We have organized the data collected in these case studies under 17 indicators.

All indicators have been examined and compared. The main results of this data collection, comparison and analysis are the following.

- The number of warehouses per million of urban residents ranges from 22 (Belo Horizonte) to 236 (greater Gothenburg). This varies with the definition of a warehouse and the accurateness of the database: comparisons are actually difficult as the type of warehouses can vary from one case study to another, and data sources have issues and are not perfect.
- The number of warehouses per million of residents has increased overtime in all case studies except Amsterdam, Randstadt and Tokyo.
- Logistics sprawl has happened in all case studies except three (Amsterdam, Belo Horizonte, Seattle).
- The average increase of the LS indicator (increase in average distance of warehouses to their barycentre (= centre of gravity)) is **0.45 km/year**.

The main conceptual relationships between logistics sprawl and the urban mobility of goods are the following.

a) Most cities can expect a **continued increase in the number of warehouses** located in the metropolitan area. Furthermore:

- The increase in the number of logistics facilities overtime is positively related to the importance of the **role of global logistics hub** played by an urban area.
- The increase in the number of logistics facilities overtime is positively related to the increase in the **digitalization of retail** (increase in B2C demand) in an urban area.
- As B2C demand increases in large metropolitan areas, the **demand for small logistics buildings within the urban area** increases.
- The increase in the number of warehouses over time is **larger in megaregions**.
- The increase in the number of warehouses over time is **larger in big cities** within megaregions.

b) **Logistics sprawl can be expected to continue** in many cities, in the following manners:

- Logistics sprawl is positively related to the **differential in land/rent values for logistics land uses** between suburban and central areas in an urban region
- Logistics sprawl is positively related to the **availability of large land parcels** in suburban settings
- Logistics sprawl is negatively related to the degree of **regional logistics land use control**
- The degree of logistics sprawl varies with the **type of logistics terminal** (i.e. stronger for distribution and fulfilment centres, weaker for parcel transport terminals)
- Logistics sprawl generates an increase in the number of freight vehicle-kilometres within the urban region <u>if</u> its rate is higher, on the same time period, than economic and residential sprawl.
- Additional vehicle-kilometres induced by logistics sprawl are likely to impact less densely populated areas, thus generating less diffused transport externalities (local pollutants, noise, accidents).

In order to analyse the potential causes of logistics sprawl, we have built a simple analytical model of the cost structure of urban logistics. Even on a simple case, the model illustrates the

complex and nonlinear **relationship** between the **land use market,** the parameters of **urban logistics** (vehicle speed, workday duration, costs and the demand) and the **location of a warehouse**. In particular, the research shows that an exogenous increase in the demand for pickup and delivery operations **results in warehouses locating further away from cities**, as a result of transport operations weighing relatively less in their cost function. On the other hand, the model hints to how an emerging market for very reactive logistics needs to be accompanied by **logistic facilities coming back in city centres**, despite the price. Finally, the model shows that the location of logistic facilities is determined by the **rent gradient, not its absolute value**: if rents are uniformly high, warehouses will have no need to move far from the city centre.

This brings some possible implications in terms of market structure and equilibrium pricing. As urban logistics is most probably characterized by economies of scales, there is economic ground to the idea of **giving some space to logistic facilities near city centres** in order to improve the efficiency of urban logistics. However, this should be done in a careful way**,** lest a mechanical increase in rents in these areas cancels the initial objective of the action.

2) **E-commerce** is defined by the OECD as "the sale or purchase of goods or services, conducted over computer networks by methods specifically designed for the purpose of receiving or placing of orders. (…) Payment and the ultimate delivery of the goods or services do not have to be conducted online. An e-commerce transaction can be between enterprises, households, individuals, governments, and other public or private organizations". We show that in a large range of countries, global business to consumer e-commerce sales have **increased sharply over the last decade**, driven by a growing online population and **changes in consumer behaviours**. China (the world's largest B2C country), the US and the UK account for 61% of total B2C e-commerce sales in the world. However, online retail of goods accounts for only about 6% of world retail.

What we have been looking at for the Observatory is e-commerce including only the sales of goods, not services, although the data has not always been easy to differentiate. In the US and Europe, it represents about 55% of overall B2C e-commerce.

In the document, we have analysed the structure and main players of e-commerce, and its relationships to urban logistics and urban traffic. Some innovations in the way e-commerce deliveries are being carried out have been identified. Actually, e-commerce appears to be **one of the main drivers for city logistics innovations** in terms of new operators, green operations, and the use of new types of vehicles. Impacts also include the type and location of new urban distribution centres, as e-retailers are getting (spatially) closer to the customers, in order to serve them more rapidly.

We came up with the proposition of **several conceptual relationships between e-commerce development and the urban mobility of goods**. These are the following:

a) Relationships between e-commerce and urban traffic

- The growth of e-commerce revenue results in **higher parcels volume.**
- The growth rates of e-commerce sales and of urban freight traffic are different.
- **'Instant deliveries'** will increase urban freight traffic.
- Growth in freight transportation due to e-commerce depends on the return rates and the reverse needs.

b) Relationships between e-commerce, land use patterns and urban freight

- Interestingly, e-commerce use is quite **similar in suburban (even rural) areas and urban areas.**
- Land use patterns influence urban freight traffic for home deliveries.
- The **environmental impacts** of delivery services are different according to land use patterns.

c) Substitution between shopping trips and deliveries

- Urban traffic due to e-commerce depends on the **substitution between personal travels (motorized or non-motorized shopping trips) and deliveries**.
- The shift from personal travel to freight transport depends on the type of goods.
- Growth in freight transport due to e-commerce depends on the level and nature of the substitution with shopping trips.
- Instant deliveries may reduce shopping trips for e-grocery.

d) Delivery options in urban, suburban and rural areas

- Potential choice of delivery options is the same in urban, suburban and rural areas.
- Trends for the development of delivery options depend on the land use.
- Preference for delivery options is different according to the land use.
- Instant delivery will be more popular in mega cities.
- **Click-and-collect solutions** grow faster than home delivery.
- The type of delivery solutions depends on consumers' habits.

e) Relationships between e-commerce and logistics facilities

- E-commerce leads to the **rise in the number of logistics facilities**
- The location of these logistics facilities depends on their size.
- The rise in same-day and instant deliveries leads to the **increase of sortation centres close to customers**.

One general conclusion we can draw in this first version of CITYLAB's *Observatory of strategic developments impacting urban logistics* is that **logistics facilities** (in their diversity: warehouses, fulfilment centres, distribution centres, cross-dock terminals) are increasing in cities, especially cities of some logistics importance as large consumer markets and/or logistics hubs processing the flow of goods generated by the global economy.

These facilities are generally located in suburban areas, but a new **niche market of urban warehouses** is emerging.

Other changes include the **rise in freight vehicles in urban areas**, dominated by small vehicles, while medium to large lorries are relatively less important. These vehicles performing delivery operations are visible in neighbourhoods and at times of day when they were not identified before: residential neighbourhoods, residential building blocks, side streets, in the early evening and on week-ends. Emerging **new types of vehicles** (clean delivery vehicles, two and three wheelers) are now visible in urban centres.

Innovations in the urban supply chains also include diverse forms of pick-up points and click-and-collect solutions, while the recent but extremely rapid rise in technologies and algorithms supporting **instant deliveries** brings with it a flourish of new companies connecting customers, suppliers and independent messengers.

The overall impact of these new trends on energy and carbon emission related to urban freight is difficult to assess. Some trends bring **more CO_2 emissions**, such as the relocation of logistics facilities far away in the suburbs, as de-consolidated shipments are delivered to urban consumers and businesses in smaller and more numerous vans. Some trends bring **less CO_2 emissions**, with a rise in cleaner vehicles and innovative solutions such as drop-off/pick-up points. Substitution patterns between personal mobility and professional freight mobility can be a good, or a bad, thing for CO_2emissions, depending on the initial circumstances and the way personal shopping was done before online orders.

What is certain is that these changes bring **diversity in the urban traffic flow**. Instant messengers are using all sorts of transport modes, including foot, bicycles, electrically assisted cargocycles, motorbikes, and various types of vans and lorries. This can negatively impact **traffic management, road safety and conflicts of road uses, congestion, air pollution**. Also, the trends we have looked at bring **new types of urban jobs**, with many unresolved legal issues and poor working conditions in many instances. New types of logistics buildings bring architectural diversity and innovation in cities, but also complaints about **noise, aesthetics,** as well as congestion and pollution at entrance and exit points.

These environmental and social impacts have been so far poorly documented and researched. Consumers are the main drivers of the changes we have observed, but they are also the residents or visitors of urban areas, and for that they carry an important share of the **burdens, as well as the benefits, of the new landscape of urban logistics**.

Initial objectives of Deliverable 2.1 and degree of completion

Initial objectives

As indicated in our proposal, this deliverable of Task 2.1 follows the initial objective as formulated below:

*"**Establish and operate an Observatory of Strategic Developments Impacting Urban Logistics.** This task establishes and operates an observatory of strategic developments and trends that impact urban logistics. The Commission call for 5.2 noted several of these important trends. This is essentially a top-down task building on knowledge held within the CITYLAB project as a result of the partners' extensive engagement in understanding key trends in urban logistics. The focus in this task is to use the CITYLAB project partners and the wider network of supporting partners to capture the key trends that are influencing urban logistics now and for the period to 2030 (the target date for the EU goal of virtually CO_2 free city logistics). The task will start with drawing a map of the best updated data available on urban freight. It will then develop a framework within which to consider major trends that are impacting on urban freight including:*

- *Land use issues and logistics sprawl*
- *New ways of servicing supply chains (including e-commerce and e-grocery, recycling and the circular economy) Growing importance of service trips*

These trends are relevant for developing and implementing actions and measures in the CITYLAB living labs that help mitigate the freight impacts associated with them.

*In terms of **land use and logistics sprawl** the focus is on the relationship between land use and logistics demand, and effects of sprawl, with the consequences on possible freight mitigation strategies. Logistics sprawl is the spatial deconcentration of logistics facilities and distribution centres in metropolitan areas (Dablanc and Ross, 2012). Warehouse location has a direct impact on the distance over which goods are moved in urban areas. Impacts of different land uses and logistics spatial patterns as well as impacts of urban planning will be assessed. We will study the differentiated locational patterns of logistics centres across European metropolitan areas, identifying the **microeconomic causes underlying logistics sprawl**, comparing various urban forms with respect to the efficiency (both economic and environmental) of urban logistics. The techniques developed by partners will be used to build a comprehensive assessment of **how logistics land use patterns will influence urban freight transport** across a range of cities and how the consequences could be dealt with.*

*In terms of **new ways of servicing supply chains** one of the focuses will be on obtaining a better understanding of **impacts of trends in e-commerce**, e-grocery, same day delivery for e-commerce, smaller shipment sizes, smaller and environmentally friendly delivery vehicles, and the use of pick-up points and locker banks. We will **compare developments across several countries and cities**, including the impact of major actors such as Amazon with new e-grocery services recently introduced in Europe. The other focus is on **recycling and the circular economy** and the impact that changes in legislation and operations in this field are having on logistics efficiency in urban areas. For example, the rise of recycling has increased the demand for transport to avoid products entering the waste stream. On the other hand, so called circular economy activities based on short supply chains and recycling and re-use have reduced vehicle-kilometres travelled for waste transport. These trends are complicated because they have happened in rather different ways in different countries – we will explore these impacts and variations in them in different locations.*

***Service trips** are poorly understood as they are difficult to capture through normal transport surveys and statistics. This task will provide more detailed understanding of the rationale for service trips and the possibilities to reduce, combine, or manage these trips in other ways will*

be addressed. However, cities rely on services for their economic well-being and these activities form a significant part of the traffic flow in the urban area. We will make use of existing surveys to better understand the pattern and rationale for a range of service trips (such as the KID Survey in Germany). In addition, we will draw on examples and case studies that have targeted service traffic such as the planning for the London Olympic Games.

The objective of this investigation of these trends and their urban freight impacts is to gather information and data (essentially through desk research). This will thereby provide a better understanding of ***how business and consumer trends will exert pressure on urban freight transport services****."*

Degree of completion of objectives

This first Deliverable (in a total of three for the duration of CITYLAB) has achieved the following:

- **90% completion of data collection of logistics sprawl case studies and comparative analysis**. Some case studies were not fully available/completed when finalizing this report. This is the case for Brussels, London, Belo Horizonte (whole metropolitan area), Bogota. Additional case studies may be realized in the following years so next Deliverables (February 2017 and February 2018) will include them.This is presented in Sections I-1 and I-2, as well as Appendices I.1 and I.2 of the present document.
- **100% completion of the study of microeconomic causes underlying logistics sprawl**. This is presented in Section I.3 of the present document.
- **50% completion of the study of e-commerce trends** and comparison across countries and cities. A major effort has been made to identify the best sources of information and collect data (Section II.1, Section II.2, Appendices). A detailed analysis has been made on the potential impacts of these trends on urban freight mobility (Section II.3). Specifically *urban* data has been difficult to collect, as urban e-commerce surveys are scarce. We are aware of on-going comprehensive surveys in Paris and Lyon, in France, and possibly other cities, and these should be available for the next version of the Deliverable in February 2017.
- **0% completion of recycling and the circular economy analysis**. To smooth out person-month efforts, these topics have been left for the next version of the Deliverable in February 2017.
- **0% completion of service trips analysis**. To smooth out person-month efforts, this topic has been left for the next version of the Deliverable in February 2017.

Introduction

What and whom is this Observatory for?

Urban freight living labs need to operate in full recognition of the **challenges that will shape the mobility of goods in urban areas** in the future. These challenges are several: macro-economic, micro-economic, demographic, technological, societal, and legal. To help CITYLAB cities implement their urban freight initiatives, a better understanding of these challenges is necessary.

This is what this *Observatory of strategic developments impacting urban logistics* intends to do, by **providing data and analysis** on some of the most important, or less well known, trends that will shape the urban mobility of goods in the future.

For each of the trends we chose to focus on (land use and logistics sprawl; e-commerce; circular economy; service trips - see below for a more detailed description of each trend), the Observatory will provide a **collection of actual data**, as up to date as can be found in the literature and statistics databases; it will provide **evidence – or hypotheses - of causal relationships** between trends and the urban mobility of goods; and it will provide **analyses of the impacts** of these trends on the different stakeholders involved in urban freight (transport companies, shippers and receivers, consumers, public authorities, agencies, business groups) and on the urban environment.

Three Deliverables are planned, one in 2016 (this version), one in 2017 and one in 2018. The first Deliverable (this version) looks at two of the four trends: land use and logistics sprawl; e-commerce, while the remaining trends will be included in the 2017 and 2018 version.

This Observatory is set to work in the following manner for the duration of the CITYLAB project:

- it will be **publically available on-line**, in the form of the most important sections of the Deliverables, including Appendices and Impact Table.
- The main findings will be presented during CITYLAB events such as local or plenary workshops.
- The on-line version will be **updated regularly** by the CITYLAB team in charge of the Observatory.
- Two fully updated versions will be provided when the new Deliverables (2017 and 2018) are finalized. They will include the analysis of two more trends: the circular economy; and service trips.

A key additional objective for the Observatory is **to make it permanent**, so that it continues to be updated and available after the end of the CITYLAB project.

The best available options to reach that goal and make the Observatory permanent will be examined and a strategy will be proposed in the second version of the Deliverable (2017).

What is in the Observatory?

As a whole, the Observatory will be focusing on the following topics:

- Land use issues and **logistics sprawl**;
- New ways of servicing supply chains (including **e-commerce** and **e-grocery**, recycling and the **circular economy**);
- Growing importance of **service trips**.

These trends do not represent the whole range of challenges that will shape urban freight. They represent some of these challenges. The reasons we do not encompass a general

overview of the drivers of future urban freight mobility are several, with a first reason being the necessary limitation in time and workforce of our CITYLAB 2.1 team. Another more legitimate reason is that these topics have **not been researched much** insofar as they impact the urban mobility of goods (and the mobility of people carrying goods).

What is in the 2016 version of the Observatory?

This first Deliverable covers land use issues and **logistics sprawl** as well as **e-commerce and e-grocery** supply chains. The next two versions of the deliverable, due in one and two years, will cover the circular economy and service trips. We have **collected data,** compared and analysed these data, and provided a list of '**conceptual relationships**' that contribute to the identification of simple relationships between trends (i.e. logistics sprawl and e-commerce) and the urban mobility of goods. We have introduced an **'Impact Table**' identifying impacts on various stakeholders and activities.

Two main sections follow: one about land use and logistics sprawl issues (Section I); and one about e-commerce and e-grocery issues (Section II). Conclusions of findings can be found after each section. A **general conclusion** provides common findings as well as an Impact Table. **Appendices** provide the collected data on each trend.

I. Logistics sprawl

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I.1. What is logistics sprawl? Spatial patterns related to warehouses

"Logistics sprawl" is the spatial deconcentration of logistics facilities and distribution centres in metropolitan areas (Cidell, 2010; Dablanc and Ross, 2012). It has been a noticeable spatial pattern for the last decades in large cities around the world, especially cities with a strong logistics activity. Logistics sprawl can have impacts on freight mobility within the metropolitan area.

Logistics sprawl is one of the spatial patterns that can be related to warehouses. Through the literature and case studies, the following three spatial patterns related to the location of logistics facilities can be identified:

- a pattern of **polarization of logistics facilities in megaregions**
- within a megaregion, a pattern of **polarization of logistics facilities around the main urban conurbations**
- Within the main conurbation, a pattern of **logistics sprawl**.

In the following sub-sections, we will detail these patterns. We will see that logistics facilities tend to increase in numbers, especially in megaregions and large metropolitan areas.At the metropolitan level, we will examine patterns of logistics sprawl. We will then examine the impacts of logistics sprawl on cities.

I. 1.1 The development of warehouses in large metropolitan areas

There are **more warehouses today** than a few decades ago, and these freight facilities tend to concentrate in large metropolitan areas.

Starting in the 1980s, the world entered a “new distribution economy” (Hesse and Rodrigue, 2004), an economy largely dependent upon efficient and increasingly globalized networks of goods distribution and just-in-time operations. This has led to a reduction in large inventories of intermediate and final products, but also to a concomitant rise in logistics facilities (Movahedi et al., 2009): global supply chains require more freightcentres, and the way these facilities are spatially organized has become a key feature of an efficient goods distribution network. The efficiency of goods’ distribution depends increasingly upon the optimal location and sizing of freight terminals. Freight transportation costs have decreased and for many industries they have become “trivial” (Glaeser and Kohlhase, 2004). Transport is now “out of consideration in economic geography” (Hall et al., 2006). Low freight costs create what Rodrigue (2004) calls an “increased locational flexibility” for freight and logistics facilities. The opportunity for good regional and national networking between facilities within a supply chain is a key factor.

"Ultimately, the changed geography of warehousing is not just about the restructuring of space within metropolitan areas, it is about the spaces connecting metropolitan, regional and national economies. The proliferation and expansion of warehouses and their predilection for easily accessed suburban sites is being driven by the thickening of long-distance linkages among distant economies" (Bowen, 2008, p. 386).

Another interesting element is that this increase in the number of freight and logistics terminals in large metropolitan areas seems to go together with **an increase in the average size** of warehouses, both in surface footprint (built m^2) and in in-door volume (m^3). See Figure I.1 for an illustration.

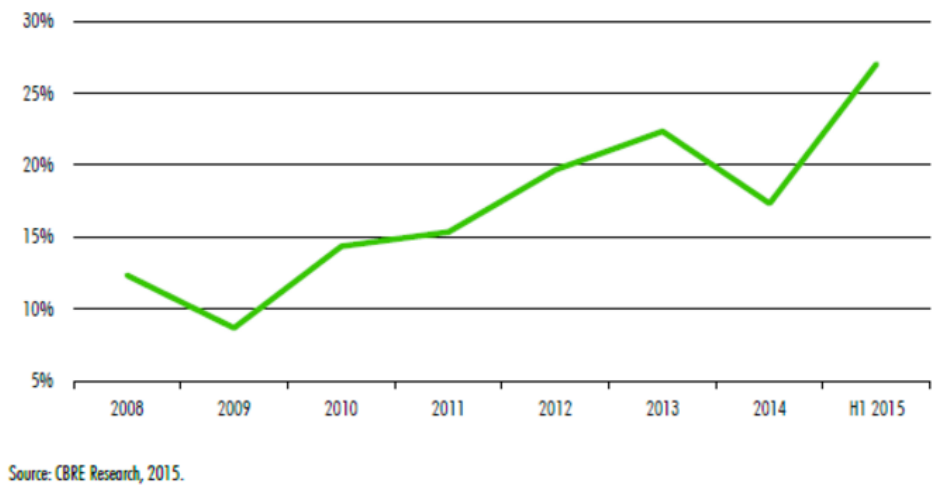


Figure I.1 Share of warehouses> 50,000m^2 in total logistics space take-up in France, the UK and the Netherlands
Source: CBRE (http://news.cbre.eu/xxl-warehouses-become-darling-of-european-industrial-and-logistics-market)

I. 1.2 Megaregions and logistics facilities

Despite higher land prices, logistics facilities tend to concentrate in"megaregions" rather than in more isolated regions. Megaregionscan be defined as large "networks of metropolitan centres and their surrounding areas… spatially and functionally linked through environmental, economic and infrastructure interactions" (Ross, 2009).

The concept of megaregionsis particularly fitted to the analysis of freight transport systems, because freight's market areas, driven by global supply chain organizations, are largely disconnected from one single city. Terminals such as regional distribution centres and cross dock terminals are spatially organized on a regional and multicity basis.

Below is a map of European megaregions (Figure I.2).

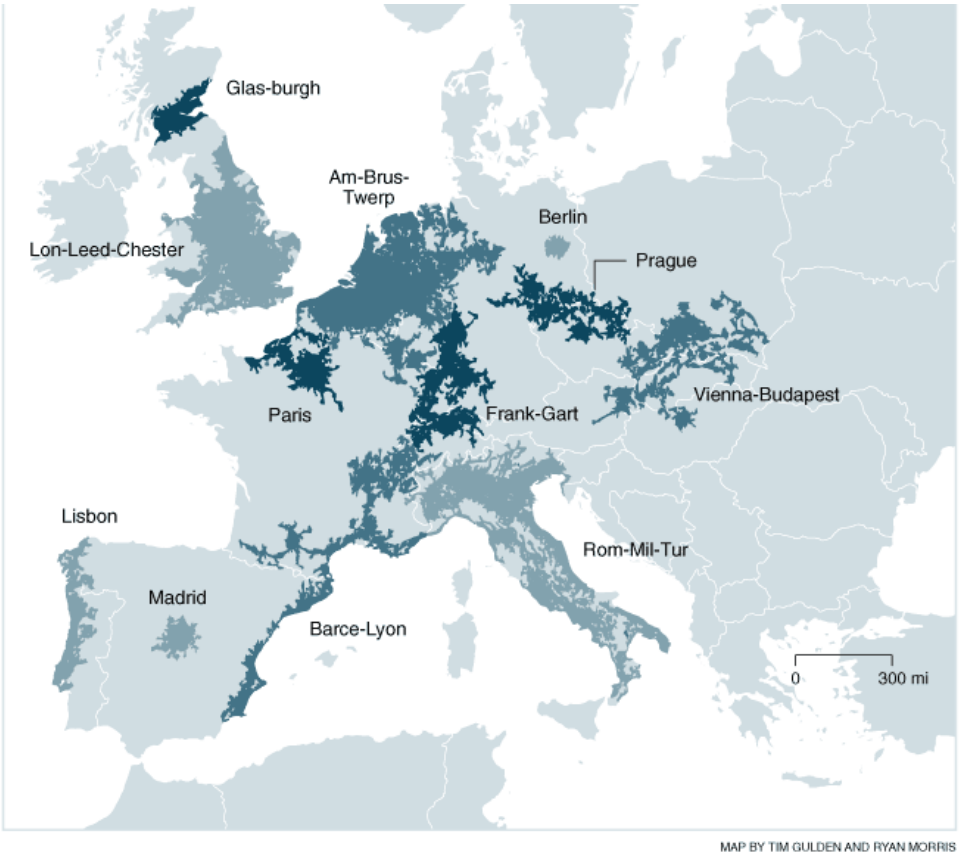


Figure I.2 Megaregions in Europe
Source: http://www.creativeclass.com/_v3/whos_your_city/maps/#Mega-Regions_of_Europe.Courtesy of R. Florida.

Many activities have tended to concentrate in megaregions, as part of ageneral relocation of capital, people, services, and production and distribution activities in large urban conurbations.

Interestingly, and despite the fact that logistics cannot afforda high cost of land, logistics activities seem to participate in the same general trend of polarization in megaregions. Even more interestingly, within megaregions, large cities seem to attract logistics faster than smaller cities or more rural areas. As an example, the average distance of warehouses to their geometrical centre in the Paris megaregion (the Parisian basin, seen around Paris on Figure I.1) went from 155 km in 2000 to 110 km in 2012 (Heitz, Dablanc 2015).

In that case, the logistics system will seek to minimize costs by other means (including decentralization in areas with cheaper landaround the mainmetropolitan areas).

I. 1.3 Logistics sprawl: comparative indicators for several case studies and main findings

This section focuses on the metropolitan level, looking at spatial patterns of freight facilities over time. Several case studies have been identified, from Europe, the US and Canada, and a few other regions.

I. 1.3.1. Case studies and selected indicators

Data has been collected from the following case studies of logistics sprawl carried out in recent

scientific works:

- Amsterdam, the Netherlands
- Atlanta, USA
- Belo Horizonte, Brazil
- Berlin, Germany
- *Study in progress*: Bogota, Colombia
- *Study in progress*: Brussels, Belgium
- Gothenburg, Sweden – metro area
- Gothenburg, Sweden - region
- *Study in progress*: London, UK
- Los Angeles, USA
- Paris, France - all warehouses
- Paris, France - parcel and express cross-dock terminals
- The Randstadt, the Netherlands
- Rotterdam, the Netherlands
- Seattle, USA
- Tokyo, Japan
- Toronto, Canada - Greater Toronto Area
- Toronto, Canada - Greater Golden Horseshoe

Appendix 1 presents a table with a summary of some of the main data collected. Appendix 2 provides the detailed data collected for each case study as well as information on the source of the work.

Table I.1 below presents the indicators collected for each of the case studies.

Table I.1. Indicators collected for logistics sprawl case studies

Name and size of studied metropolitan area
Type of metropolitan area (Monocentric or rather monocentric; Polycentric or rather polycentric; Megaregion)
Population
Population density
Name of warehouse data source and brief description
Number of warehouses (specify year(s))
Number of warehouses per million people (specify year(s))
Number of warehouses per 1000 km^2 (specify year(s))
Average size of warehouses (specify year(s)) (can be any indicator such as m^2, m^3 or number of employees)
Time period studied for logistics sprawl analysis
Average distance of warehouses to centre of gravity (most recent year) (NB this doesn't apply to megaregional types of urban regions)
Change in average distance of warehouses to centre of gravity (over the years)
Change in average distance of warehouses to centre of gravity per year
Cluster indicator
Type of land use control (Strictly local; Some sort of metropolitan-wide land use control; Some sort of region-wide or state-wide land use control)
Other comments/information
Scientific or technical references

These indicators are presented in Appendices 1 and 2, and are analysed in sub-section I.1.3.3 below.

I. 1.3.2 Presentation of two case studies

Out of the 18 identified case studies, we have selected two from Europe to present two examples of logistics sprawl, with contrasting geographic and size situations. One, from Paris, shows the example of a very large monocentric city included in an important megaregion. The other one, from Sweden, shows the example of Gothenburg, a smaller city, not included in a megaregional context, but with an important interurban corridor towards a capital city 470 kilometres away.

Paris parcel transport terminals' relocation over time

In Figure I.3, two maps from Paris are shown displaying the location of parcel and express transport companies' terminals in 1974 and in 2010 (Andriankaja, 2014). Parcel and express transport represents around one third of total urban freight activity (in commercial vehicle-trips).

The standard distance of these terminals to their barycentre went from 6.3 km in 1974 to 18.1 km in 2010. Therefore, during this period, it can be said that the relocation of parcel and express transport companies' terminals has generated approximately an average of ten additional kilometres per delivery round from the terminal to deliver goods inside Paris.

According to Andriankaja (2014), this spatial relocation of parcel transport terminals supplying Paris has generated about 16,500 additional tonnes of CO_2 in 2010 compared with 1974, all other things being equal.

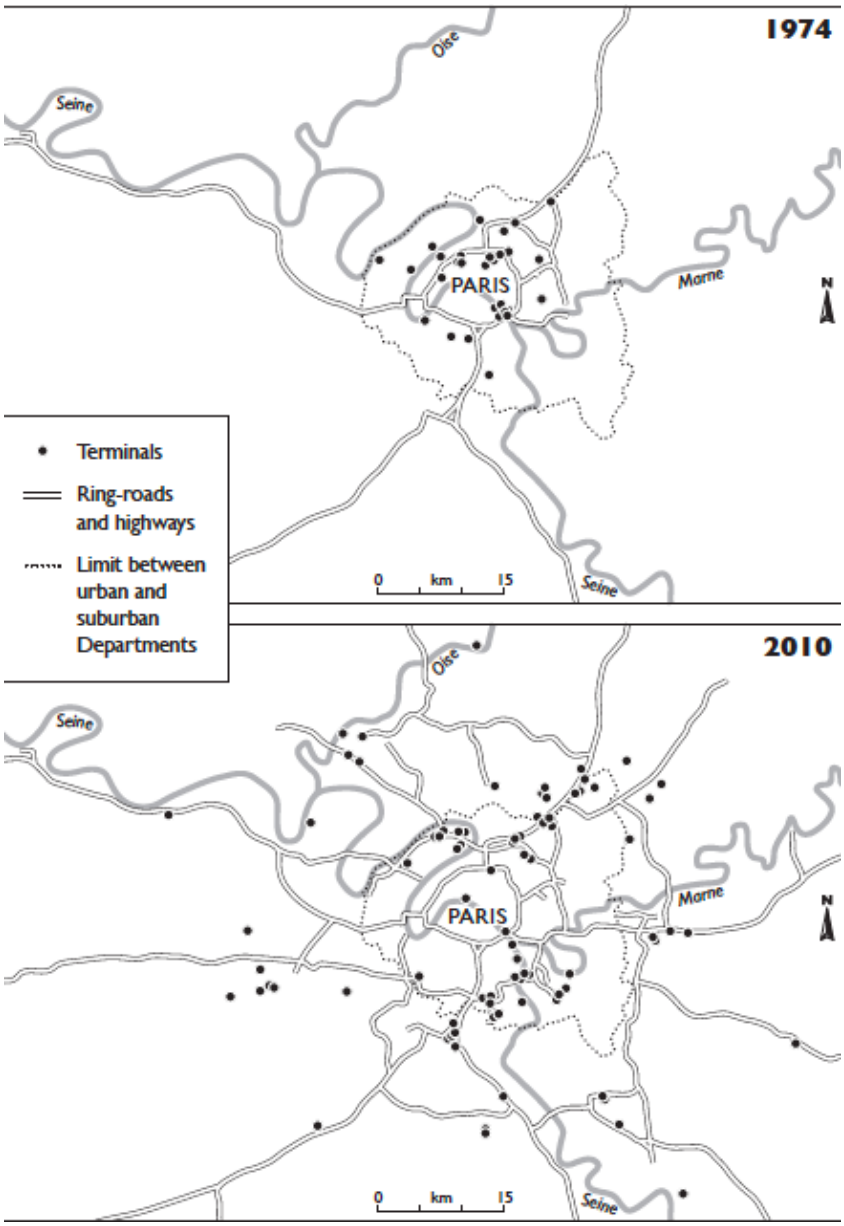


Figure I.3. Location of parcel and express transport terminals in the Paris metropolitan area, 1974-2010 (city of Paris = area within the most central ring-road)

Source: Andriankaja, 2014

Gothenburg warehouses' relocation over time

In Figure I.4, two maps from Gothenburg (large region) are shown displaying the location of warehouses in 2000 and 2014. The standard distance to their centre of gravity went from 79.3 km in 2000 to 81.4 km in 2014. At the same time, warehouses have clustered: the k-nearest neighbours indicator[1] went from 25.5 km to 13.3 km.

The warehouses relocated along the main roads from Gothenburg to Stockholm, around the principal urban settlements.

Gothenburg is still the main host of the warehouses in the metropolitan area. The presence of a large maritime port helps concentrate a large number of warehouses, which is increasing in

1

the Gothenburg municipality between 2000 and 2014(+33.1%).

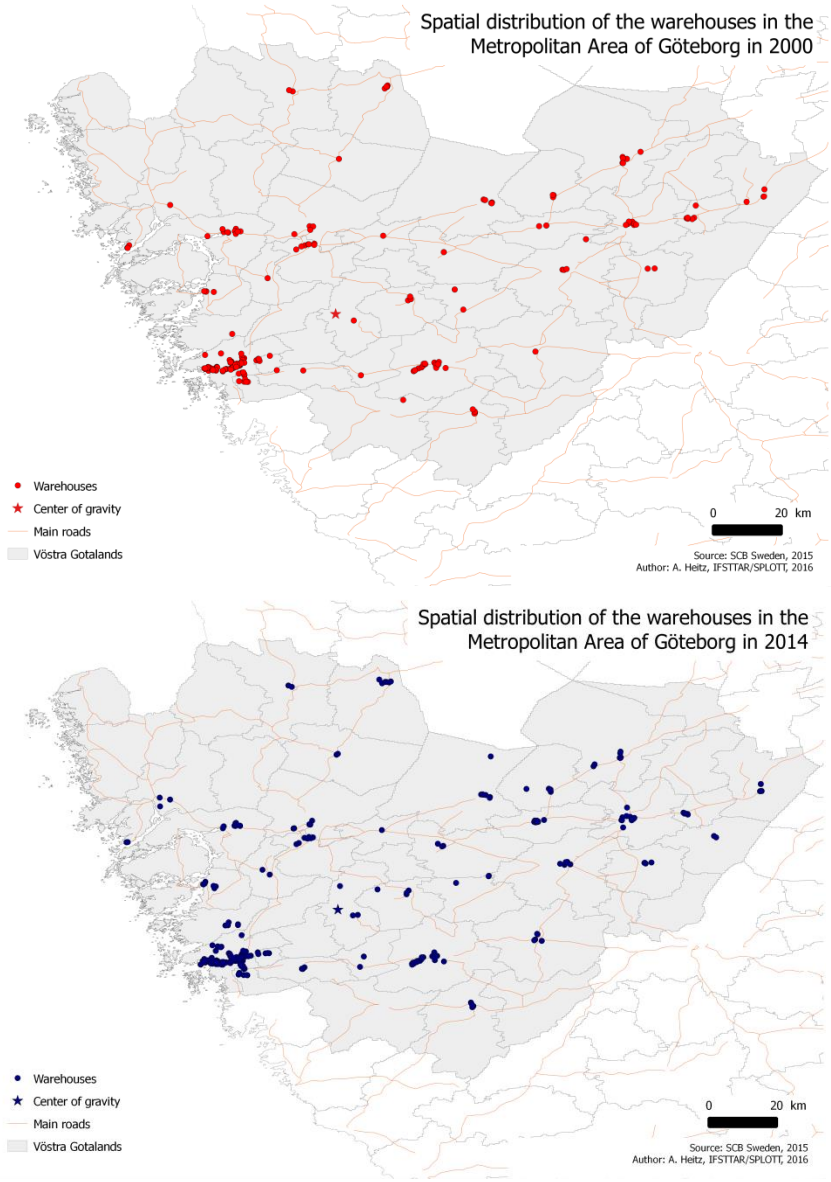


Figure I.4 Location of warehouses in the Gothenburg region in 2000 and 2014.
Source: Heitz et al., 2016.

I. 1.3.3 Comparative analysis of indicators

We carried out a comparative analysis of Table I.1 indicators (see Appendix 1 as well as Appendix 2 for specific data collected for each case study). There are 15 case studies observed, and 10 regions covered, as Paris, Toronto, Gothenburg and the cities in the Randstadt are being looked at at different scales or for different freight sectors.

The **main findings** are the following:

- The number of warehouses per million of residents ranges from 22 (Belo Horizonte) to 236 (greater Gothenburg). This varies with the definition of a warehouse and the accurateness of the database: comparisons are actually difficult as the type of warehouses can vary from one case study to another, and data sources have issues and are not perfect.

- The number of warehouses per million of residents has increasedover time in all case studies except Amsterdam, Randstadt and Tokyo.

- Logistics sprawl has happened in all case studies except three (Amsterdam, Belo Horizonte, Seattle).

- The average increase of the LS indicator (increase in average distance of warehouses to their barycentre) is **0.45 km/year**.[2]

The observations across each of the indicators presented in Appendix 1 are the following:

- ***Name and size of studied metropolitan area***

There are 15 case studies observed, and 10 regions covered, as Paris, Toronto, Gothenburg and the cities in theRandstadt are being looked at at different scales or for different freight sectors.

Most are metropolitan (or megaregional) areas, only Belo Horizonte is looked at at the city (municipal) level.

Their sizes range from 331km^2 (City of Belo Horizonte) to 87,940 (greater Los Angeles), with an average size of 17,494 km^2 (Randstadt and Toronto GGH excluded).

- ***Type of metropolitan area*** (Monocentric or rather monocentric; Polycentric or rather polycentric; Megaregion).

Most case studies are monocentric. Four are polycentric (Los Angeles and the Randstad are obvious polycentric areas; Berlin and Tokyo are somewhat polycentric). There is one obvious megaregion, the Randstadt. Greater Los Angeles can also be considered both a metropolitan area and a megaregion.

- ***Population***

Population varies from 973,000 (metro Gothenburg) to 34.5 million (greater Tokyo), with an average of 8.55 (Randstadt, Gothenburg region and Toronto GGH excluded).

- ***Population density***

Population density varies from 69 (Greater Gothenburg) to 1971 (greater Tokyo) inhabitants per km^2, with an average of 743 (Randstadt, Gothenburg region and Toronto GGH excluded).

- ***Name of warehouse data source and brief description***

Data sources vary. Some case studies focus on one specific sector (parcel/express for one of the Paris cases; general cargo (groupage) large hubs for the Berlin case). Most case studies cover all sectors, but sources can be very different, covering a very comprehensive definition of a "warehouse" (such as in Tokyo, with a size limit of only 400m2), or quite a limited definition, such as for many NorthAmerican cases (own-account distribution centres are generally not included). Size limits also differentiate warehouses, with Tokyo not excluding small warehouses for example. One case study (Toronto) has "cleaned" the North American NAICS database, eliminating mini-storage facilities wrongly associated with the "warehouse and storage" category.

- ***Number of warehouses***and***number of warehouses per million people***

In the latter years observed, the number of warehouses ranges from 54 (Belo Horizonte) to 955 (Paris) (specific studies excluded, such as Paris 2 and Berlin). What is more interesting is to compare the number of warehouses per million of residents. This ranges from 22 (Belo Horizonte) to 236 in greater Gothenburg. This varies with the definition of a warehouse (see above) and the accurateness of the database (see

[2] Calculated for seven case studies (Atlanta, Belo Horizonte, Berlin, Gothenburg, Los Angeles, Tokyo, Toronto. For Toronto, the area considered is the Greater Golden Horseshoe).

above too). However, it can also reveal some specificities: Gothenburg is an industrial and logistics hub for Sweden, and this is reflected in a high rate of warehouses per capita. Los Angeles compared with Toronto (using the same data source) has a higher rate of warehouses per capita, which also indicates its important role as a logistics hub for North America.

Another indicator was calculated showing the annual rate of growth of the number of warehouses per capita. Belo Horizonte and Seattle lead the list of cases (more than 19% annual growth rate), while Tokyo has seen an annual decrease of 18%.

- ***Number of warehouses per 1000 km²***

This ranges from 11 (Los Angeles, as the metropolitan unit considered is extremely large) to 163 in Belo Horizonte.

- ***Average size of warehouses***

This information is generally not included in the case studies. Other sources will be further investigated.

- ***Time period studied for logistics sprawl analysis***

A lot of the case studies cover a time-period more or less corresponding to the decade starting in 2000. Some case studies stop before the beginning of the world economic downturn (2008). Some cover a rather small time period (Dutch studies). Some case studies look at very longperiods (Paris, second study, starting from the 1970s, and Tokyo, covering the period of the housing market bubble in Japan, which ended in 2003).

- ***Average distance of warehouses to centre of gravity***

This is part of the logistics sprawl indicators. This ranges from 3.3 km (Belo Horizonte) to 82 km (Gothenburg) (all case studies considered except Randstadt).

- ***Change in average distance of warehouses to centre of gravity (over the years)*** and ***Change in average distance of warehouses to centre of gravity per year***

- All case studies except four (Amsterdam, Belo Horizonte, Rotterdam, Seattle) have experienced logistics sprawl (increase in the average distance). This ranges from 1.2 km (Toronto GTA) to 11.8 km (Paris, second study on parcels/express). More interestingly is the indicator per year, as time periods vary from one case study to another. It ranges from 0.12 km per year (Toronto GTA) to 0.95 km per year (Toronto GGH). The average increase is **0.45 km/year**.[3]

- ***Cluster indicator***

This information is generally not included in the case studies. Other sources will be further investigated.

- ***Type of land use control*** (Strictly local; Some sort of metropolitan-wide land use control; Some sort of region-wide or state-wide land use control)

This has been introduced in the data collection and list of indicators as it can represent an important explicative variable for differences in logistics sprawl. Regional types of land use control (Seattle, cities in the Netherlands, Toronto GTA), are associated with limited or non-existing logistics sprawl. This requires much further detailed examination before drawing general conclusions, but may show an interesting trend.

- ***Other comments/information***

[3] Calculated for seven case studies (Atlanta, Belo Horizonte, Berlin, Gothenburg (metro), Los Angeles, Tokyo, Toronto. For Toronto, the area considered is the Greater Golden Horseshoe).

Several case studies have looked at sprawl indicators for economic activities in general, as well as population, in order to compare it with the logistics sprawl indicator. In all cases, economic activities (or jobs, or establishments) have sprawled much less than logistics facilities.

I. 1.4 Impacts of logistics sprawl on freight vehicle-kms

I. 1.4.1 More freight vehicle-kms within a metropolitan area

Logistics sprawl generates economies of scale for the logistics industry but has impacts on urban landscapes. One consequence of the deconcentration of freight terminalsin suburban areas is the **increase in distances travelled within metropolitan areas by trucks and vans** to deliver commodities to urban areas where jobs and businesses remain relatively more concentrated. Andriankaja (2014) has estimated the net CO_2 emissions' impacts of the relocation of parcel cross-dock facilities serving the Paris regionto an addition of 16,500 tonnesin 2010 compared with 1974.

The following Figure I.5shows a hypothetical metropolitan journey of a freight shipment that is part of an Amazon transaction within the Los Angeles metropolitan area in California.

Figure I.5. A shipment's journey within the Los Angeles metropolitan area
Source of map: GoogleMaps

Many shipments for Amazon arrive in maritime containers from Asia to the Ports of Long Beach and Los Angeles. Containers are then processed and goods are dispatched on trucks servicing Amazon fulfilment centres in the eastern part of the city, about 100 kilometres away from the ports. Some of these goods are then distributed to Los Angeles final consumers, for example households living in West L.A. In this case (hypothetical but realistic), a total of 200 kilometres have been necessary within the Los Angeles area in order to connect a point of origin (the ports) to a point of final destination (a house in West L.A.) that are only 45 kilometres apart.

I. 1.4.2 Less freight vehicle-kms on a global scale?

While increasing within metropolitan areas because of logistics sprawl, freight vehicle-kmscan at the same time **decrease on a more global scale**. As large distribution hubs are located further away from dense and central neighbourhoods, and usually closer to major freight

corridors (especially highway nodes), coming in and out of thesecentres can be more direct, more simple and can therefore be organized through better consolidated modes of transport (large trucks, trains, barges). Distribution centres serving a national market are better off when placed far away from the dense areas of the region they belong to.

However, as Figure I.6 below shows, there is not always a geographical "logic" in the precise location of distribution centres within a metropolitan area. This map shows how large French retailers' distribution centres are located in the Paris region. Many distribution centres serving a national area (in red on the map) remain located close to the dense area of Paris, whereas many DCs serving mostly Parisian stores (in green on the map) are located in faraway suburbs.

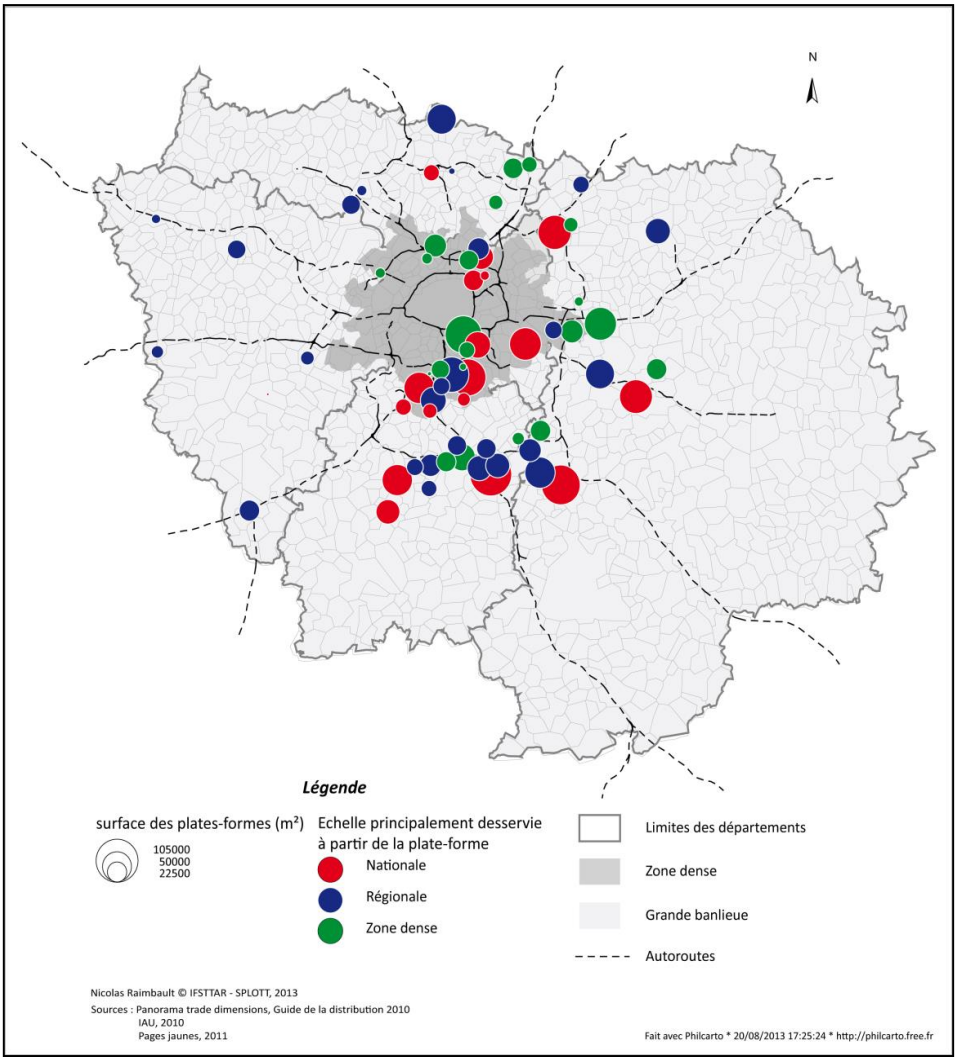


Figure I.6. French retail industry's distribution centres in the Paris region
Source: Raimbault (2014)

This map shows that the minimization of metropolitan transport distances is <u>not</u> the main driver for the location of logistics terminals.

I.1.4.3. Other issues related to impacts of logistics sprawl

Logistics sprawl can bring un-anticipated types of environmental benefits. As distribution centres are relocated in less populated areas, the amount of truck traffic they locally generate may be detrimental to a fewer total number of people in terms of direct local pollutants such as

NOx and particulate matters. Similarly, noise and accidents issues are better managed in a suburban logistics park than in a warehouse located within an urban environment.

There are therefore trade-offs linked to the location of freight and logistics facilities. A global assessment is required in order to reach relevant conclusions about logistics sprawl's impacts.

I. 1.5 Would moving logistics facilities "back to the city" bring benefits?

If logistics sprawl brings additional freight vehicle-kilometres within metropolitan areas, could a reverse trend (logistics facilities closer to the city centres) bring benefits? Some private initiatives can be identified ranging from large multi-story facilities to small-scale urban logistics service depots. Some policies on land use and planning promote the relocation of logistics facilities into urban environments.

I. 1.5.1 A new urban logistics real estate market

A new**urban logistics real estatemarket** is emerging in some parts of the world, especially in Asia and very large cities in Europe and North America.

In Japan or Hong Kong, large multi-story logistics facilities have been developed in dense areas of the largest conurbations. Below is a photo of a seven-story logistics facility in Tokyo built and managed by Prologis, the largest logistics developer in the world.

Figure I.7. Prologis urban logistics terminal in Tokyo (built in 2005)
Photo: Prologis

In Europe, small-scale freight facilities have made an appearance in city centres. In the city of Paris, more than 35 urban logistics facilities exist today (Figure I.8).

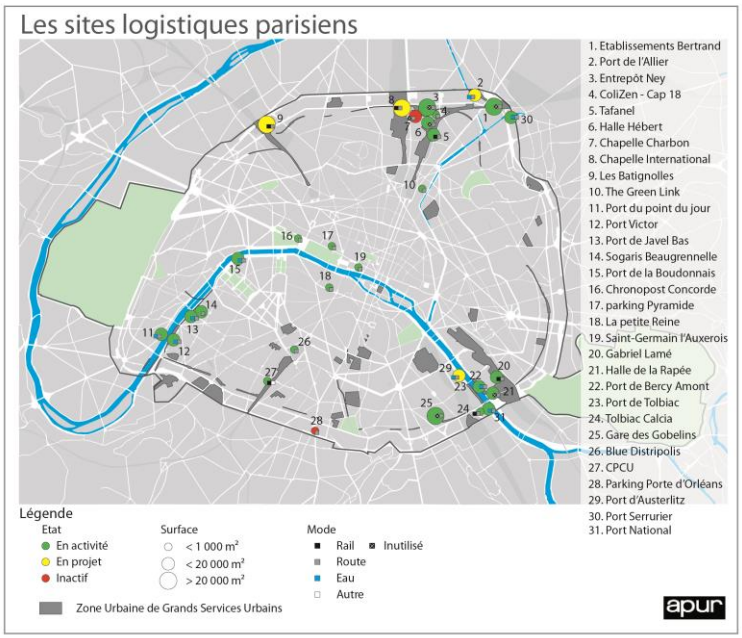


Figure I.8. Currently operating urban logistics spaces in Paris
Source: APUR (Paris Planning Agency)

The largest current logistics development project in Paris is Chapelle International, a three story 45,000 m^2 facility mixing logistics activities and other types of activities (data centre, offices, sport, urban agriculture). Works have started in September 2015 and operations should start in September 2017. See a photo of works as of January 2016 on Figure I.9. Chapelle International is located within the first Paris ring-road, five kilometres North of Notre-Dame cathedral, and can be seen on Figure I.8 (project number 7).

Figure I.9. Chapelle International Sogaris logistics hotel building site, 27 January 2016
Source: photo L. Dablanc

In Lyon, France, four small urban logistics terminals are currently operating. One larger project is under consideration involving the port of Lyon.

In many European cities, urban consolidation centres have also emerged. These terminals have usually been established with a commitment from city authorities (through labelling, regulations or direct subsidies) (Browne et al., 2005; Leonardi et al., 2015).

In the US, Amazon's new faster delivery services (Amazon Prime Now, Amazon Fresh, Amazon Pantry) require the company to use warehouses closer to major consumer markets. In New York City, Amazon has set up a 5,000 sq metre distribution centre on the 5th floor of a Manhattan building on 37th street. Several thousands of products are pickedup and delivered within one to two hours after order. In Boston, Amazon leased a 10,000 m^2 warehouse in a logistics area that hosts grocery and food distributors and is about nine kilometres from downtown Boston. "The ability to deliver goods to Boston within an hour was the main reason Amazon wanted to lease the space" (quote from the president of the company representing the land owner in the transaction, quoted in the *Boston Globe*, C. Woodward, Sept 10, 2015).

In total, as mentioned by Conwell (2015), as of October 2015, Amazon's new strategy for one hour delivery involved 40 new urban local delivery terminals, of about 1,500 to 5,000 m^2 each. Conwell also mentioned urban strategies from developers such as Prologis, particularly in San Francisco and Seattle which have recently experienced the development of multi-story logistics facilities less than three or four miles from the city centre.

I. 1.5.2 Local policies towards urban logistics terminals: from regulatory obstacles to promotional strategies

One obstacle to the emergence of large urban logisticsfacilities is the local authorities' requirements. For example, in Paris, one requirement for logistics buildings in the 2006 Paris zoning code is that they be served by railway or river. In that case, efficienturban intermodal services, for the moment costly and complex, will be key to the success of an effective return of logistics to the heart of cities. Chapelle International (Figure I.8 above) will have a rail component, which added a lot to the overall cost of the required investments.

Without the connection to rail and waterway, logistics may be able to re-enter the city only in the form of smaller structures, which can blend into small logistics spaces and modest distribution centres.

Close cooperation with the urban planning authorities, real estate practitioners, market experts and practitioners will be an indispensable condition to the development of urban logistics buildings.

The economic feasibility is specifically influenced by land costs, and in particular by the size of the differential between office space and residential real estate prices on the one hand, and logistics land prices on the other hand.

Acceptability from residents for the introduction of new logistics buildings in urban environments will require great care provided to architectural, environmental and landscaping quality of the building, as well as planning for quiet and non-polluting operations afterwards. A building such as Chapelle International in Paris will bring several dozen vehicles in and out of the site everyday, including some heavy trucks, as rail will not provide 100% of the incoming goods. A specific care was taken to provide specific road entrances and exits to the site. The use of natural gas and electric vehicles will be promoted.

From the point of view of real estate practitioners, urban logistics buildings will be easier to develop when technical standards are established. Standardization should potentially improve profitability for the investors. Public authorities have a role to play in the establishment of these technical standards.

Recent public initiatives towards the promotion of urban logistics facilities can be noted. Below (Figure I.10) is a map from the first public draft of the upcoming new Paris zoning law (made public in December 2015). This map specifically focuses on urban logistics activities. All coloured spots will have a vocation for logistics activities. The new zoning law will be discussed for approval by Paris municipal council in early Spring 2016.

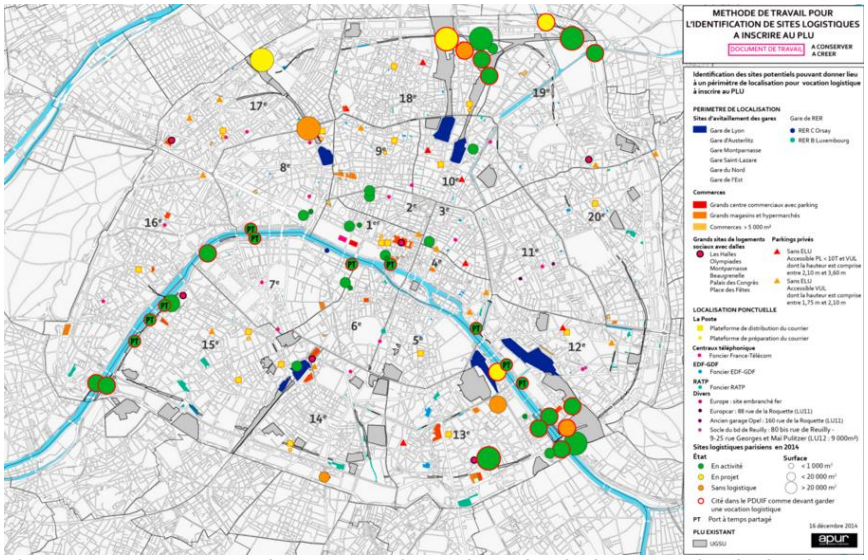


Figure I.10.Proposed strategy for urban logistics terminals in the upcoming Paris zoning law. In green, existing logistics sites. In yellow: development in progress. All other colours: potential logistics sites for the future.
Source: map from APUR, released by Paris Department of Planning, December 2015

I. 2. Key conceptual relationships

In this section, we identifya number of key conceptual relationships that help understand spatial patterns of logistics facilities and help foresee future trends for these facilities.

These are mostly hypotheses, made from the literature and from the case studies. As the number of case studies and data collection increase, as well as diversify, these relationships will be further tested towards final (in)validation.

I. 2.1 Increase in the number of warehouses

- The increase in the number of logistics facilities over time is positively related to the importance of the role of global logistics hub played by an urban area.
- The increase in the number of logistics facilities over time is positively related to the increase in the digitalization of retail (increase in B2C demand) in an urban area.
- As B2C demand increases in large metropolitan areas, the demand for small logistics buildings within the urban area increases.
- The increase in the number of warehousesover time is larger in megaregions.
- The increase in the number of warehouses over timeis larger in big cities within megaregions.

I. 2.2 Logistics sprawl

- Logistics sprawl is positively related to the differential in land/rent valuesfor logistics land uses between suburban and central areas in an urban region
- Logistics sprawl is positively related to the availability of large land parcels in suburban settings
- Logistics sprawl is negatively related to the degree of regional logistics land use control
- The degree of logistics sprawl varies with the type of logistics terminal (i.e. stronger for distribution and fulfilment centres, weaker for parcel transport terminals)
- Logistics sprawlgenerates an increase inthe number of freight vehicle-kilometres within the urban region <u>if</u> its rate is higher, on the same time period, than economic and residential sprawl.
- Additional vehicle-kilometres induced by logistics sprawl are likely to impact less densely populated areas, thus generating less diffused transport externalities (local pollutants, noise, accidents).

I. 3. Focus: a theoretical exploration of the cost structure of urban logistics

François Combes, CEREMA

The causes and impacts of logistics sprawl are not easy to identify. The function of many of the logistic facilities at the periphery of metropolitan areas is to make the connection between interurban logistics and urban logistics, also known as the last-kilometre. It allows supply chains to benefit both from the economies of scales of long distance interurban freight transport where shipments are carried together by large capacity vehicles and from the efficiency of urban freight transport, where small vehicles make tours to deliver several shipments in one operation.

The location of warehouses is a strategic decision in a supply chain. Locating a warehouse close to the metropolitan area it provisions reduces transport costs on the urban side, but may increase them on the regional and national side, and most probably increases land/rental costs. Urban locations, in many cases, may also just prove impossible due to the lack of adequate land parcels. This basic reasoning, while qualitatively simple, involves complicated, nonlinear relationships that this section aims to clear up, at least partially.

The objective of this section is **to present a simplified, theoretical approach of the costs of urban logistics**, with the objective to illustrate the various mechanisms at work, and to answer, at least partially and qualitatively, to some of these questions. The approach is inspired from Daganzo (2005): simplified geographical hypotheses are adopted (such as: the city consists of two uniform zones, the centre and the periphery), in order to design a tractable analytical model. The model takes into account explicitly several important parameters: land use costs, transport costs, the duration of drivers' work days, vehicle speed in the city centre and periphery, and the amount of deliveries in the city centre. Comparative statics are derived in order to analyse the role of the model's parameters in the location of warehouses at the edge of the city.

I. 3.1 A simplified representation of freight transport

Urban logistics is a complex issue. Shipments arriving in cities, or leaving them, can be carried in many ways, for shippers and receivers with very varied demands. In a simplified manner, one can consider that for a given shipment, freight transport can be organized in three ways (Figure I.11):

- (a) ‘one-to-one transport’: have a vehicle carry the shipment alone, from the plant to the customer and then come back;
- (b) ‘one-to-many transport’: have a vehicle carry multiple shipments, from the plant to a series of customers in the city and then come back;
- (c) ‘many-to-many transport’: have a heavy goods vehicle move all the shipments due a certain day or week to a warehouse located near the city, then load them in smaller vehicles which deliver them to the customers.

This basic segmentation disregards multimodal transport, where the sequence of operations is necessarily even more complex. It also disregards the problem of the choice of vehicle, to which it is closely related.

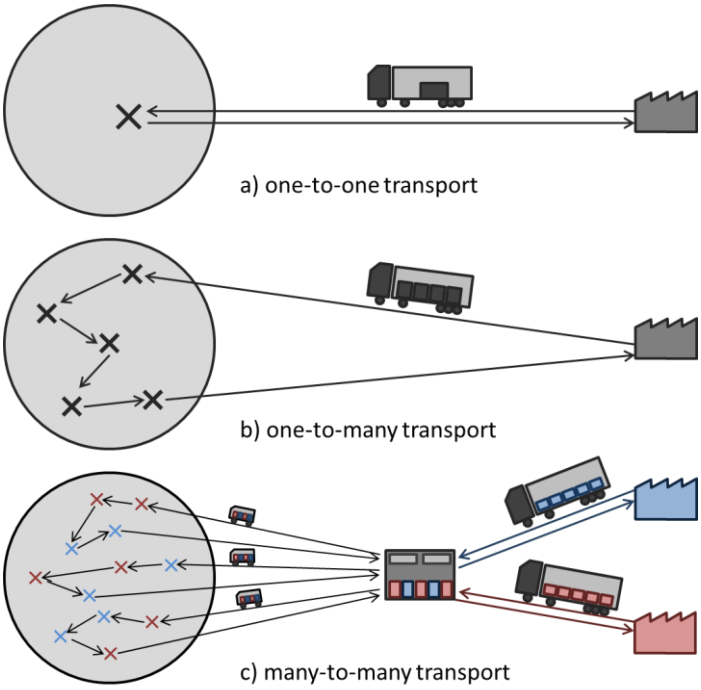


Figure I.11. Three typical transport organizations
Source: F. Combes

Each organization corresponds to a specific demand: option (a) is more adapted to large shipper-receiver flows whereas option (c) is relevant for small flows of fast moving goods; option (b) is somewhat intermediate (Combes and Tavasszy, 2015). The main advantages of option (c) over the two others are that it allows using simultaneously small vehicles and large vehicles in the same supply chain. On the other hand, it requires a building and the associated land/rent and transhipment costs.

Option (c) is particularly interesting when studying logistics sprawl: by contrast with options (a) and (b), it is extremely efficient in an urban context for many commodity types; it also raises both transport and land use issues. The objective of the following sections is to develop a simple model of that option, in order to better understand the economic mechanisms involved.

I. 3.2 The cost structure of the supply chain

Let us now set the assumptions of the model. Consider a shipper sending commodities to a city of area *A* from a plant or a national warehouse located far from that city. The supply chain between that plant and the customers in the city consists of a sequence of successive stages, which can be described as follows: the commodities are transported from that plant to a warehouse located at distance *l* from the city centre (a). The commodities are unloaded in the warehouse and stored, and sorted, and then loaded into smaller vehicles to be delivered to the customers in the city (b); each of those vehicles makes a round, delivering several customers in the process. The round consists of an approach movement and a return movement (c), and all the intermediate movements inside the city, between the consecutive delivery locations (d). Figure I.12 describes this sequence. It shows how one shipment (the red box) is carried from a plant to a customer through a cross-docking platform, together with many other shipments that have distinct origins and destinations. The grey, dashed lines depict the movements of other vehicles, delivering or picking up shipments from or towards other destinations.

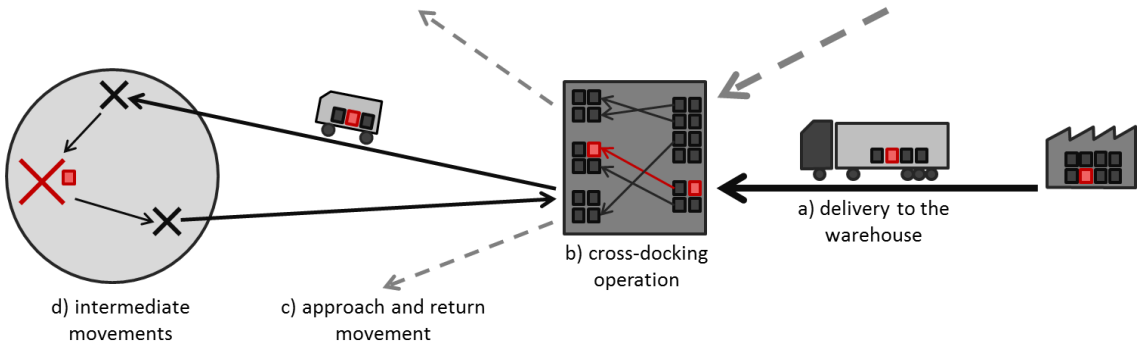


Figure I.12. Description of the transport operation
Source: F. Combes

The total transport and transshipment costs consist of three components: the cost of carrying the commodities from the plant to the warehouse, the warehouse and transshipment costs, and the cost of carrying the commodities from the warehouse to customers. The first cost component is not critical in the context of this research: the commodities are transported by heavy goods vehicles over typically long distances, and the corresponding cost does not depend much on the location of the warehouse or on what happens on the city side.

The second cost component is critical in the context of this research. It consists of the fixed and variable cost of the warehouse C^w. Out of simplicity, let us assume that the warehouse's size is proportional to its throughput, and that its rental and operating costs are both proportional to its size, and decreasing functions of the distance of the warehouse to the city centre (on the basis of the radial symmetry assumption). Let $c_w(l)$ denote the warehouse and transhipment cost, in monetary unit per shipment. The warehouse cost is:

$$C^w = c_w(l) + F$$

The third cost component is the transport cost on the city side, or the last-kilometre transport cost, C^t. It is also of utmost interest in the context of this research. Each vehicle delivers multiple customers by making rounds. The more customers there are in a round, the less costly it is to deliver to each of them. However, round's lengths are constrained. In practice, several types of constraints, or regimes, can be distinguished. The following two will be examined in this research:

- Regime 1: the round's length is constrained by the duration of the driver's work day H. (H depends on whether deliveries are made in the morning and pickups in the afternoon or during the whole day).
- Regime 2: the round's length is constrained by the delivery lead time expected by the customers, and that delivery lead time is lower than the driver's work day duration. If customers expect to be delivered in less than H hours after ordering, the round's duration cannot[4] be larger than H.

These two regimes are not very different from the perspective of the supply side: in both cases, the round duration cannot exceed H. The main distinction will be on the demand side; under regime 2 the round duration H is endogenous.

The following two other regimes could also be considered:

- Regime 3: the round's length is constrained by the capacity of the vehicle: there can be no more shipments in the vehicle than it is technically designed to carry.

[4]This is a simplifying assumption. It may be - theoretically - possible for the shipper to dispatch before customers actually order, thus anticipating the delivery process, given adequate forecasting technologies. However difficult this may seem, the paper will hopefully show the extremely strong financial appeal of such an organization.

- Regime 4: the round's length is constrained by the vehicle's autonomy.

Studying these regimes would be instructive, but would add a significant layer of complexity to the modelling work, without being central to the issue of this research. Regime 3 is not an absolute constraint: it is in fact related to the issue of the choice of vehicle capacity. Regime 4 is only a constraint for some transport technologies. Electric vehicles can be concerned, internal combustion or hybrid vehicles will not.

For the time being, consider the number of shipments to be delivered during a period of duration *H* as given and equal to *F*. Then, the length of each round will depend on the length of the approach and return movements, approximately *l*, and also on the distance between two consecutive customers in the city centre. Let δ denote this distance. It is very difficult to compute exactly, as finding the rounds that minimize the transport cost is known to be a NP-hard problem. However, it can also be approximated. Intuitively, if the area of the city is multiplied by 4 and the number of customers to deliver is unchanged, then δ is only multiplied by 2. This is illustrated by Figure I.13: if there are two times more delivery points in an area of given size, the average distance between two successive points in an optimal round decreases by the square root of 2.

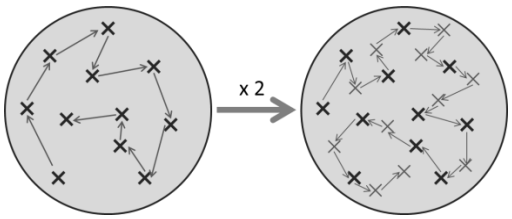


Figure I.13. Relationship between the number of delivery points and transport distances
Source: F. Combes

In general, in a uniform area, δ is approximately equal to:

$$\delta = k\sqrt{\frac{A}{F}}$$

with*k* a positive constant (Daganzo, 2005). Now, denote by v_a (resp. v_z) the vehicle speed outside (resp. inside) the city centre. Consider a vehicle delivering *x* customers. The round's duration is then:

$$d = 2\frac{l}{v_a} + x\left(h + \frac{\delta}{v_z}\right)$$

where*h* is the time a delivery actually takes, or the idle time for the vehicle at each customer's, and *x* is unknown. In both regimes 1 and 2, the round's duration is constrained: *d* = *H.* This equation has important implications: the number of locations which can be delivered during a given round depends on the distance of the warehouse to the city centre. More precisely: the farther the warehouse from the city centre:

- the more time it will take for vehicles to reach the city centre;
- the less customers a vehicle will be able to deliver;
- the higher the unit transport cost (i.e. the transport cost per delivery).

As a matter of fact, it is possible, with a few calculations (Appendix 3), to derive the transport cost function. The transport consists of two basic components: the vehicle operating cost c_l, assumed proportional to the distance covered, and the workforce and vehicle capital cost c_h, proportional to the time vehicles and drivers are operated.

The transport cost function is then[5]:

$$C^t = \frac{c_R}{H_r} hF + \left(\frac{1}{v_z}\frac{c_R}{H_r} + c_l\right) k\sqrt{AF} \tag{1}$$

When the warehouse is located farther from the centre, the useful time during a round H_r, i.e. the round's duration once removed the duration of the approach and return movement, decreases.

The other cost component in the supply chain is the rental cost C^w. The total cost is the sum of C^t and C^w:

$$C = \left(c_w(l) + \frac{c_R}{H_r} h\right) F + \left(\frac{1}{v_z}\frac{c_R}{H_r} + c_l\right) k\sqrt{AF}$$

The unit cost is:

$$\frac{C}{F} = c_w(l) + \frac{c_R}{H_r} h + \left(\frac{1}{v_z}\frac{c_R}{H_r} + c_l\right) k\sqrt{\frac{A}{F}}$$

The analysis of the unit cost shows the crucial role of the density of delivery points in the cost function: the unit cost actually decreases when the number of deliveries increases. Indeed, when there are more deliveries in a given area, the average distance between each of them decreases; this allows vehicles to do more vehicles during the same round. The increase in density has thus two effects on the total cost: a direct one through the reduction in distance between two successive deliveries, and an indirect one through the decrease in the number of approach and return movements.

Now, observe that the cost depends on the distance between the city centre and the platform. The immediate question is whether there is a distance for which the total cost and minimum and what its value is.

I. 3.3 Optimal location of the warehouse

The contribution to the cost function of the warehouse's distance to the city centre is twofold. On the one hand, the closer the warehouse to the city centre, the higher the rental and building costs; on the other hand, the lower the transport costs. Let us assume that c_w is a differentiable function of l. The optimal distance is defined here as the distance which minimizes the total cost for a fixed demand. Then, if the optimal length is not a border solution[6], a necessary condition for l to be optimal is that:

$$\frac{\partial C}{\partial l} = 0$$

Equivalently (Appendix 3):

$$Fc_w' + 2Fc_l\frac{h_o}{H_r} + 2Fc_R\frac{h_o}{H_r^2 v_a} = 0 \tag{2}$$

Where h_o = h + $\delta l v_z$ is the duration of a delivery operation, including the corresponding transport. At the optimal location, the additional cost of being one kilometre closer to the city

[5]Where $c_R = 2c_l\, l + c_h H$ denotes the "fixed" part of the transport cost, i.e. the part which does not depend on δ; and $H_r = H - 2l/v_a$ denotes the duration of the round once removed the duration of the approach and return movements.
[6]That is to say, the optimum is not to locate the warehouse in the city centre or at its far periphery, but somewhere in the middle of these two extremes.

centre should be equal to the travel cost it saves. If it were not the case, it would be profitable for the warehouse to relocate somewhere else. The travel cost savings come from the reduced length of the approach and return movements and from the fact that less rounds are necessary to deliver *F* customers when the warehouse is closer to the city centre. Note that the optimal location appears to be independent on *F*; it doesn't: the density parameter δ, which depends on *F*, influences both h_o and H_R.

The warehouse's optimal location does not depend on the rental costs gradient, but on its *variation*. The willingness of the shipper to pay to reduce the warehouse's distance to the centre increases with *l*: the impact of *l* on the number of rounds is stronger when *l* is large. If the variation of the rental cost is constant or decreasing with *l* (i.e. if the rental curve is decreasing and convex), then the optimal location is necessarily unique. The optimal price in the case of an interior solution is illustrated in Figure I.14 with a generic sample, with an interior solution. If the rate is convex and decreasing fast enough, then the solution is unique; but in general many configurations are possible[7].

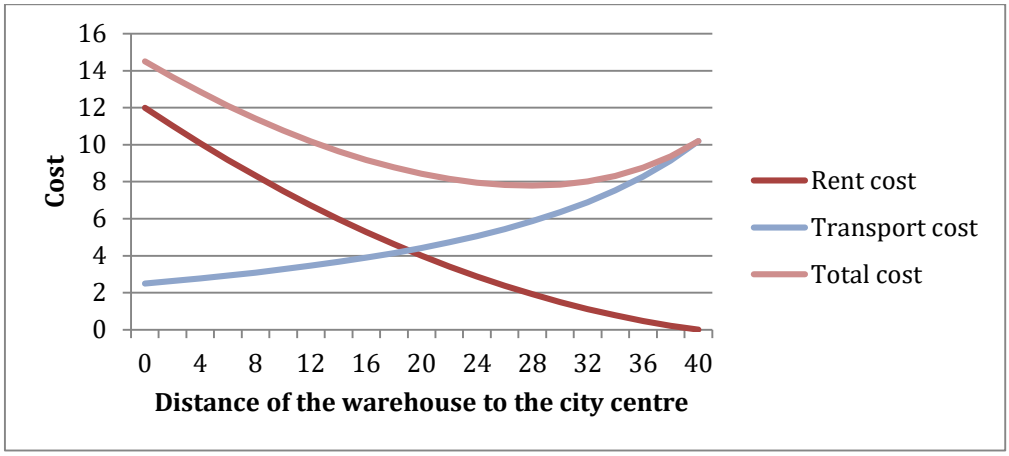


Figure I.14. Variation of the cost functions with the warehouse's location
Source: F. Combes

Let us now examine how the optimal distance depends on the various parameters of the model. Examination of the cost function (see Appendix 3) allows concluding that in general:

- The optimal distance decreases with c_l and c_h: when the kilometre cost or the hour cost of operating a vehicle increases, transport costs more; it is then profitable to be closer to the city centre.
- The optimal distance decreases with *h*: the slower the delivery and pickup operations, the heavier they weight in the transport cost. When the duration of these operations increases, it is profitable to bring the warehouse closer to the city centre.
- The optimal distance increases with *H.* Under Regime I, when the work's day duration increases, the relative weight of the approach and return movements decreases in the cost function. It is not necessary to pay as much to be close to the city centre. This is true as well with the delivery time under Regime II: warehouses need to be closer from the city centre to deliver customers quickly in a cost-efficient way.

[7]The right hand side of the equation increases from $2Fc_l\, h_o/H + 2\, Fc_R h_o/H^2 v_a$ to ∞ when *l* goes from 0 to $H - 2l/v_a$. Therefore, the optimal length is never larger than $H - 2l/v_a$$.If the rate gradient c_w' is always lower than $2c_l h_o/H + 2c_R h_o/H^2 v_a$ then the warehouse will locate inside the zone it serves. If the rate c_w is convex and decreasing, and the rate gradient is not too low, then a unique interior solution exists. If not, an interior solution may still exist. For *l* a zero of the derivative of the cost function to be an optimum, it is necessary, but not sufficient, that c_w be decreasing and that c_w'' be larger than the differential of the rest of the equation's LHS with respect to *l*.

- The optimal distance increases with v_z and v_a: when the vehicle speed increases in the city centre or during the approach and return movement, it is possible to deliver more customers with a given round. Transport weighs comparatively less in the cost function; it is profitable to locate the warehouse further from the city centre.
- The optimal distance decreases with δ, i.e. increases with F. When there are more delivery or pickup operations, they are denser in a given area. Each operation costs less, so that transport weighs comparatively less in the cost function; it is profitable to locate the warehouse further from the city centre.

These results can be summarized as follows (Table I.2): if any of the cost parameter increases, the optimal distance decreases; if any of the speed parameter increases, the optimal distance increases; if the unit cost of a delivery operation increases, due to a longer delivery duration or to a lesser delivery location density, the optimal distance decreases; under Regime 1, if the work day constraint H increases, the optimal location increases; under Regime 2, if customers want to be delivered faster (i.e. H decreases), the optimal location decreases. Finally, if the average distance δ increases, the optimal location decreases.

Table I.2. Variation of the optimal warehouse's location with the model's parameters.

Increasing Parameter	Variation of warehouse location
vehicle operating cost c_l	Closer to the city centre
Driver cost and vehicle ownership cost c_h	Closer to the city centre
Duration of delivery operation h	Closer to the city centre
Maximal round duration H	Farther fromthe city centre
Vehicle speed in the city's periphery v_z	Farther from the city centre
Vehicle speed in the city centrev_a	Farther from the city centre
Density of delivery locations $1/\delta$	Farther from the city centre
Amount of deliveries F	Farther from the city centre

It should be noted that when the total demand increases, then the optimal distance increases. Indeed, the more customers for a given warehouse, the higher the density of delivery locations, hence the unit cost decreases and the benefit to be close to the city centre is not as large. As a consequence, logistic sprawl could be caused as much by the exogenous trends of logistics of the past decades such as the development of e-commerce which increased the quantity of pickup and delivery operations in cities, as by the evolution of the land use market.

On the other hand, it should also be noted that when the constraint on the round's duration H is very strong (e.g. customers are to be delivered two hours or less after ordering, it is cost efficient for warehouses to locate near city centres, despite the rent cost, provided the customers are ready to pay for the additional cost).

I. 3.4 Analysis of the cost structure of the supply chain

The cost structure of the supply chain and the consequences in terms of regulation depend directly on the relationship between F and C. If δ were fixed then the cost function would be linear; there would be no returns to scale[8]; and thus no ground for regulation[9], and the marginal

[8]To the extent where several strong assumptions hold, including the constant returns to scale of the warehousing costs.

[9]This statement is made from a neoclassical economic perspective, where regulation is called for in the presence of market imperfections, and aims at correcting them, partially or totally. Besides, the statement disregards the regulation of all the transport externalities: congestion, accidents, noise, pollution and GHG emissions, for which other instruments exist.

cost and the average cost would be equal. However, δ is not fixed, and the marginal cost of an additional customer in the time period is (Appendix 3):

$$C_F = c_w + \frac{1}{2} c_l \delta + c_R \frac{h_o - \delta}{2v_z} H_r \quad (3)$$

It can be compared to the average cost *C/F* derived earlier. The marginal cost is lower than the average cost: the cost structure of the supply chain of this model exhibits increasing returns to scale. The difference between the marginal cost and the average cost is the marginal external cost of an additional customer.

$$\frac{C}{F} - C_F = -\frac{1}{2} c_l \delta - c_R \frac{h_o - \delta}{2v_z} H_r$$

This difference derives from two causes: first, an increase in density reduces the distance between two successive operations inside the city centre, and thus the corresponding cost. Second, this also allows delivering more locations during the same time: the cost pertaining to the approach and return movements from and to the warehouse is shared among more customers.

The negative marginal external cost is exactly symmetric to the positive marginal external cost of congestion in road transport. Not only does an additional driver on a given road suffer from the traffic jam; by contributing to the traffic jam it also inflicts on all the other drivers a marginally increased travel time. In the case of urban logistics it is the contrary: an additional customer will cost less than the average cost because it has good chances to be on the way between two existing customers. A large amount of new customers will increase the overall efficiency of urban logistics, because there will be more locations to deliver to and less distance between each of these locations. Indeed, it can be considered as a source of economies of agglomeration, although one difficult to confirm empirically.

From the perspective of market structure, whichever way the market works, the prices will always be larger than the marginal cost, without regulation (i.e. subsidies). As a consequence, the demand will be lower than it would be at its first-best optimal level[10]. This is a typical market failure, which calls for a correction.

This correction can take many forms. The most obvious, but perhaps the politically least realistic one is that of a direct subsidy to urban logistics, notwithstanding the fact that a careful analysis of market structure would be required to confirm the feasibility and efficiency, even from a theoretical standpoint. Other indirect means can be considered, such as urban planning options. A possible urban planning option would be to assign land to logistic premises. This raises complex issues, such as how and where this should be done, and also whether and how the resulting land use prices should be controlled, to actually correct the imperfection. Those questions are still open.

I. 3.5 Conclusion

In order to analyse the potential causes of logistics sprawl, this section presents a simple analytical model of the cost structure of urban logistics. Even on a simple case, the model illustrates the **complex and nonlinear relationship between the land use market, the parameters of urban logistics** (vehicle speed, workday duration, costs and the demand) **and the location of a warehouse**. In particular, the research shows that **an exogenous increase in the demand for pickup and delivery operations results in warehouses locating away further from cities**, as a result of transport operations weighing relatively less in their cost

[10]This optimal level is the one that would be obtained by a 'benevolent planner' or, perhaps a little – but not much – more realistically, if all inhabitants planned together the location of warehouses

function. On the other hand, the model hints to **how an emerging market for very reactive logistics needs to be accompanied by logistic facilities coming back in city centres**, despite the price. Finally, the model shows that **the location of logistic facilities is determined by the rent gradient, not its absolute value**: if rents are uniformly high, warehouses will have no need to move far from the city centre.

Besides, the section briefly sketches some possible implications in terms of market structure and equilibrium pricing. Even accounting for the limitations of the model, **urban logistics is most probably characterized by economies of scales**. This results in non-trivial conclusions in terms of the efficiency of the market, and also of the **policy actions that could or should be taken to address potential market imperfections**. In particular, one conclusion is that **there is economic ground to the idea of giving some space to logistic facilities near city centres in order to improve the efficiency of urban logistics,** for the benefit of city centres' inhabitants; however, this should be done in a careful way**, lest a mechanical increase in rents in these areas cancels the initial objective of the action.**

At this stage, this line of research is very much a work in progress. Many directions still need to be explored: the most important one is to consider an endogenous level of demand. Next, the implications in terms of market structure and potential ground for the implementation of policy measures should also be closely examined. From a technical perspective, it is **necessary to extend the model to an endogenous demand, where the amount of pickup and delivery operation derives from the price charged by shippers**. This demand could be generic, or could derive from models of inventory theory. The second option, while it needs an empirical validation, is useful insofar as it explains why pickup and delivery frequency has value to the inhabitants of the city centre.

This work will leave **many open questions for the medium to long term**. One particularly important question, both technically and empirically, is about how the urban logistics market works. Markets with economies of scales are complicated to study; they are often characterized by monopolistic competition. In our context, a particular question is **whether this competition leads to spatial specialization of logistic service providers and carriers or not**. In other words, do they compete in the same areas in the city centre, irrespective of the location of warehouses, or do they tend to locate in distinct territories? The answer depends most probably on the market segment, and data will be required at some point to explore the question further.

The implication of this question on this work is direct, as it governs the density of pickup and delivery operations as perceived by a given operator: if many operators compete over the same area, then the efficiency of urban logistics is much lower than if each operator operates in a zone of which the competition is virtually absent. The second important question pertains to the externalities of urban freight transport: congestion, pollution, noise, and accidents. It should be studied together with the policy instruments already in place to address them. Precisely, the question is: to what extent do the conclusions obtained in this study still hold when these externalities are accounted for?

I.4 Conclusion on logistics sprawl

As we have seen in these Sections, "**Logistics sprawl**" is the spatial deconcentration of logistics facilities and distribution centres in metropolitan areas. It has been a noticeable spatial pattern for the last decades in large cities around the world, as identified by about twenty case studies covering mostly European and North American cities, with Tokyo, Belo Horizonte and Bogota in addition. We have organized the data collected in these case studies under 17 indicators.

All indicators have been examined and compared. The main results of this data collection, comparison and analysis are the following.

- The number of warehouses per million of urban residents ranges from 22 (Belo Horizonte) to 236 (greater Gothenburg). This varies with the definition of a warehouse and the accurateness of the database: comparisons are actually difficult as the type of warehouses can vary from one case study to another, and data sources have issues and are not perfect.
- The number of warehouses per million of residents has increased over time in all case studies except Amsterdam, Randstadt and Tokyo.
- Logistics sprawl has happened in all case studies except three (Amsterdam, Belo Horizonte, Seattle).
- The average increase of the LS indicator (increase in average distance of warehouses to their barycentre) is **0.45 km/year**.

The main conceptual relationships between logistics sprawl and the urban mobility of goods are the following.

a) Most cities can expect a **continued increase in the number of warehouses** located in the metropolitan area. Furthermore:

- The increase in the number of logistics facilities over time is positively related to the importance of the **role of global logistics hub** played by an urban area.
- The increase in the number of logistics facilities over time is positively related to the increase in the **digitalization of retail** (increase in B2C demand) in an urban area.
- As B2C demand increases in large metropolitan areas, the **demand for small logistics buildings within the urban area** increases.
- The increase in the number of warehouses over time is **larger in megaregions**.
- The increase in the number of warehouses over time is **larger in big cities** within megaregions.

b) **Logistics sprawl can be expected to continue** in many cities, in the following manners:

- Logistics sprawl is positively related to the **differential in land/rent values for logistics land uses** between suburban and central areas in an urban region
- Logistics sprawl is positively related to the **availability of large land parcels** in suburban settings
- Logistics sprawl is negatively related to the degree of **regional logistics land use control**
- The degree of logistics sprawl varies with the **type of logistics terminal** (i.e. stronger for distribution and fulfilment centres, weaker for parcel transport terminals)
- Logistics sprawl generates an increase in the number of freight vehicle-kilometres within the urban region <u>if</u> its rate is higher, on the same time period, than economic and residential sprawl.
- Additional vehicle-kilometres induced by logistics sprawl are likely to impact less densely populated areas, thus generating less diffused transport externalities (local pollutants, noise, accidents).

In order to analyse the potential causes of logistics sprawl, we have built a simple analytical model of the cost structure of urban logistics. Even on a simple case, the model illustrates the complex and nonlinear **relationship** betweenthe **land use market,** the parameters of **urban logistics** (vehicle speed, workday duration, costs and the demand) and the **location of a warehouse**. In particular, the research shows that an exogenous increase in the demand for pickup and delivery operations **results in warehouses locating further away from cities**, as a result of transport operations weighing relatively less in their cost function. On the other hand, the model hints to how an emerging market for very reactive logisticsneeds to be accompanied by **logistic facilities coming back in city centres**, despite the price. Finally, the model shows that the location of logistic facilities is determined by the **rent gradient, not its absolute value**: if rents are uniformly high, warehouses will have no need to move far from the city centre.

This brings some possible implications in terms of market structure and equilibrium pricing. As urban logistics is most probably characterized by economies of scales, there is economic ground to the idea of **giving some space to logistic facilities near city centres** in order to improve theefficiency of urban logistics. However, this should be done in a careful way**,** lest a mechanical increase in rents in these areas cancels the initial objective of the action.

II. E-commerce and urban freight

Corinne Blanquart
Zeting Liu
Saskia Seidel
Laetitia Dablanc
Martin Koning

II.1 E-commerce and challenges for urban freight: state of the art

II.1.1 Definition of e-commerce, structure and actors

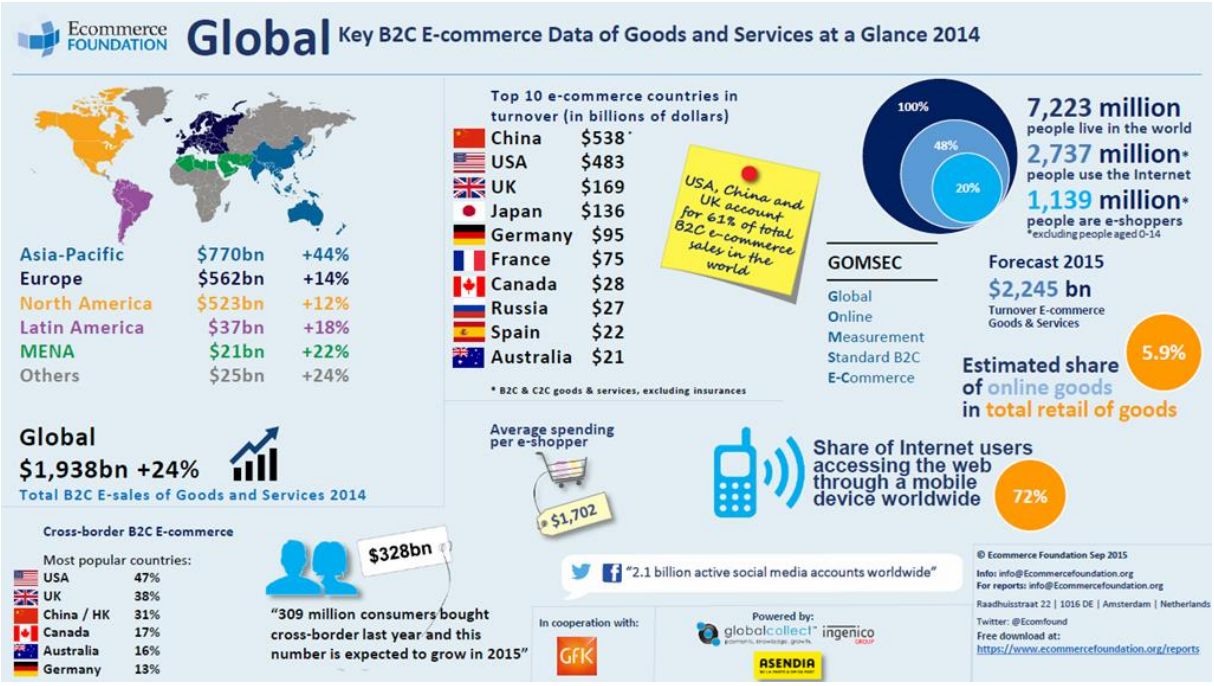
II.1.1.1 Definition of e-commerce

OECD defines an e-commerce transaction as "the sale or purchase of goods or services, conducted over computer networks by methods specifically designed for the purpose of receiving or placing of orders. The goods or services are ordered by those methods, but the payment and the ultimate delivery of the goods or services do not have to be conducted online. An e-commerce transaction can be between enterprises, households, individuals, governments, and other public or private organizations" (OECD, 2011). It includes various forms according to the parties involving in the transactions: B2B, B2C, B2G (business to government) and C2C, etc. We concentrate here in the business-to-consumer model.

Global B2C e-commerce sales have increased sharply over the last decade, driven by a growing online population and changes in consumer behaviours. In 2014, it is estimated that total (world) B2C e-commerce sales reached US$1.9 trillion for goods and services (source: ecommerce foundation, see Figure II.1). China is the world largest B2C e-commerce country. With the USA and the UK, the three countries account for 61% of total B2C e-commerce sales in the world. In Europe, the UK itself accounts for 30% of total European B2C e-commerce turnover (34.5% of EU28). Together, the UK, Germany and France represent 60% of total B2C e-commerce turnover in Europe (69% of EU28) in 2014. France is the sixth biggest e-commerce country in the world and the third biggest in Europe in terms of turnover. However, despite the large proportion of e-shoppers among internet users (60%), online retail of goods accounts for only 4.6% of total retail of goods in France, which is lower than the 5.9% of world level and the 6.4% of European level (13% for the UK and 9% for Germany).

B2C e-commerce includes the sales of goods and services online. The share of goods and services in e-sales varies in different regions and countries. In 2014, in North America, e-sales of goods accounted for 55% of overall B2C e-commerce while services accounted for the other 45%. In the same year, in Europe, the proportion was 53% for goods and 47% for services. In France, the e-sales of goods and services are equal, each accounting for 50%. In Germany goods represent 59.7% of total e-sales and services contribute to the other 40.9%. In the UK, 55% of e-sales are goods and 45% are services.

In Figure II.1 below, from www.ecommerce-europe.eu, more data is provided on comparisons between countries, globally, at the European scale, and at the French scale.


Ecommerce FOUNDATION
Global Key B2C E-commerce Data of Goods and Services at a Glance 2014
Asia-Pacific $770bn +44%
Europe $562bn +14%
North America $523bn +12%
Latin America $37bn +18%
MENA $21bn +22%
Others $25bn +24%
Global
$1,938bn +24%
Total B2C E-sales of Goods and Services 2014
Top 10 e-commerce countries in turnover (in billions of dollars)
China $538*
USA $483
UK $169
Japan $136
Germany $95
France $75
Canada $28
Russia $27
Spain $22
Australia $21
* B2C & C2C goods & services, excluding insurances
USA, China and UK account for 61% of total B2C e-commerce sales in the world
100%
48%
20%
7,223 million people live in the world
2,737 million* people use the Internet
1,139 million* people are e-shoppers
*excluding people aged 0-14
GOMSEC
Global Online Measurement Standard B2C E-Commerce
Forecast 2015
$2,245 bn
Turnover E-commerce Goods & Services
Estimated share of online goods in total retail of goods
5.9%
Average spending per e-shopper
$1,702
Share of Internet users accessing the web through a mobile device worldwide
72%
Cross-border B2C E-commerce
Most popular countries:
USA 47%
UK 38%
China / HK 31%
Canada 17%
Australia 16%
Germany 13%
$328bn
"309 million consumers bought cross-border last year and this number is expected to grow in 2015"
"2.1 billion active social media accounts worldwide"
In cooperation with:
GFK
Powered by:
globalcollect ingenico
ASENDIA
© Ecommerce Foundation Sep 2015
Info: info@Ecommercefoundation.org
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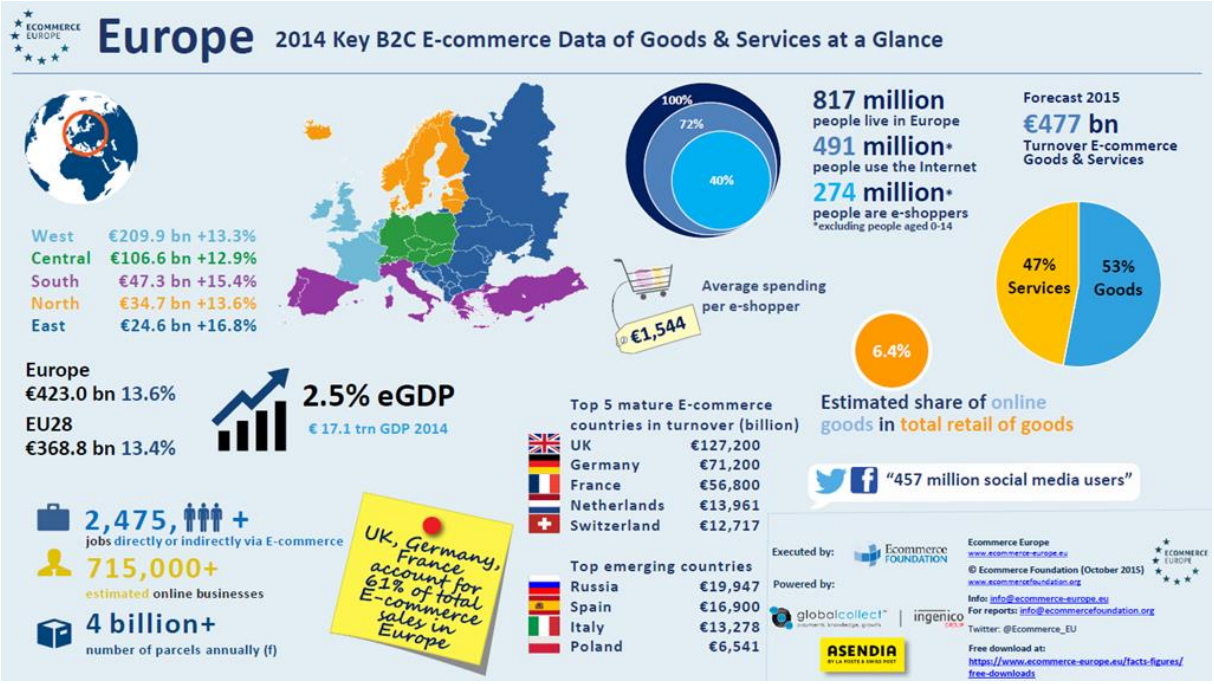
ECOMMERCE EUROPE
Europe 2014 Key B2C E-commerce Data of Goods & Services at a Glance
West €209.9 bn +13.3%
Central €106.6 bn +12.9%
South €47.3 bn +15.4%
North €34.7 bn +13.6%
East €24.6 bn +16.8%
Europe
€423.0 bn 13.6%
EU28
€368.8 bn 13.4%
2.5% eGDP
€ 17.1 trn GDP 2014
2,475,+
jobs directly or indirectly via E-commerce
715,000+
estimated online businesses
4 billion+
number of parcels annually (f)
UK, Germany, France account for 61% of total E-commerce sales in Europe
100%
72%
40%
817 million people live in Europe
491 million* people use the Internet
274 million* people are e-shoppers
*excluding people aged 0-14
Forecast 2015
€477 bn
Turnover E-commerce Goods & Services
47% Services
53% Goods
Average spending per e-shopper
€1,544
6.4%
Estimated share of online goods in total retail of goods
Top 5 mature E-commerce countries in turnover (billion)
UK €127,200
Germany €71,200
France €56,800
Netherlands €13,961
Switzerland €12,717
Top emerging countries
Russia €19,947
Spain €16,900
Italy €13,278
Poland €6,541
"457 million social media users"
Executed by:
Ecommerce FOUNDATION
Powered by:
globalcollect ingenico
ASENDIA
Ecommerce Europe
www.ecommerce-europe.eu
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www.ecommercefoundation.org
Info: info@ecommerce-europe.eu
For reports: info@ecommercefoundation.org
Twitter: @Ecommerce_EU
Free download at:
https://www.ecommerce-europe.eu/facts-figures/free-downloads

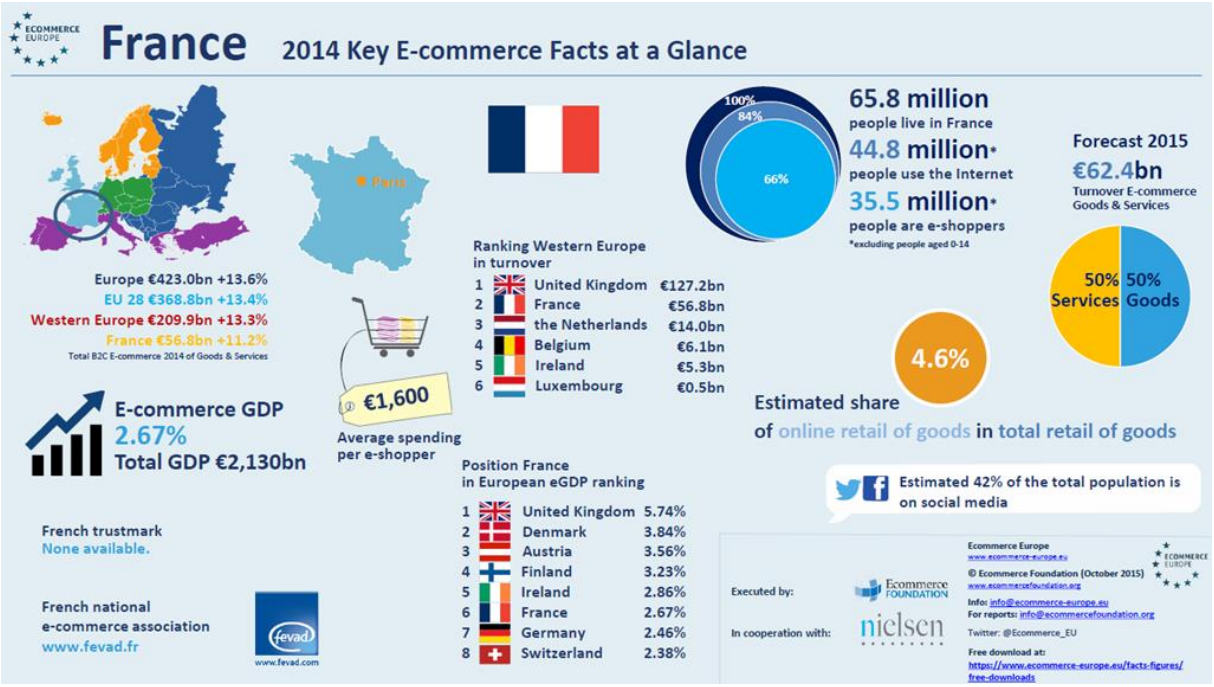


Figure II.1. Key B2C e-commerce data of global market, Europe and France, in 2014
Source: www.ecommerce-europe.eu

II.1.1.2 Actors and structures of e-commerce

E-commerce does not necessarily imply the removal of physical stores, but rather an evolution of how retailers fulfil orders. E-commerce has therefore led to an increase in innovative combinations of physical and digital solutions through concepts such as click-and- collect and other collection methods (Ericsson, 2014). We can distinct the pure players and multichannel retailing:

- Pure players are online selling platforms.

These include online retailers such as Amazon, Cdiscount, Zalando, Wanimo, Zooplus or online market places between sellers/buyers such as eBay, Priceminister, Amazon Marketplace, Le Bon Coin.

Some of these pure players are generalist (Amazon, Cdiscount) and some of them are specialized on one specific sector such as Zalando on garment, Wanimo and Zooplus on pet goods.

- Multichannel retailers are mostly physical shops known as clicks-and-mortar.

These are traditional businesses such as Carrefour, Auchan, Walmart launching online services in order to catch the share of e-retail market or to test the market before launching a physical shop (such as Tesco before it entered the US market).

II.1.1.3 E-commerce logistics and delivery

E-commerce has changed the conventional process of how goods are moved from the seller to the customer. The goods purchased online are in most case delivered by a logistic operator through different ways (home delivery, pick and collect, etc.) that we will study later in this report. This raises the concern on the freight flows generated by the growth of e-commerce in particular in urban areas.

Due to their different nature, the e-retail of goods and of services has inverse impact on freight traffic. Trends seem to indicate that B2C e-commerce for goods increases the total number of

urban freight movements and leads to greater fragmentation of consignments at the city logistics level. It tends to increase the amount and the frequency of deliveries and decreases the size of a single delivery. On the other hand, B2C e-commerce for services can eliminate some journeys by allowing certain products to be downloaded electronically (book, music, home entertainment) (DG Move, 2012).

II.1.1.4 The specificity of e-grocery

In the e-retail market, e-grocery represents a special issue due to the specific conditions of storage and handling of fresh and cold foods and the high costs of home delivery. In contrast to the average general merchandise order, which comprises from one to three separate items, the online grocery orders can contain dozens of items, many of which are low value, perishable and in need of rapid picking and delivery. In the case of on-line purchased goods provided by existing store-based grocery retailers, in which there are no existing physical distribution channels for home delivery operations, these companies have to decide where to locate storage, order processing, picking and delivery activities. As the online business grows, they tend to switch the shelf-picking model to the dedicated picking model which offers potential for efficiency gains but needs a high sales volume to cover the higher investment costs (DG Move, 2012).Indeed, the profitability of e-grocery is a major issue. In France, the only currently existing model of e-grocery is clicks-and-mortar.[11]

II.1.2 E-commerce and urban logistics

The growing maturity of consumers brings with it new desires and expectations. E-commerce fast development in 2002-2003 started when prices of products sold online became more interesting than prices in physical stores. Today, expectations other than prices prevail. At the top of the wish list, consumers expect fast delivery and convenience throughout each step of the online process. According to Gevaers et al. (2011), although direct-to-consumer deliveries are not new (as evidenced by the mail-order firms of the 1980s and 1990s), the expansion of e-commerce has stimulated their further development.

According to a study from Barclays (2014), in 2013, letterbox-sized packages and small parcels (i.e. no larger than a standard UK shoebox) made up 59.5% of all deliveries from orders made online, with an estimated average growth of 42% between 2013 and 2018.

E-commerce has triggered transformation in the entire distribution system (Hesse, 2002). In B2C e-commerce, two physical distribution models are observed:

- The products flow along existing physical distribution channels, using existing physical distribution channels of express companies and postal networks. In this hub-and-spoke logistics network, last-mile delivery involves transportation over short distances with smaller trucks, and is carried out by the receiving depots in their regions.
- A new physical distribution channel to supply goods to consumers is established by retailers. In this case, logistics operations can be located at existing facilities/stores or in fulfilment centres, which are dedicated to e-commerce orders.

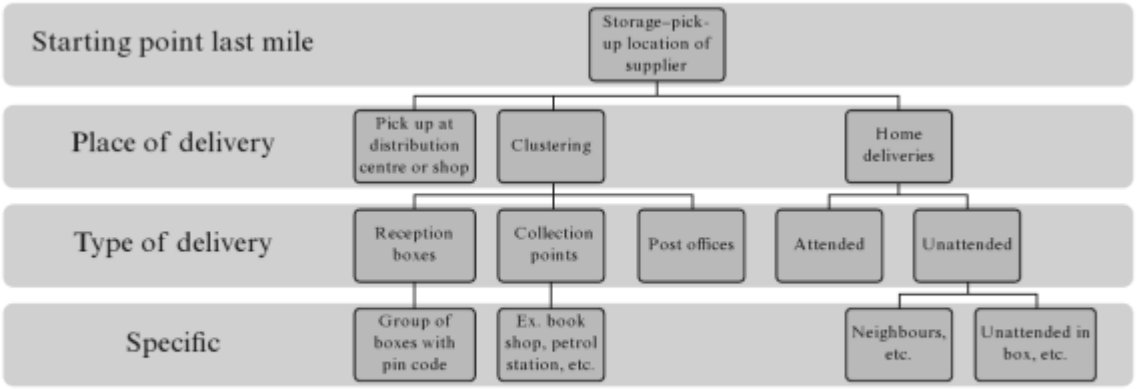
II.1.2.1 The last mile competition of B2C e-commerce

The rapid growth in the number of parcels has drawn attention to certain issues in the final part of the supply chain, which is referred collectively as the *lastmile problem*. One of the biggest challenges in B2C e-commerce is this last mile delivery to the consumer. Particularly in the e-grocery business it is difficult to combine profitability, customer convenience and traceability.

[11]Houra is associated to Cora, and Ooshop to Carrefour

For acceptable delivery costs and prices for customers, the volume and the number of deliveries have to attain a certain threshold (DG Move, 2012).

In e-commerce, the last mile is the final leg in a business-to-consumer delivery service whereby the consignment is delivered to the recipient either at the recipient's home or at a collection point (Gevaers et al., 2011). The authors (2011) identify various delivery methods based on their potential impact on efficiency and cost.



Sources: based on Gevaers et al. (2008, 2009a,b), Leavit (2008), Madlberger (2005), Murphy (2006), Punakivi et al. (2001), Van Oosterhout (2004) and Weltevreden (2008).

Figure II.2. Various delivery methods in the last mile
Source: Gevaers et al. (2011)

As shown in Figure II.3 below, the service can be fulfilled either through a direct delivery to home or to a specific address (e.g. office) (1) or through a delivery to a collection point outside the home (click-and-collect). In the latter case, the consumer will collect the goods at a PUDO (pick-up/drop-off), also known as *pickup point* (PP); or, (2) in the special case of e-grocery, at a *drive* (click-and-collect at a special facility, or distribution centre or store) (3).

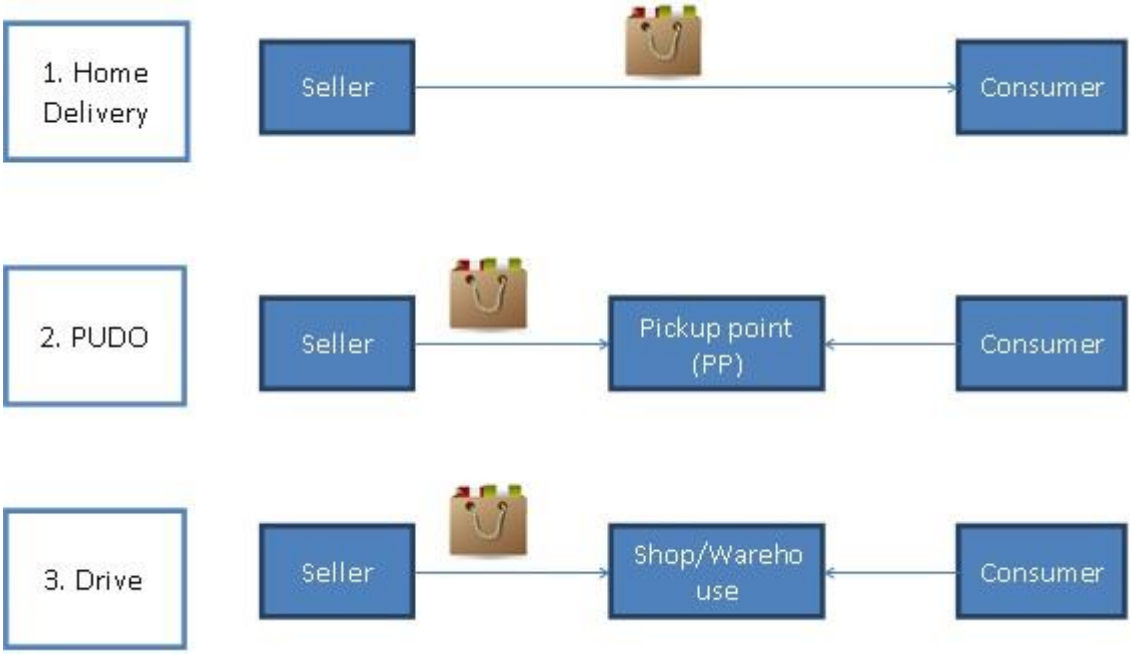


Figure II.3. Different business-consumer relations in B2C e-commerce last mile
Source: the authors

As the Barclays survey (2014) shows, while home delivery remains the main delivery solution, click-and-collect also gains momentum in developed markets, as consumers increasingly opt for the convenience of collection (JLL, 2013).

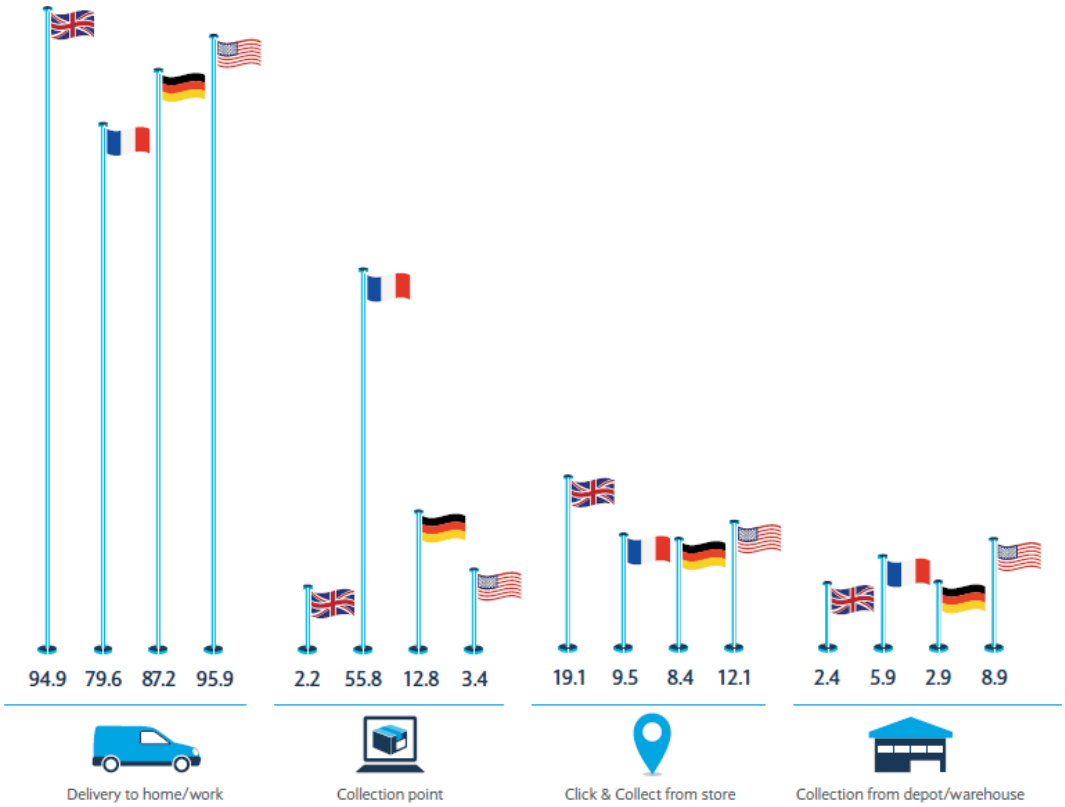


Figure II.4. Percentage of consumers that have used various delivery methods at least once over the past 12 months, per country (US, UK, Germany, France)
Source: Barclays, 2014

Augereau et al. (2009) identify two categories of collection points: pickup points (PP), comprising networks of tobacconists, dry cleaners, florists, etc.) and automated lockers (referred to as 'automated packstations' (APS) by DHL in Germany).

Table II.1. Trends for reception point networks in Europe

Company	Service type*	Country	No. sites 2008	No. sites 2012	Growth rate 08–12	Parcel volumes 2012
ByBox	APS	UK	1000	1300	+30%	N.A.
Collect Plus	PP	UK	Not available	5000	N.A.	N.A.
PackStation	APS	Ger.	1000	2500	+150%	N.A.
Paketshop (Hermes)	PP	Ger.	13,000	14,000	+7.7%	N.A.
ByBox	APS	F	Not implemented	170	N.A.	N.A.
Cityssimo	APS	F	20	33	+55%	N.A.
Kiala	PP	F	3800 (with M.R.)	4500	+18%	15 million
Pickup Services	PP	F	3100 (à2pas)	5200	+68%	9 million
Mondial Relay (Point Relais)	PP	F	3800 (with Kiala)	4300	+13%	12 million
Relais Colis (Sogep)	PP	F	4000	4200	+5%	23 million

Source: the authors with company data from various sources
* APS = automated pack station; PP = pickup point

Source: Morganti et al., 2014

It is interesting to observe that the APS model is particularly underdeveloped in France compared to the UK and Germany. Instead, the PP model is well established in France. This may be linked to the early development of the *point relais* networks for traditional mail order companies 30 years ago. Click-and-collect from the store is another alternative that starts to develop. For example, the French pure player Cdiscount has set up a partnership with the supermarket chain Casino to use the shops of the latter as its pickup points. The physical shops of Darty and Fnac also served as PP for goods sold by their online retailing business unit (which are independent from physical shops).

Analysis of the French PP model shows that the deployment of PP networks is directly linked to population density and frequency. This means that urban areas have larger numbers of PPs than suburban/rural areas. And in suburban and rural areas, PP are more likely located in the centre and main commercial avenues.

As shown in Figure II.5, the PPs are numerous in the western side of the Seine et Marne Department, belonging to the Paris conurbation, where population densities are higher than 1000 per square km. More precisely, within the whole Department, PP distribution patterns show a significant positive correlation with population density, with a predictable decline in PP density in rural areas.

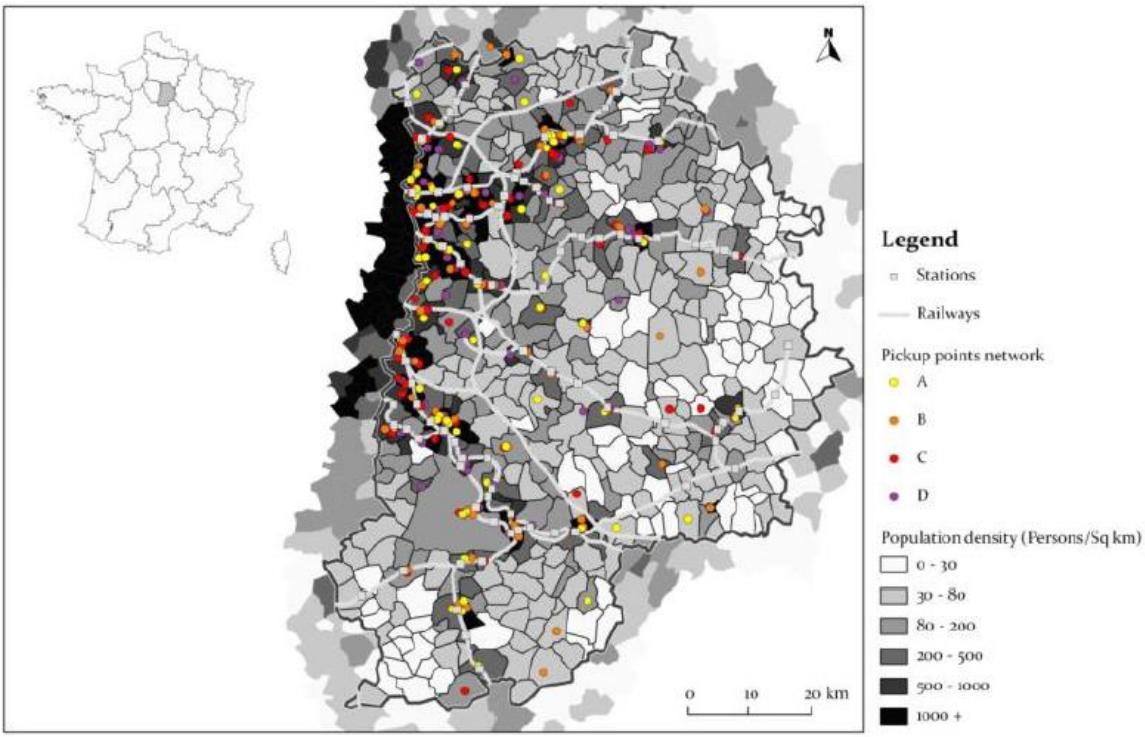


Figure II.5 : Pickup point networks in Seine-et-Marne, 2012- Map by François Fortin
Source: Morganti et al., 2014

II.1.2.2 The special case of French e-grocery

In general, there are four ways for online grocery orders delivery: i) van delivery to home; ii) *drives* (drive-through outlets); iii) in-store pickup where shoppers drive to the store and pick up the order; and iv) parcel delivered by 3PL (for example the French pure player Telemarket.fr (which has been put in liquidation in 2013) has used parcel delivery through a partnership with Chronopost, see Gavaud, 2010). In France, the click-and-collect (or “drive” in the local language) solution has expanded rapidly from 2012 onward.

The expansion of *drives*, or drive-through outlets of goods bought online, is one of the most cost-efficient solutions in dense population areas to cope with a growing number of mobile and active shoppers (in particular young active couples with children). It helps large retailers compensate the loss of shoppers and stagnation of sales in hypermarkets (Gavaud, 2010; Heitz et al., 2011; Fabuconnier, 2012; Carrelet and Cruzet, 2014). Indeed, as consumers' perception of time and space has changed due to the use of internet and smart phones (m-commerce), super/hypermarkets have to develop new models in order to attract a larger extent of consumer groups outside their traditional catchment areas (for example, from resident to office, less served areas) (Heitz et al., 2011; Fabuconnier, 2012).

Today, all the major brands in France have developed the *drive* model, with some variation (Carrelet and Cruzet, 2014; Lapoule, 2014). Even the only French e-grocery pure player, Houra (belonging to the Cora group), has implemented a *drive* in Marignane (Marseille region).

Table II. 2. Number of drive-through outlets (including pick-and-goes*) per French retailer

Le Drive Intermarché	713	Chronodrive	66
Courses U	577	Monoprix.fr	67
E. Leclerc Drive	406	Cora Drive	56
Carrefour Drive	324	Simply Drive	39
Mes coursescasino.fr	152	Collect&Go	6
Auchan Drive	87	Casinoexpress.fr (solos)	18
Leader Drive	81	Houradrive	1

Source: A3 Distrib, November 2013.

Source: Lapoule, 2014

* Pick-and-go is the model where online customers collect their purchases at the shop.

In France, *drives* can be divided into three categories: *drive* "picking" (which is closest to the in-vehicle pickup common in the US), which is the most common form, *drive* attached to the store and *drive* "warehouse" (Carrelet and Cruzet, 2014).

II.1.2.3 The problem of profitability and the development of logistic solutions

The last mile is currently regarded as one of the more expensive, least efficient and most polluting sections of the entire logistics chain due to, for example, the following:

- Home deliveries that raise concerns on security and in particular the 'not-at-home' problem which leads to high rates of delivery failure and empty trips, which substantially affect the cost, efficiency and environmental performance;
- Lack of critical mass in some areas or regions, which will also affect the cost. For example, hypermarkets in Dijon tend to concentrate their home delivery service for goods in urban or dense suburban areas in order to rationalize delivery costs (Motte-Baumvol et al., 2012);
- Environmental concerns due to the high use of vans, which results in higher emissions per parcel compared to truck deliveries (Gevaers et al., 2011).

And this is particularly true for e-grocery. A study from Sinha and Weitzel (2015) on US online retail of groceries and consumer packaged goods shows that most models are hardly profitable if one includes all direct costs (such as delivery) and indirect costs (such as human cost preparing and packing the order) measured by activity-based costing method. *Drive* (in-vehicle pickup) and delivery by small vans from distribution centres are the most cost-efficienct delivery systems in dense population markets (Sinha and Weitzel, 2015). Intermarché, the third largest French grocery retailer, has developed the largest network of drives in order to "avoid having to make home deliveries and bear the substantial costs associated with the last mile (Lapoule,

2014).In the US, a few pure players are experimenting with van deliveries (e.g. Amazon Freshis providing van deliveries in Seattle, San Francisco, Los Angeles, San Diego, and now New York (Sinha and Weitzel, 2015)).

One interesting point is that the authors highlight that consumers are ready to pay a reasonable sum in exchange for a quick delivery (Sinha et al., 2015). Another study on the attitude of French consumers on unattended delivery for e-grocery purchases also shows that 75% of respondents mentioned they were willing to pay for delivery services (Goethals et al., 2012). This suggests that there is room for innovations in supply chain management that will help to reverse the cost.

II.1.3. E-commerce and urban traffic

II.1.3.1 E-commerce and urban freight traffic

The increasing volume of e-commerce transactions has created an explosion of freight traffic for personal deliveries in residential areas and office districts previously dominated by personal transport (Ericsson, 2014). This amplifies the conflicts on urban goods movement (Nemoto et al., 2001; Russo and Comi, 2012):

- Logistics service providers try to minimize logistics costs, which are under pressure due to growing demand from shippers for services such as time-specific deliveries, temperature control and regulations.
- Government is assumed to seek maximization of social welfare to reduce negative impacts of growing urban freight transport in environment and quality of life.

Studies suggest that e-commerce does not reduce urban traffic and may even increase it as the reduction of shopping trips is substituted by the increase in delivery trips.

Hesse (2002) had already suggested that the expansion of e-commerce may lead to the atomization of freight flows as rising carrier competition, increasing order flexibility supports on-time delivery, often with less than a full truck load, at higher frequencies and with smaller vehicles. At the same time, Nemoto estimated that the use of ITC and intelligent transport system (ITS) could make logistics operations more efficient by optimizing fleet management based on real-time traffic data (Nemoto et al., 2001). It is still expected that the use of ITC tools will help logistic companies optimize delivery routing and efficiency, government to provide better transportation infrastructure and information, and consumers to better organize their pick-up trips to avoid congestion (Caglianoa et al., 2015).

Taniguchi and Kakimoto (2003), using modelling techniques of vehicle routing and scheduling with time windows, show that e-commerce can lead to more traffic in urban areas and negative impacts on the environment. When e-commercepenetration rate reaches over 10%, however, the reduction in traffic for shopping by passenger cars overcomes the increase in home delivery truck traffic. Moreover, pickup points and co-operative freight transport systems of home delivery companies and designating time windows by home delivery companies can substantially reduce total running times and NOx emissions. Visser et al. (2014) also highlight that consolidation of home deliveries will increase their efficiency and add more deliveries per trip, which will reduce the number of vehicle-kms per delivery (Visser et al., 2014)

Cortright (2015) shows that, compared to the level of 2007, the rapid growth of e-commerce sales in general, and the expansion of Amazon in particular, result in a growth of efficiency and an increase in delivery density. These in turn result in less urban truck traffic (measured by vehicle miles travelled). The author argues that by increasing delivery density, thanks to increased volumes and computerized routing algorithms per loading, deliveries become more efficient.

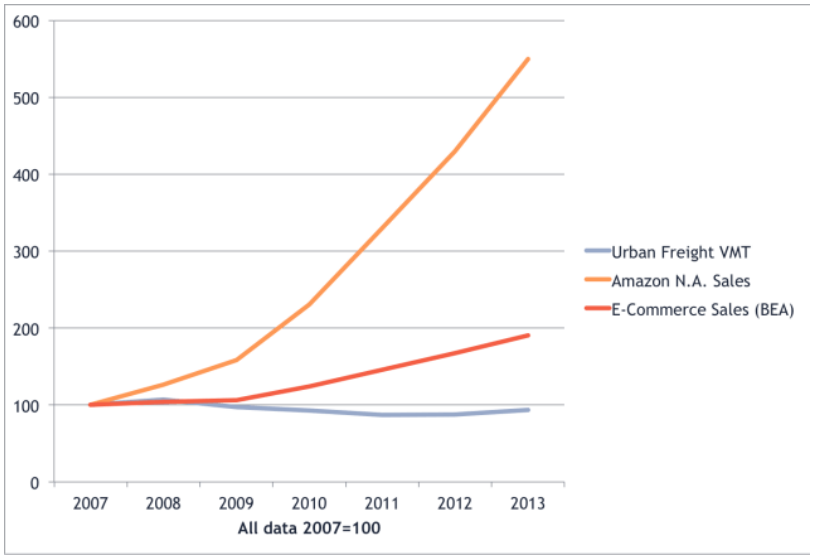


Figure II.6. Trends of e-commerce sales, Amazon North American sales and Urban Freight Transport, defined as vehicle miles travelled

Source: Cortright, 2015 (N.A.: North America; BEA: Bureau of Economic Analysis; VMT: vehicle-miles travelled).

II.1.3.2 E-commerce and customers' shopping trips

Shopping trips represent approximately 13% of the total energy use for passenger transport in Sweden, and there are similar metrics in other European countries (Hiselius et al., 2012). However, the impact of e-commerce on personal shopping trips is not homogenous according to the period and countries.

A Japanese survey in 1998 shows that, in central Tokyo, the modal share of car for personal trips for shopping and leisure is only 12%, which leaves very little possibility of substitution (Nemoto et al., 2001).

A Swedish survey on consumer buying and travel habits based on the travel diaries of regular and not online shoppers (Hiselius et al., 2012) shows that:

- On the whole, those who shop regularly online make the same total number of trips as those who do not shop regularly online;
- There is no large difference in individual trip length between those who shop regularly online and those who do not;
- With regards to shopping trips, there is no difference in the mode travelled between regular online shoppers and non-regular online shoppers.

Thus although a particular shopping trip may be substituted for an online purchase, the overall travel behaviour with regards to the total number of trips and trip length remains largely unchanged for online shoppers.

Contrary to the Swedish survey, US studies show that the substitutions of shopping trips by ordering on line do reduce urban traffic. Levinson (2014) shows that shopping trips comprise fewer than 9% of all trips, down from 12.5% in 2000 in the US due to the substitution of online shopping. A typical UPS delivery truck can make 120 or more deliveries a day, which is more efficient than personal car shopping trips by customers. Each delivery truck may be responsible for dozens of car-based shopping trips (Cortright, 2015). A study from Wygonik and Goodchild (2012) on US grocery delivery shows that delivery vehicles incur fewer vehicle miles travelled (VMT) when compared with corresponding individual trips to collect these goods.

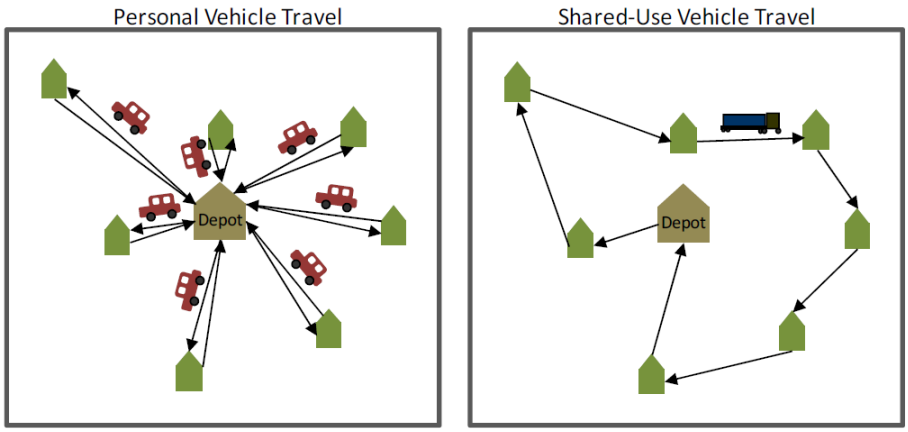


Figure II.7. Illustration of Personal Vehicle Travel Compared to Shared-Used Vehicle Travel
Source: Wygonick and Goodchild, 2012

This is partly confirmed by the study from Durand and Gonzalez-Feliu (2012) in the Lyon region. The authors use an empirical simulation approach to test last mile inter-establishment movements and the end-consumer movements based on three e-groceries delivery models: 1) store-picking and home delivery, 2) warehouse-picking and home delivery (pure home delivery); and 3) depot-picking and out of home delivery (pickup points) (pure pickup). When reaching more than 50% of e-shoppers with home delivery service, the pure home delivery model with light goods vehicles will generate substantial gains in km.PCU (passenger car unit) (16%); however it also has important impacts on total road occupancy. The pure depot pickup provides the most substantial gain in km.PCU (20%), which “reflects a sharp decline in motorized shopping trips over 30%”.

It seems that the click-and-drive model can reduce urban personal traffic in two ways. First, the depots are located near the heart of residential neighbourhoods and the density of these points is sufficient to lead to changes in user behaviour (Durand and Gonzalez-Feliu, 2012). Second, it offers consumers a chance to combine their shopping trips with other daily activities such as travel to the work place, thus reducing total trips (Schenk et al., 2007, Rauh, 2007).

II.1.4 E-commerce and innovation

Innovations can help service providers increase e-commerce delivery efficiency, at a low cost while limiting emissions and pollution through optimization of routing, ITS, etc.; and propose new services to attract (or sustain) new customers.

E-commerce has contributed to the co-evolving of European Courier, Express and Parcel sector (CEP), leading to the creation of an urban parcel distribution segment of convergent structures, strategies and organization (Ducret, 2014). There are three categories of delivery methods (Ducret, 2014; Lierow et al., 2014; Hausladen et al., 2015):

1) Third party logistics, which is the most frequently adopted method and normally ensured by the Courier, Express and Parcel sector (CEP);
2) Own delivery capacity, e.g. Auchan in France, and most grocery companies in Germany (Lierow et al., 2014);
3) New entrants, based on the development of applications that propose new and innovative localized delivery solutions.

The last-mile competition in urban areas leads these actors to propose greener, faster, safer and more convenient services. However, these practices are limited to niche markets and many are still at an experimental phase.

II.1.5 City logistics: greener and more efficient delivery

Although city logistics is not limited to e-commerce, logistics operators face strong pressures from the increasing volume of parcels due to e-commerce and the 'delivery wars'. These 'wars', for example, are currently represented by new services from e-retailers or logistics providers offering 'instant delivery' services to e-shoppers.

It is estimated that 4% of UPS overall volume is tied to Amazon (Hook, 2015). For DHL, e-commerce contributes to 20.9% of the growth of its Post-eCommerce-Parcel (PeP) division in Q3 2015. Giving the importance of e-commerce in their business, logistic operators have to find innovative solutions to offer faster, cheaper and more flexible delivery service in urban areas. Ducret (2014), for example, identifies three types of innovative urban logistics organizations: city hub, virtual exchange point, and mobile city hub.

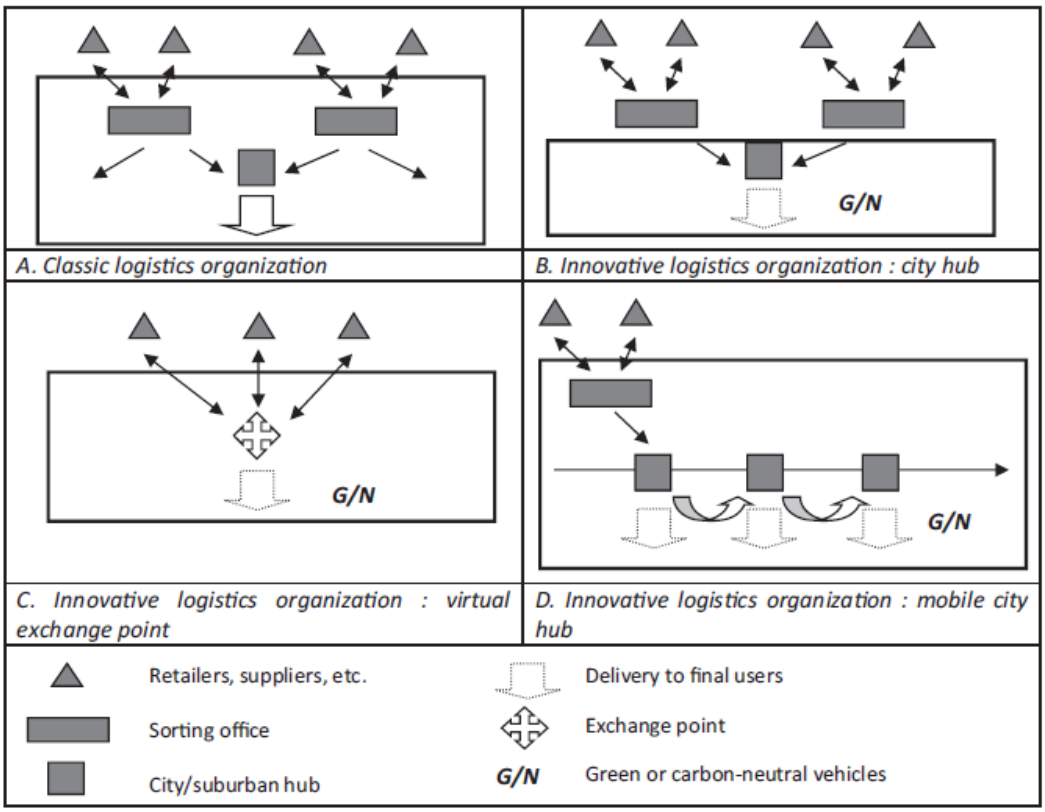


Figure II.8. Innovative logistics organizations
Source: Ducret, 2014

Here are some examples of initiatives that are linked to e-commerce:

- In Germany, Deutsche Post / DHL group has implemented a network of automatic stations for collecting goods, Packstation;
- Also in Germany, Tower24, a concept developed by Fraunhofer-Institute for Material Flow and Logistics IML in Dortmund, was a decentralized pick-up terminal equipped with a fully automatic storage system for small consignments (model B shown in above figure).

In terms of sustainability, applying the sustainable logistic framework developed by Russo and Comi (2012), Schliwa et al. (2015), Hausladen et al. (2015) rate different delivery methods. The cargo bike solution is considered to have the highest sustainability potential. Schliwa et al. (2015) also argue that if low-carbon vans are beneficial for environmental goals, they do not resolve the problem of traffic congestion and accidents in dense urban areas.

Table II.3. Analysis of city logistics concepts according to their potential environmental, social and economic impacts

	Environmental			**Economic**			**Social**			
	Re-source use	GHG emis-sion	Other emis-sions	Long-term ori-entation	Invest-ment costs	Opera-ting costs	Quality of life	Impact on city structure	Data security	Ø [%]
Cargo bike	●	●	●	◔	◔	◔	●	●	●	92
Cargo tram	◐	●	◔	◐	◕	◐	◔	●	●	69
E-mobility	◔	●	◔	◔	◐	◔	◔	◔	◔	75
Dabba-wala	●	●	●	●	◔	◔	●	●	◔	92
Drone	●	●	◐	◐	◐	◔	◕	●	◐	67
Crowd logistics	●	●	◔	●	◔	◔	◔	●	◐	83
Cargo tube	◕	●	●	◐	○	◐	●	◔	●	67
Pack-station	◔	●	●	●	◔	◔	●	◔	◔	86
Parcel box	●	●	●	●	●	●	●	◔	●	97
Tower24	◐	●	●	◐	◕	◐	◔	◐	◔	64
Shop PUDO	●	●	●	◔	◔	◔	●	●	◔	89
Freight village	○	◔	◐	◔	◕	◐	◕	◐	●	50
Integrated mall	○	◔	◔	◔	○	◐	◔	○	◔	47

Source: Hausladen et al., 2015

Among these concepts, cargo bike, e-mobility, drone, crowd logistics, parcel box, Tower24, Shop PP are all considered as possible solutions to provide cleaner, cheaper and more flexible delivery services to urban e-consumers.

II.1.6 Same-day deliveries: big players and localized lastmile delivery brokers in urban area

As many people increasingly work in a freelance or short-contract capacity within many modern economies, the time available for visiting shops, collecting items or waiting for home deliveries can either diminish or become less predictable. The competition of e-commerce in urban areas is moving to instant delivery with e-retailers proposing one-hour, two-hour, or same-day deliveries (for example: Amazon offers same-day delivery in several US cities. Amazon Prime

Now goes a step above. Using the Prime Now app, members can order more than 25,000 eligible items (as well as food from area restaurants) and get free delivery within one to two hours; However, Amazon isn't the only company testing same-day delivery: 2 hours delivery by courier of Fnac in Paris and Lille regions). This means that for logistics operators such as FedEx or UPS who used to focus on bringing large volumes of packages to a relatively small number of businesses now have to find innovative solutions to deliver in smaller volumes to more widely dispersed consumers while keeping the costs in check (Hook, 2015). But it also represents opportunities for start-ups to provide innovative solutions to satisfy the requirement of speedy urban consumers as the case of Shult in UK (bought by ebay).

At the same time, many smaller stores in local areas suffer due to competition from online and large-scale retailers. One response to this has been the creation of localized lastmile delivery brokers within a variety of urban areas, allowing people to buy items from local stores or restaurants and have them delivered by local drivers to the home or office location that is most convenient at the moment (Ericsson, 2014).

For example, in September 2013 Google launched Google Shopping Express (now Google Express) in San Francisco and is now also available in Chicago, Boston, Los Angeles, New York, Washington D.C. It allows consumers to order goods from a range of brands available locally (e.g. Costco, Fairway, Target, Walgreens, Toys'R'Us, Staples, L'Occitane, etc.) online (https://www.google.com/express/) or through a mobile application (Google Express). The seller receives the order through an application of Google, and sends an employee to look for the product – as well as other products that will be distributed during the same time slot– and prepare the parcels. A Google truck will pick up all the parcels to its sorting centre, and a small car will redistribute the goods to their destinations according to each order. The cost of each delivery is from zero to US$4.99 and over.

In France, TokTokTok (toktoktok.com) launched in Paris in 2011 works with brands such as Fnac, Darty etc. but also with local small businesses (restaurants, flower shops, drug stores, etc.) and the deliveries are assumed by the 'runners' who will pick up the order and deliver it to the consumer in one hour. It allows consumers to check their order through an app. The cost of delivery is from 8€ to 20€. It is available in Paris, Lille, Lyon, Toulouse, Bordeaux, Marseille, London and Barcelona.

The success of TokTokTok shows another interesting trend in urban last mile logistics: the 'uberization', or crowd shipping, of home delivery (ride hailing service). This trend could be considered as an innovative solution in the search of a profitable model for customized, flexible and cheap instant delivery services in urban areas. In addition to e-commerce specific players such as TokTokTok and Amazon Flex, others are private service providers not specifically targeted towards e-commerce, such as Uber Rush in Manhattan, and in France CoursierPrivé, Coliweb, PickUp, GoGoRunrun. In 2015, Shopify has announced a partnership with Uber to offer same-day delivery with Uber Rush, which is now available in selected cities (New York City by bike messengers, Chicago by car and San Francisco by both) with plans to offer the service in more locations over time.

II.2 E-commerce indicators

There is only scarce data on e-commerce, in particular *urban* data, and data about its impact on mobility and traffic.

To develop the analysis on these issues as well as to provide comparison between countries, the following indicators have been selected for this report. Data has been collected when available (see Appendix 4). This list of indicators represents what seems most relevant to us when studying relationships between e-commerce and urban freight.

As seen on the Table in **Appendix 4**, our sources of data are incomplete. They are from various sources, including official data (Eurostat, OECD), public research institute/universities (Copenhagen Economics), professional association/federations (Universal Postal Union, UPU; International Postal Corporation, IPC; Ecommerce-europe.eu), or private data such as consultants' studies (AT Kearney, Nielsen TradeDimensions).

There are still research gaps in the analysis of the relationships between e-commerce and freight, especially in urban areas. The major one involves data. Freight surveys could be helpful, researching whether the order being shipped was placed electronically or by conventional means. This would also allow questions such as: are e-commerce shipments longer than other shipments? Are they more likely to be international shipments? Detailed case studies could specify the changes in supply chains that are driven by e-commerce and their effects on the quantity and quality of freight services demanded.

A useful database to analyse the links between e-commerce, urban traffic and land use could be structured as shown below. In Appendix 4, we have started filling in data for these categories of indicators:

GENERAL FIGURES

Name and size of studied area

Total B2C e-commerce (goods *and* services) turnover (€ billion)

Total B2C e-commerce (goods *and* services) increase (% increase compared to year before)

Share of goods purchased online (%)

Share of services purchased online (%)

E-commerce % on total GDP

Estimated share of online retail of goods in total retail of goods (%)

Average spending per e-shopper (€)

Total grocery e-commerce turnover (€ billion)

Share of grocery e-commerce in total grocery commerce (%)

DELIVERY INDICATORS

Total shipments parcels (express and non express) B2B, B2C, C2C in million units and euros

Share of B2C and C2C in total shipment parcels

National Postal Operator's market share relative to B2C parcels and packets shipments (%)

Share of shipments delivered as express delivery by national postal operators (%)

If city case studies are available: share of e-commerce deliveries in total urban deliveries (%)

(example New York City: 800,000 e-commerce deliveries out of 2.2 million deliveries a day, a share of 36%)

LOGISTIC FACILITIES

Number of pick up points

Number of pick-up-point per urban inhabitant

Market share of pick-up points in total number of e-commerce deliveries (%)

Number of *automated* pick-up points

Number of "drives" (grocery e-commerce pick-up-points)

MARKET STRUCTURE

National Postal Operator's share of revenue due to e-commerce (%)

Main alternative operators active in B2C deliveries

E-SHOPPERS

Total residents (million)

Internet users (million)

Share of internet users (%)

Total urban residents (million)

Urban internet users (million)

Share of urban internet users (%)

II.3 Elements for urban planning and public decision-making

E-commerce implies new use of space and new planning issues. It means adapting public decision making to the new reality in retail.

This section highlights the importance of understanding urban planning aspects of city logistics, including managing truck traffic associated with the last mile portion of the e-commerce supply chain.

Citylogistics also means discussing logistics systems for e-commerce: location of logistics centres and their functions, and new operators'strategies in terms of delivery services.

One limitation of our research is that data on e-commerce shipments are scarce, especially for urban areas. Moreover, effects depend on a wide range of factors, very different according to the countries. Lastly, the high speed of changes poses special challenges for forecasting the future of e-commerce and assessing its impacts.

Both data collection and assessment processes are needed to evaluate impacts at detailed local and urban level, regional level, state level and a national level. In the absence of such measures, we have attempted to provide some assumptions from the literature survey, that have to be further tested.

These assumptions focus on the relationships between:

- E-commerce and urban traffic
- E-commerce and delivery options, as an important driver for urban freight
- E-commerce and logistics facilities

II.3.1 E-commerce and urbantraffic

II.3.1.1 The growth of e-commerce revenue results in higher parcels volume

The higher the internet sales the more parcels are sent.

The following figures (II.10 and II.11) show the growth of e-commerce sales and the increasing number of parcels in particular domestic parcels between 2000 and 2012. The growing parcel volume follows the trend of e-commerce sales. However, as we can observe, the pace of parcel volume growth is lower than the growth of e-commerce.

On average, parcels and express volumes in Europe have grown by more than 5% annually over the last three years, with the rate of growth increasing to 6.3% in 2014 (Source: Ecommerce Europe: data for 2012 and 2014; IPC, 2015). In Europe alone, the number of parcels/year accounts for more than 4 bn/year in 2014.

In2014**,** the growth rate of the e-commerce turnover still achieved double digits. In total, European B2C e-commerce sales increased by more than 14%, reaching € 423.8bn. The 28 member states of the European Union together experienced a similar growth, resulting in a EU28 B2C e-commerce turnover of € 368.7bn.

Giving the fact that e-commerce includes services and goods (both digital and physical goods), the following questions need to be addressed:

- it is possible that the sales of digital goods are growing faster.
- this can also be due to higher added-value per item shipped.

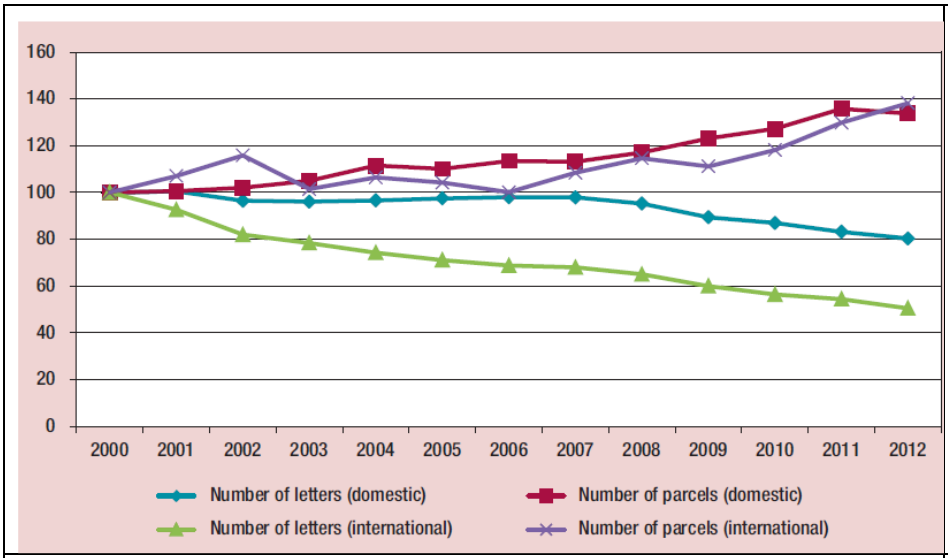


Figure II.10. Letter and parcel traffic handled by the postal system (world), 2000-2012 (index 2000 = 100)

Source: UNCTAD[12], 2015

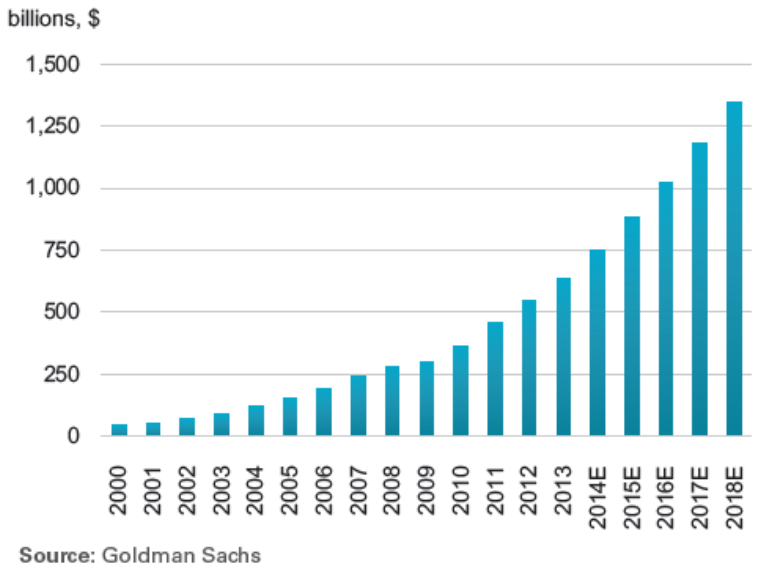


Figure II.11. Global annual E-commerce sales (goods and services)

Source: Prologis, 2014

II.3.1.2 The growth ratesof e-commerce sales and of urban freight traffic are different

From 2007 to 2013, Amazon‘s North American sales increased by a factor of 5, from $8 billion to $44 billion. Between 2007 and 2013, the total e-commerce revenues in the United States has doubled, from about $137 billion to about $261 billion according to the U.S. Department of Commerce. However, according to the US DOT data as tabulated by Brookings (assembling several decades of US DOT data on vehicle miles travelled), over this same time period truck traffic in urban areas has actually declined (Cortright, 2015).

[12] United Nations Conference on Trade and Development.

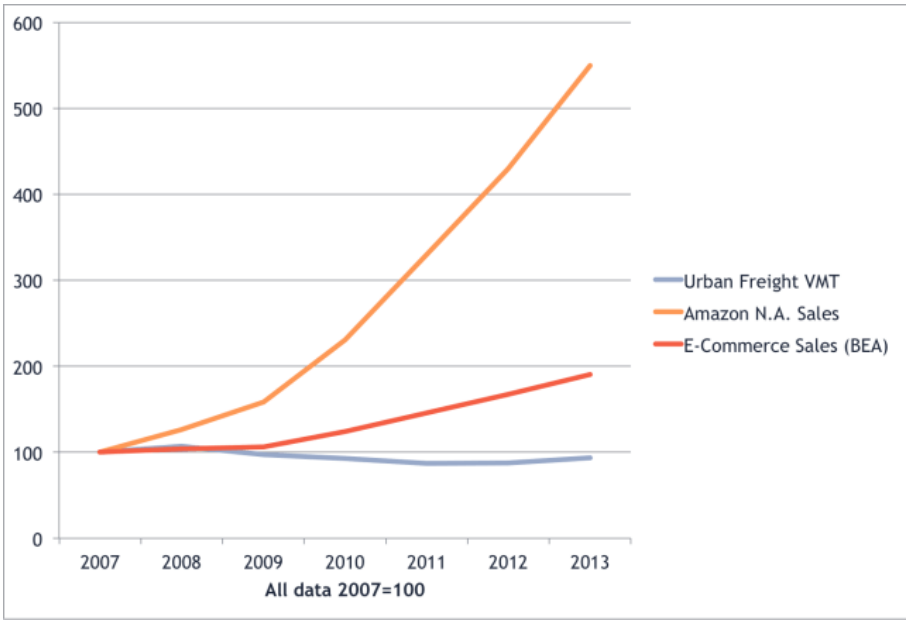


Figure II.12 E-commerce sales, Amazon North America sales and Urban Freight Transport
Source: Cortright, 2015
* N.A.: North America
** BEA: Bureau of Economic Analysis

The logistics performance can explain this difference in the growth rate, through a load rate optimization, multiple customer deliveries in the same trip, or shorter distances with the development of sortation centres closer to the city centre.

II.3.1.3 Instant delivery will increase urban freight traffic

It is assumed that the more quickly delivery is demanded, the less efficient the delivery trip may be (Mokhtarian, 2004).

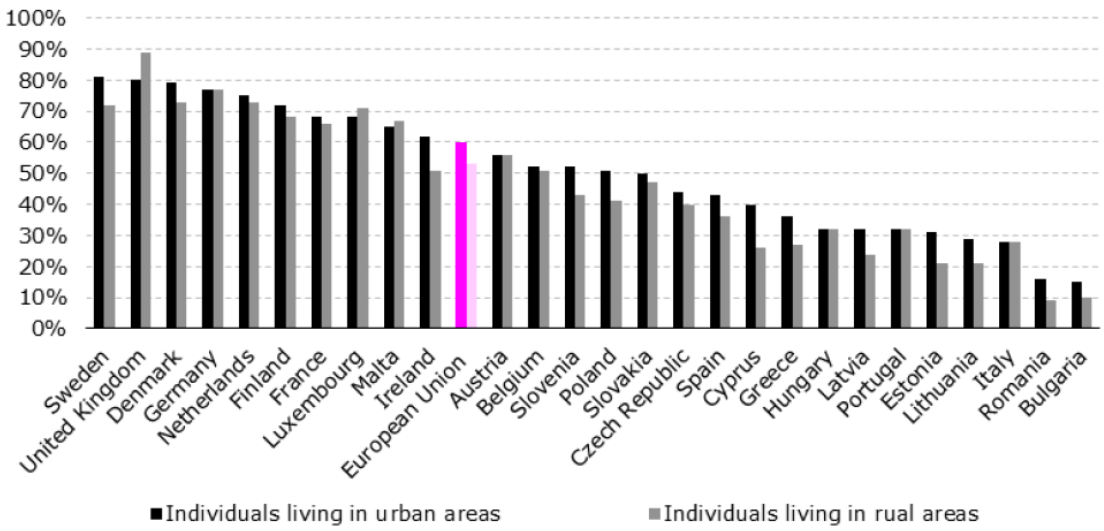
II.3.1.4 Growth in freight transportation due to e-commerce depends on the return rates and the reverse needs

Earlier studies estimated customer return rates at 6-15% for mass merchandisers and up to 35% for catalogue and e-commerce retailers (Dowlatshahi, 2005; Sarkis, Meade, Talluri, 2004).

II.3.2 E-commerce, land use patterns and urban freight

II.3.2.1 E-commerce use is quite similar in rural and urban areas

The share of internet users engaging in e-commerce is in general higher in urban than in rural areas. Still, the differences between countries are much larger than the differences between urban and rural households.



Note: Share of internet users in urban/rural areas that bought goods or services online during the past 12 months

Source: Eurostat (2013a)

Figure II.13. E-commerce in urban and rural areas

II.3.2.2 Land use patterns influence urban freight traffic for home deliveries

Higher population density and therefore higher delivery density means less urban traffic.

Higher population density means better logistics performance because it will increase delivery density measured by stop per mile. Boyer, Prud'Homme& Chung (2009) show that more deliveries per trip reduce number of vehicle-kms per delivery. Consolidation therefore makes home delivery more efficient. More home deliveries do not necessarily mean less efficient deliveries (Visser et al., 2014).

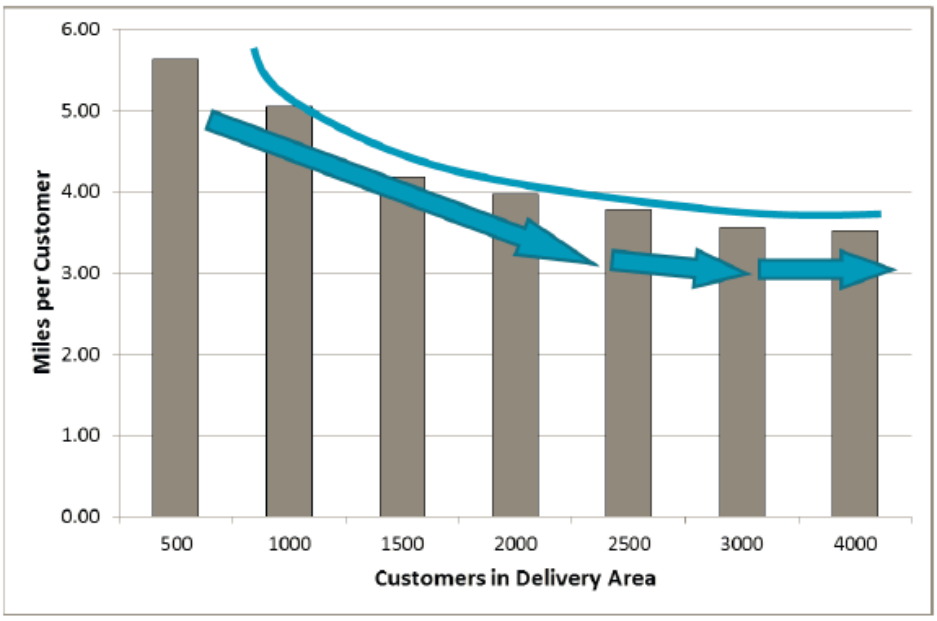


Figure II.13. The impact on customer density on the average distance per stop in miles per customer
Source: based on Boyer, Prud'Homme& Chung, 2009

II.3.2.3 Environmental impacts of delivery services are different according to the land use patterns

Delivery services offer relatively more CO_2 reduction benefit in rural areas when compared to CO_2 urban areas, and in all cases delivery services offer significant VMT reductions. Delivery services in both urban and rural areas, however, increase NOx and PM10 emissions (Goodchild, 2013).

II.3.3 Substitution between shopping trips and deliveries

II.3.3.1 Urban traffic due to e-commerce depends on the substitution between personal travels and deliveries

Cairns (1997, 1998, 2005) observed reductions in vehicle miles travelled (VMT) between 60 and 80 percent when delivery systems replaced personal travel. The Punakivi team found reductions in VMT as high as 50 to 93 percent (Punakivi and Saranen, 2001; Punakivi et al., 2001; Punakivi and Tanskanen, 2002; Siikavirta et al., 2002). Wygonik and Goodchild (2012) saw reductions of 70-95%.

Looking at personal travelling involved in shopping activities in the Netherlands between 2003 and 2010, the number of trips, total distance and average distance linked to shopping all diminished continually, before stabilizing. Since 2004, the duration of shopping trips has also decreased.

The trends visible in the Netherlands can also be observed in the results of the National Travel Surveys in England and Germany. In 2013 the average person in England made 180 shopping trips, travelling on average 769 miles. These figures are 24% and 14% lower respectively, than the same figures for 1995/97. The decrease in shopping trips has been the largest overall contributor to the 16% fall in all trips in England recorded between 1995/97 and 2013 (Francke, Visser, 2014).

II.3.3.2 The shift from personal travel to freight transport depends on the type of goods

The majority of shopping trips undertaken are for groceries. As such, e-shopping for groceries is likely to lead to a shift from personal travel to freight transportation. In a study by McKinsey and Company, 82 percent of consumers who order groceries online do it as a substitute for frequent regular trips to a grocery store, rather than substituting for infrequent trips to stock up on limited items or for special occasions (Sneader et al., 2000).

II.3.3.3 Growth in freight transport due to e-commerce depends on the level and nature of the substitution with shopping trips

Some studies suggest that e-commerce may lead to more freight trips and more kilometres mainly because e-shopping will lead to substitution of personal travel with home deliveries (Anderson et al, 2003; Cohen, 2000; Dodgson et al, 2002).

Regarding e-commerce, freight transport efficiency compared to shopping trips (and the VMT associated) depends on the extent to which the substituted personal trip was part of a chained trip, and the modal split for shopping related travel (Gärling, Ettema, Friman, 2014).

II.3.3.4 Instant deliveries will reduce shopping trips for e-grocery

Other factors negatively influencing consumers' decisions to purchase groceries online include the need or want for immediate delivery of products. So, more frequent instant deliveries will

generate higher freight traffic, but reduce individual shopping trips and thus reduce emissions as a whole.

II. 3.4 Delivery options in urban, suburban and rural areas

II.3.4.1 Potential choice of delivery options is the same in urban, suburban and rural areas

Home delivery and the PP model are used in urban, suburban and rural areas.

Rural e-consumers' accessibility to PP sites has reached a viable level. A case study in the Paris Region (Seine et Marne) shows that distances to the nearest PPs vary significantly between urban and rural areas. Nevertheless, access time to the nearest PP is the same (8 mins), by car in rural areas and by foot in urban areas (Morganti et al, 2014).

II.3.4.2 Trends for the development of delivery options depend on the land use

Home delivery services of e-grocery are more developed in urban areas with high population density than in suburban/rural area (Blanquart et al, 2015). This can be explained by the critical mass and higher purchasing power of urban customers who can afford the delivery fees.

PP location is also linked to the density of population. Urban areas have larger numbers of PPs than exurban/rural areas. Moreover, PP density in remote areas decreases faster than population density (Morganti et al, 2014). And in suburban and rural areas, PPs are more likely to be located in the centre and main commercial districts.

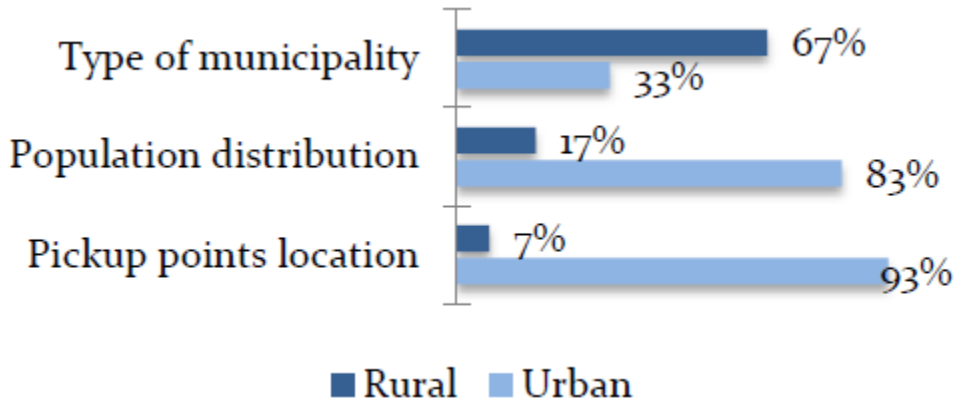


Figure II.14. Disparities between urban and rural areas (Seine et Marne, part of the Paris Region, case study)
Source: Morganti et al., 2014

The location of PPs in higher density areascan be explained by two factors: the capacity of each PP to handle a certain number of clients and the access time to PPs. To be profitable, each PP needs to have a sufficientnumber of clients but its capacity is limited. Thus, there are more PPs in urban areas than in rural areas. In exurban/rural areas, PPsaremostly located in main commercial districts with higher numbers of visitors and residents.

II.3.4.3 Preference for delivery options is different according to the land use

A case study in the Paris Region (Seine et Marne) shows that PPs are over-represented in urban areas in comparison with their share of the population. This results in a reduced accessibility to PPs for rural populations, and may contribute to explaining a marked higher preference for home deliveries in rural areas (Morganti et al, 2014).

II.3.4.4 Instant delivery will be more popular in mega cities

The competition of e-commerce in urban areas is moving to instant delivery with e-retailers proposing one-hour, two-hour, or same-day deliveries (e.g., as seen above, Amazon offering same-day delivery as well as the possibility to order more than 25,000 eligible items and get free delivery within one to two hours).

II.3.4.5 Click-and-collect grow faster than home delivery

The 'click and collect' model is expectedto become more significant in developed markets as online retail expands and consumers increasingly opt for the convenience of collection.

It has emerged as a solution for home delivery failure.

The number of click-and-collect locations in Europe was about half a million in 2015, according to Deloitte. This would be a twenty percent increase on the previous year.

Figure II.15. Click-and-collect expected increases in Europe
Source: Deloitte

For example, the volume of UK non-food sales made via the internet for collection at store will increase by 33 million parcels this year, on a par with the increase in units for home delivery at 36 million, the Financial Times reported (A. Felsted, April 21, 2014). The growth in the volume of units ordered online but collected in store is forecast to overtake that for home delivery for the first time in 2015, rising by 53 million parcels year on year.

II.3.4.6 The type of delivery solutions depends on consumers' habit

For example, collection points are particularly popular in France and Netherlands while in the UK, Germany and US home delivery is much more appreciated (Foresight, 2000, 2001; Browne, 2001; Nemoto et al., 2001; FernieandMcKinnon, 2003, 2004; McKinnonandTallam, 2003; McLeod et al., 2006; Blanquart et al, 2015).

In France, pickup points (PP) as alternatives to home delivery represent a fast-growing solution, accounting for about 20% of parcel deliveries to households (Morganti et al, 2014). The French system of point relais (reception-points) has atypical features, such as its early

development, which began 30 years ago to manage mail-order deliveries, and the large number of players, with different shareholding structures (Morganti et al, 2014).

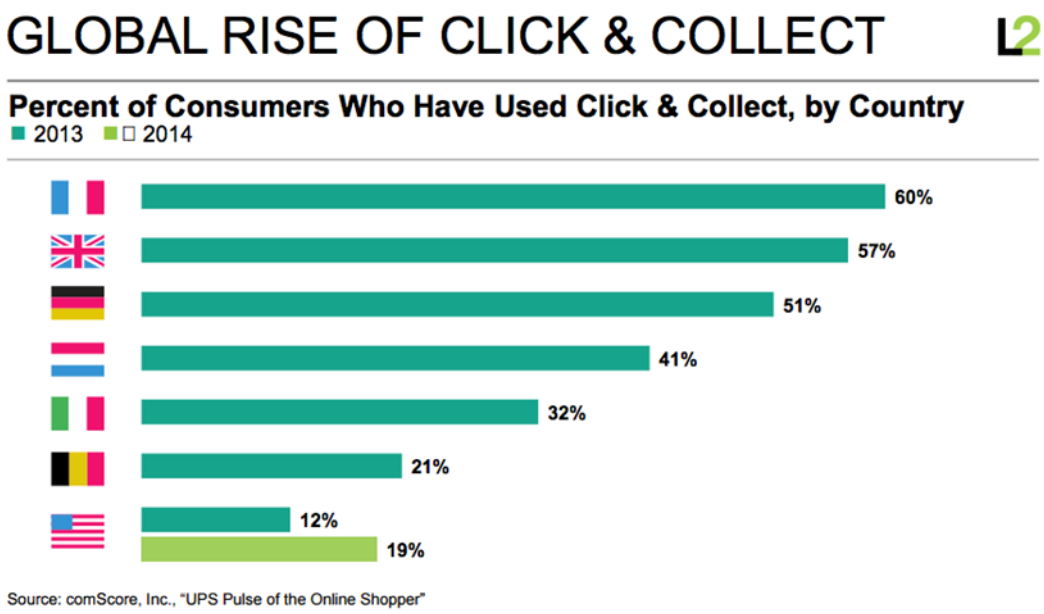


Figure II.16. Rise of click-and-collect per country
Source: comScore

II.3.4.7 More home delivery means higher failed delivery

Home deliveries raise concerns aboutthe 'not-at-home' problem, which leads to high delivery failure and empty trip rates. As home delivery increases, so does the number of failed deliveries.

Many parcels do not fit through mail boxes or require consignee signature, which implies that customers need to be at home when the parcel is delivered.

However, often consumers are not at home when a package is delivered, which leads to increased delivery cost as the packages need to be redelivered or returned to the sender.

IMRG (2006) estimated that the direct costs of failed deliveries in 2006 in the UK were €682 million.

II. 3.5 Logistics facilities for e-commerce

II.3.5.1 E-commerce leads to the rise in logistics facilities

With the rise of Ecommerce, comes the increase and need for fulfilment centres.

Amazon is also rapidly adding new fulfilment centres, as shown in figure below.

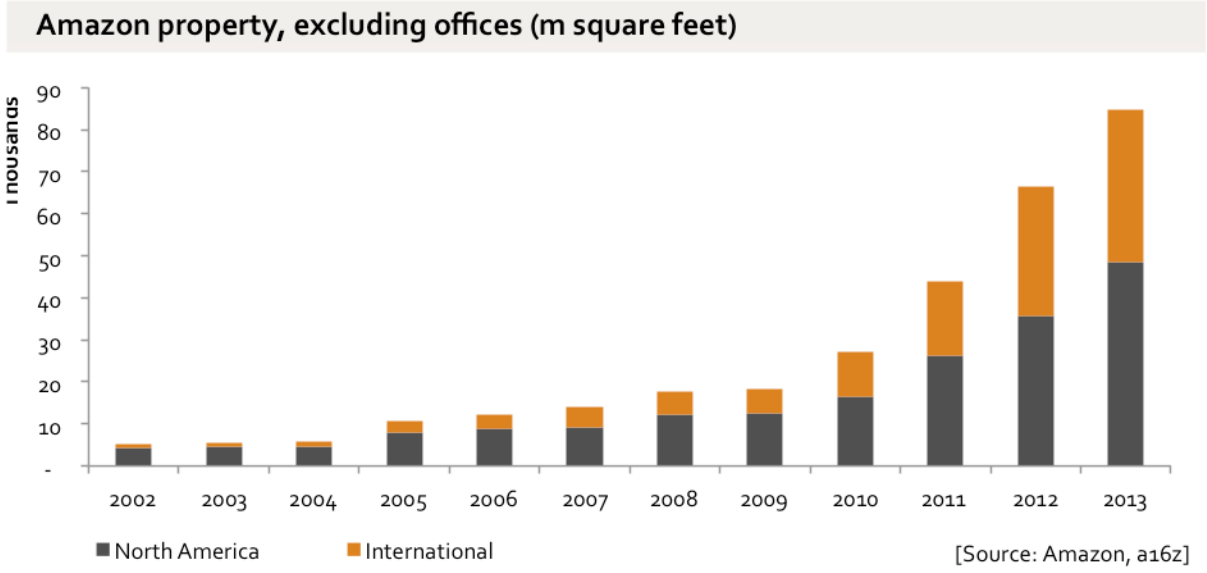


Figure II.17. Increase in Amazon properties
Source: Amazon

II.3.5.2 The location of these logistics facilities depends on their size

E-fulfilment blends with urban logistics, as these facilities will be mainly based around the major population centres where online sales densities are highest.

Local parcel delivery centres and urban logistics depots are set up at the edge of major cities and urban areas for home delivery or delivery to collection points.

Mega e-fulfilment centres are located near to parcel hubs but outside the traditional ‘centre of gravity’ and large labour supply as it requires high levels of staffing (source: JLL, 2013, E-commerce boom triggers transformation in retail logistics. Driving a global wave of demand for new logistics facilities).

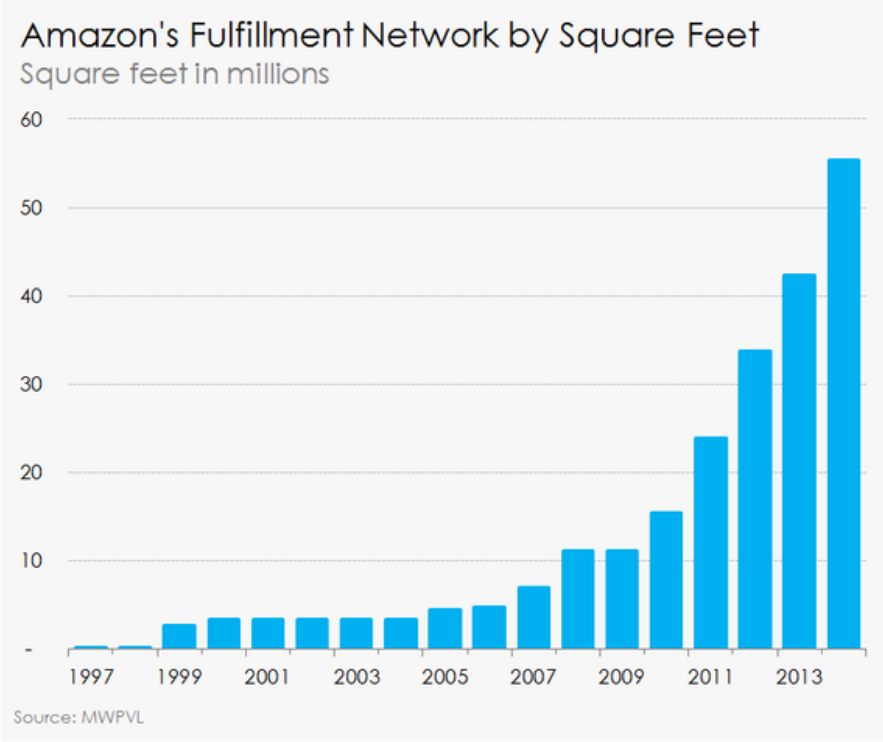


Figure II.18. Evolution of Amazon fulfilment network size
Source: MWPVL

II.3.5.3 The rise in same-day delivery leads to the increase of sortation centres close to customers

As online retail grows further, quick and save delivery of goods to consumers becomes increasingly a competitive advantage.

As a result, this will encourage some retailers to set up their own networks of local depots (Blanquart et al, 2015).

For example, in the U.S., Amazon has started to open smaller scale distribution facilities to offer same-day delivery services. In the UK, Amazon mentioned a requirement for some 20 smaller distribution facilities around major urban areas (2013 Global Retail E-Commerce Index).

With sortation centres in place, it can not only provide faster delivery to customers but also save on shipping costs.

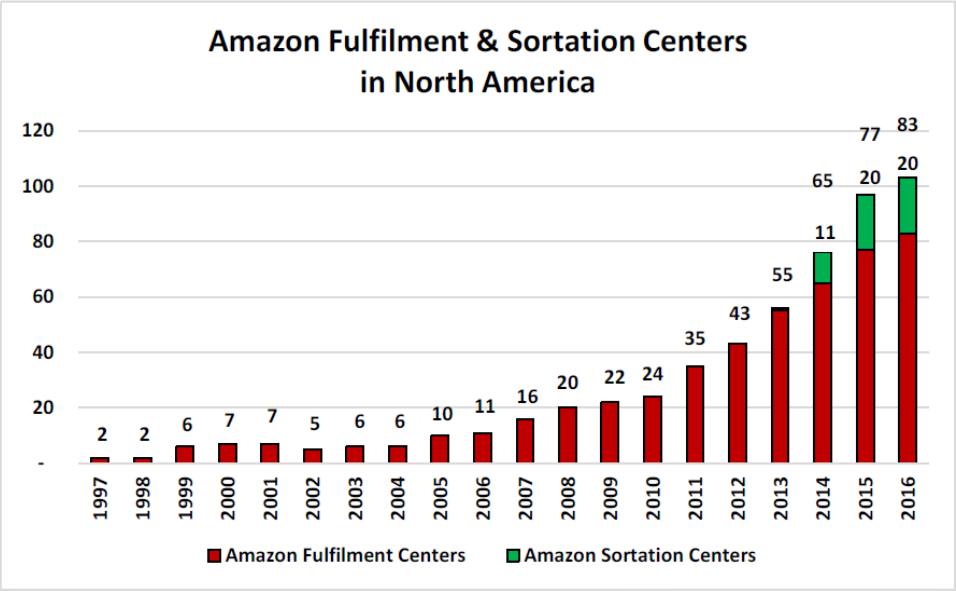


Figure II.19. Number of Amazon fulfilment and sortation centres
Source: MWPVL

Sortation centres are smaller operations that can be located beside, adjacent to, or nearby larger fulfilment centre where shipments from one or more fulfilment centres will be aggregated for delivery into a defined regional grouping of zip codes typically belonging to a nearby set of populated urban areas.

II.4 Conclusion on e-commerce

Consumption patterns as well as consumer behaviour play a decisive role in terms of urban freight transportation. E-commerce in the future will lead to even reinforced impacts for urban freight transportation. We can summarize the major trends, as follow, both in terms of freight traffic and land use.

The growth of e-commerce revenue results in higher parcels volume. But the growth rate of urban freight traffic is lower than the growth rate of e-commerce sales.

We summarize below the factors that could influence, positively or negatively, urban traffic:

Elements that could increase urban traffic	Elements that could decrease urban traffic
Instant delivery (except for grocery if previously made by car)	High population density
High return rate	High substitution with shopping trips
Low substitution with shopping trips	Rise of e-grocery (=substitution with shopping trips if previously made by car)
Many failed deliveries	Instant deliveries for e-grocery (= substitution with shopping trips if previously made by car)
	High density of pick-up points in urban centres

In terms of logistics land uses, the trends that most require observation are the following:

- Demand for pick up points in city centres
- Demand for small sortation centres close to/in urban areas for instant deliveries
- Logistic sprawl of large e-commerce fulfilment facilities.

III. General conclusion and table of impacts

III.1 General conclusions applying to logistics sprawl and e-commerce

Several conclusions can be drawn from this first version of CITYLAB's *Observatory of strategic developments impacting urban logistics*.

The first one relates to **logistics facilities**. These facilities (in their diversity: warehouses, e-commerce fulfilment centres, distribution centres, cross-dock terminals) are increasing in cities, especially cities of some logistics importance as large consumer markets and/or logistics hubs processing the flow of goods generated by the global economy.

These facilities are generally located in suburban areas, but a new **niche market of urban warehouses** is emerging.

Another conclusion that can be made following the analysis of logistics sprawl and e-commerce is that there isa potential risk in an **increase in freight vehicles in urban areas**, increasingly dominated by small-sized vehicles, while medium to large lorries will become relatively less important. These vehicles performing delivery operations are visible in neighbourhoods and at times of day when they were not identified before: residential neighbourhoods, residential building blocks, side streets, in the early evening and on week-ends. Emerging **new types of vehicles** (clean delivery vehicles, two and three wheelers) are now visible in urban centres.

Innovations in the urban supply chains also include diverse forms of pick-up points and click-and-collect solutions, while the recent but extremely rapid rise in technologies and algorithms supporting **instant deliveries** brings with it a flourish of new companies connecting customers, suppliers and independent messengers.

The overall impact of these new trends on energy and carbon emission related to urban freight is difficult to assess. Some trends bring **higher CO_2 emissions**, such as the relocation of logistics facilities far away in the suburbs, as deconsolidated shipments are delivered to urban consumers and businesses in smaller and more numerous vans. Some trends bring**lowerCO_2 emissions**, with a rise in cleaner vehicles and innovative solutions such as drop-off/pick-up points. Substitution patterns between personal mobility and professional freight mobility can be a good, or a bad, thing for CO_2emissions, depending on the initial circumstances and the way personal shopping was done before online orders.

What is certain is that these changes bring **diversity in the urban traffic flow**. Instant messengers are using all sorts of transport modes, including foot, bicycles, electrically-assisted cargocycles, motorbikes, and various types of vans and lorries. This can negatively impact **traffic management, road safety and conflicts of road uses, congestion, air pollution**. Also, the trends we have looked at bring **new types of urban jobs**, with many unresolved legal issues and poor working conditions in many instances. New types of logistics buildings bring architectural diversity and innovation in cities, but also complaints about **noise, aesthetics,** as well as congestion and pollution at entrance and exit points.

These environmental and social impacts have been so far poorly documented and researched. Consumers are the main drivers of the changes we have observed, but they are also the residents or visitors of urban areas, and for that they carry an important share of the **burdens, as well as the benefits, of the new landscape of urban logistics**.

In order to better understand the different impacts that logistics sprawl and e-commerce can have on different stakeholders and activities in the future, we have drawn an Impact Table

looking at various stakeholders, activities and places impacted by new trends and challenges. This Table is shown in the next sub-section.

III.2 Impact Table: impacts of new trends on urban freight mobility and city life

	Logistics Sprawl	E-commerce
Impacts for stakeholders		
City managers (urban planning)	Broader commitment required on logistics regional planning and land use control New thinking about urban warehouses	New thinking (architecture, zoning, economics) about urban e-commerce fulfilment terminals Promote the development of alternative ways to deliver goods (collective parcel boxes in apartment buildings, pickup points, etc.) Consider the urban mobility of goods in urban planning Create database to analyse e-commerce movements
City managers (transport)	Expect increased van traffic on city streets Promote urban warehouses to promote more consolidation and shorter last mile trips	Diversity of residential deliveries bringing increased diversity of last mile vehicles, modes, time windows Providing for infrastructure to accommodate new types of urban deliveries (bike lanes, charging stations for CNG/electric vans and trucks)
City managers (elected officials)	Logistics activities and warehouses becoming part of the political agenda because of links between smart cities, urban sustainability, urban food policies, circular economy.	Logistics activities becoming part of the political agenda because of links between smart cities, urban sustainability, new consumption trends
Metro/regional managers	Expect more trucks and vans on regional highways Regional planning for logistics facilities and freight infrastructure becoming an issue on the political and technical agenda Small suburban communities dealing with large developers for giant warehouses/logistics parks Regional multimodal infrastructure for freight may become a strategic item	Regional planning for e-commerce logistics facilities becoming an issue on the political and technical agenda Small suburban communities dealing with large developers for giant e-commerce fulfilment centres/logistics parks
Transport companies (small)	Increased distance travelled (and associated costs) between freight terminals where shipments are picked (or delivered), and urban areas where shipments are delivered (or picked)	New markets for urban deliveries - need to assess costs and benefits of residential deliveries Increased competition from independent messengers connecting to instant delivery apps
Transport companies (large)	Increased distance travelled (and associated costs) between freight terminals where shipments are picked. This may deter large	New markets for urban deliveries - need to assess costs and benefits of residential deliveries

	transport companies to operate urban deliveries, outsourcing to smaller transport operators. Large transport companies may be interested in more urban warehouses if access to cities becomes more complicated.	Explore opportunities to promote unattended deliveries and consolidated deliveries at pickup points
Shippers (own account deliveries)	Suburban locations bring benefits in terms of size and national networks connectivity but urban deliveries generate more vehicle-kilometres and associated costs. Overall carbon footprint can worsen. May require eventually to outsource urban transport	The increase in home deliveries will make it important for e-retailers (acting as shippers in this case) eager to develop this market to their customers to out-source deliveries to an adequate urban logistics provider.
Shippers (third party deliveries)	Suburban locations bring benefits in terms of size and national networks connectivity	The increase in home deliveries will make it important for e-retailers (acting as shippers in this case) eager to develop this market to their customers to find adequate urban logistics providers able to develop innovative urban logistics services
Receivers (own account deliveries)	Store supplies will generate more vehicle-kilometres and associated costs To find a solution to increased costs, receivers may need to turn to out-sourced delivery providers, or increase their inventory in the store to reduce the frequency of deliveries.	The increase in home deliveries will make it important for urban store owners eager to home-deliver their customers to out-source deliveries to an adequate urban logistics provider.
Receivers (third party deliveries)	May bring less reliability on deliveries May bring higher costs (unlikely)	The increase in home deliveries will make it important for urban store owners eager to develop home deliveries towards their customers to out-source deliveries to an adequate urban logistics provider. They may look for providers able to develop innovative urban logistics services
Real estate developers	Need to have a close overview of the evolution of land availability in the region May need to think about implementing freight villages and multi-story logistics facilities in suburban communities	Accommodation of large e-commerce fulfilment centres in metropolitan areas Need to have a close overview of the evolution of land availability in the region New urban warehouse markets?
Other stakeholders	Public authorities and agencies (rail infrastructure managers, Department of Defence, airport authorities, utilities…), may be owners of large land parcels in urban areas that can be converted into urban logistics facilities.	Alternative delivery solutions such as pickup points need to be further embraced by final consumers as a mean to alleviate impacts of residential deliveries on the urban environment and last mile transport efficiency. Consumers must be aware of impacts on

	Industrial brownfields – new commercial brownfields – logistics brownfields	working conditions, road safety, of on-demand transport and instant deliveries.
Impacts on the urban environment		
Local air pollutants (PM and NOx)	Expected increase in PM and NOx emissions due to increased van and truck-kilometres	E-commerce deliveries have contradicting impacts on local air quality. They can bring an increase in/a decrease in PM and NOx emissions depending on start conditions, type of city, type and location of consumer. Increased biking can reduce local air pollutants from e-commerce.
CO2 emissions	Expected increase in CO_2 due to increased van and truck-kilometres	E-commerce deliveries have contradicting impacts on CO_2 emissions. They can bring an increase in/a decrease in CO_2 emissions depending on start conditions, type of city, type and location of consumer. Increased biking can reduce carbon footprint of e-commerce.
Traffic/congestion	Expected increase in traffic due to increased van and truck-kilometres	Increased biking can increase heterogeneity of traffic in city streets: usually leads to more congestion, or could participate in the general trend towards deterring car use in city streets Demand for non-traditional delivery times (evenings, week-ends) increases Land use patterns influence the characteristics of urban freight traffic for home deliveries
Road safety/conflicts of street use	Expected increase in road safety problems due to increased van traffic	Increased biking for deliveries can increase the conflicts of street uses
Noise emissions	Expected increase in noise emissions due to increased van and truck-kilometres	E-commerce deliveries have contradicting impacts on noise emissions. They can bring an increase in/a decrease in noise emissions depending on start conditions, type of city, type and location of consumer. Increased biking for e-deliveries can reduce noise.
Quality of life, local street life	Expected increase in van and truck-kilometres	Less local stores as competition from e-retailers increases (does not apply to e-grocery). However, e-commerce also leads to the introduction of new types of stores (Amazon bookstores/pick-up points)
Impacts on the regional environment		
CO2 emissions	Expected increase in CO_2 emissions due to increased van	E-commerce deliveries have contradicting impacts on CO_2 emissions at a regional scale.

	and truck-kilometres on the regional network	They can bring an increase in/a decrease in CO_2 emissions depending on start conditions, type of city, type and location of consumer. The decentralization of e-commerce fulfilment centres in suburban areas brings additional truck-kilometres (therefore CO_2 emissions) within the region.
Traffic/congestion	Expected increase in van and truck-kilometres on the regional network	The decentralization of e-commerce fulfilment centres in suburban areas brings additional truck-kilometres (and associated potential congestion) within the region.
Multimodal infrastructure	In the future, logistics sprawl can stimulate the use of multimodal freight hubs if logistics sprawl goes together with clustering of large logistics facilities around suburban logistics parks New urban logistics hotels can be promoted around rail or waterway access (e.g. Chapelle International logistics hotel)	
Impacts on urban freight efficiency		
Costs for last mile deliveries	Logistics sprawl increases last mile average distances, which can have contradicting effects on regional transport companies	Residential deliveries are complicated and costly Need for alternative solutions leading to consolidation of deliveries in order to decrease costs
Shipments consolidation	Logistics sprawl in the future can stimulate the use of freight hubs facilitating shipment consolidation, if logistics sprawl goes together with clustering of large logistics facilities around suburban logistics parks New urban logistics hotels can be promoted around shipment consolidation closer to the city centre (e.g. Chapelle International logistics hotel)	Residential deliveries are poorly consolidated. Alternative solutions for e-deliveries (pickup points, click-and-collect) can promote shipments consolidation and reduce transportation costs and CO_2 impacts.
Innovation in city logistics	Promotion of innovative behaviours for urban warehouses, such as logistics hotels	E-commerce deliveries appear to be one of the main drivers for innovations in sustainable city logistics services. Many start-ups are emerging, while large players have developed special operations for urban areas (clean vehicles, alternative modes, urban warehouses, instant delivery apps).
Impacts on working conditions and legislation		

Local transport companies, owner-drivers, independent messengers	Logistics sprawl increases last mile average distances and changes the way last mile operators (often sub-contractors) organise their activities.	Potentially dangerous driving behaviour as pay is often linked to number of trips (motor bikes, bicycles) On-demand transport services and instant delivery apps: unstable status of worker/employee Labour laws will have to adapt to rising on-demand transport services.
Employees of transport companies	Logistics sprawl increases last mile average distances and changes the way last mile operations are organised	Work on Sunday and/or at night can be a problem in some countries
Transport and logistics companies	Logistics sprawl increases last mile average distances and changes the way last mile operations are organised	Potential unfair competition from on-demand transport services and instant delivery apps.

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V. Appendices

Appendix 1. Table of logistics sprawl indicators

Name and size of studied metro area	Amster-dam 4,092 km2	Atlanta 21,700 km2	Belo Horizonte 331 km2	Berlin 3,778 km2	Gothen-burg (metro) 3,695 km2	Gothen-burg (region) 22,752 km2	L.A. 87,940 km2	Paris 1 (all WHs) 12,058 km2	Paris 2 (parcel/ express) 12,058 km2	Randstad 14,668 km2	Rotterdam 3,418 km2	Seattle 15,209 km2	Tokyo 14,034 km2	Toronto GTA 7,124 km2	Toronto GGH 31,562 km2
Type of metropolitan area	Mono	Mono	Mono	Poly	Mono	Mono	Poly/Mega	Mono	Mono	Poly/Mega	Mono	Mono	Mono/Poly	Mono	Mono
Population (millions – most recent year)	2.7	5	2.5	4.3	0.97	1.6	18.5	11.8	11.8	8.6	3.6	3.5	34.5	6.1	8.7
Population density Inhab/km2	591	230	849	1,150	263.5	69	210	977	977	586	1,043	230	1,971	849	276
Name of warehouse data source and brief description	NACE 52.1	NAICS 493	CMC-CNAE	Own	SBC	SBC	NAICS 493	NACE 52.1	Own collection from yellow pages	NACE 52.1	NACE 52.1	NAICS 493	TMFS WH>400m 2 and away from coast	EPOI (NAICS 493 “cleaned”)	EPOI (NAICS 493 “cleaned”)
Number of warehouses (most recent year)	278	401	54	22 (focused study)	205	382	946	955	90	631	185	212	209	228	350
Number of warehouses per million people (most recent year)	102.5	77	22	5	199.5	236	51	81		73	52	61	6.1	37.7	40.2
% change per year in number of WH per million people	-2.17%	Not calculated	20%		3.4%			+2%		-0.77%	+1.1%	+19%	-18%	3.4%	
Number of warehouses per 1000 km2 (most recent year)	68	15	163	6	76	17	11	79		43.2	54.1	14	15	32	
Average size of warehouses	na	na	1,548m2	na	na	na	na	na	na	na	na	na	na	na	na
Time period studied for logistics sprawl analysis	2007-2013	1998-2008	1994-2014	1994-2004	2000-2014	2000-2014	1998-2009	2000-2012	1976-2010	2007-2013	2007-2013	1998-2009	1980-2003	2002-2012	2002-2012
Average distance of warehouses to centre of gravity (most recent year) (km)	19.6	33	3.3	16	13	82	51	21	18.1	Not calculated		19.3	30.7	17.9	39.1
Change in average	-2	4.55	-0.92	4	4.2	2.7	9.7	3.5	11.8	Not calculated		-1.3	4.2	1.2	9.5

distance of WHs to centre of gravity (over the years) (km)															
Change in average distance of WHs to centre of gravity per year (km/year)	-0.33	0.45	-0.05	0.2	0.3	0.19	0.88	0.29	0.33	Not calculated		-0.12	0.18	0.12	0.95
Cluster indicator	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
Type of land use control	regional	local	none	local	metropo-litan		local	local	local	regional		regional	local	regional	regional

Appendix 2. Logistics sprawl case studies

I.6.1 Amsterdam, The Netherlands

Name and size of studied metropolitan area

Amsterdam Metropolitan Area: Noord Holland province (4,092 km^2)

53 municipalities

Type of metropolitan area

Monocentric or rather monocentric ☒

Polycentric or rather polycentric ☐

Megaregion ☐

Population (2014)

2014: 2 713 780

2007: 2 613 070

2000: 2 420 402

Population density (2014)

591.5 /km^2

Name of warehouse data source and brief description

NACE 52.1

The Statistical Classification of Economic Activities in the European Community, commonly referred to as NACE, is the industry standard classification system used in the European Union. The current version is revision 2 and was established by Regulation (EC) No 1893/2006. It is the European implementation of the UN classification ISIC, revision 4.NACE is similar in function to the SIC and NAICS systems.

This item includes: This class includes:
- operation of storage and warehouse facilities for all kinds of goods:
- operation of grain silos, general merchandise warehouses, refrigerated warehouses, storage tanks etc.

This item also includes: This class also includes:
- storage of goods in foreign trade zones
- blast freezing

This item excludes: This class excludes:
- parking facilities for motor vehicles, see 52.21
- operation of self-storage facilities, see 68.20
- rental of vacant space, see 68.20

Number of warehouses(specify year(s))

2007: 318

2013: 278

Number of warehouses per million people (specify year(s))

2007: 117.2

2013: 102.5

Less warehouses per/people reflect an increase of population.

Number of warehouses per 1000 km^2 (specify year(s))

2007: 77.8

2013: 68

Average size of warehouses (specify year(s)); can be any indicator such as m^2, m^3 or number of employees

No information

Time period studied for logistics sprawl analysis

2007-2013

Average distance of warehouses to centre of gravity (most recent year)(NB this doesn't apply to megaregional types of urban regions)

2007: 21.6 km

2013: 19.6 km

Change in average distance of warehouses to centre of gravity (over the years)

-2km

Cluster indicator

Warehouses are mainly concentrated in the municipality of Amsterdam with 31% of the total number of the warehouses. The second major concentration is in Zaanstad with 16.2% of the total number of warehouses).

Type of land use control

Strictly local ☐

Some sort of metropolitan-wide land use control ☐

Some sort of region-wide (or state-wide) land use control ☒

Other comments/information

While the number of warehouses is decreasing between 2007 and 2013 in the Noord Holland, the warehouses are more concentrated, especially in municipality like Zaanstad, so there is no dispersion of the logistics activities. We can make the hypothesis that the logistics activities have been spatially reorganized and clustered just outside Amsterdam.

Scientific or technical references

Heitz A., Dablanc L., Tavasszy L. (2016a), Logistics sprawl in monocentric and polycentric metropolitan areas: the case of Paris, France and the Randstad, submitted to the WCTRS Shanghai 2016.

I.6.2 Atlanta, USA

Name and size of studied metropolitan area

Atlanta Metropolitan Area (21,694 km^2)

110 municipalities

Type of metropolitan area

Monocentric or rather monocentric ☑

Polycentric or rather polycentric ☐

Megaregion ☐

Population

2012: 5 million

Population density

230/km^2

Name of warehouse data source and brief description

US Census Bureau County Business Patterns Survey, category 493 (Warehouse & Storage) of NAICS (North American Industrial Classification System)

"Warehouse" defined as: "Industries in the Warehousing and Storage subsector are primarily engaged in operating warehousing and storage facilities for general merchandise, refrigerated goods, and other warehouse products. These establishments provide facilities to store goods. They do not sell the goods they handle. These establishments take responsibility for storing the goods and keeping them secure. They may also provide a range of services, often referred to as logistics services, related to the distribution of goods. Logistics services can include labelling, breaking bulk, inventory control and management, light assembly, order entry and fulfilment, packaging, pick and pack, price marking and ticketing, and transportation arrangement. However, establishments in this industry group always provide warehousing or storage services in addition to any logistic services. Furthermore, the warehousing or storage of goods must be more than incidental to the performance of services, such as price marking." (NAICS)

US Census Bureau County Business Patterns Survey provides an analysis of the number of establishments in all the counties and zip codes in the United States based on a detailed breakdown of industrial sectors and according to nine employment-size classes.

Number of warehouses (specify year(s))

1998: 132

2008: 401

Number of warehouses per million people (specify year(s)))

2008:77.1

Number of warehouses per 1000 km^2 (specify year(s))

2008: 14.75

Average size of warehouses (specify year(s)); can be any indicator such as m^2, m^3 or number of employees

Not calculated

Time period studied for logistics sprawl analysis

1998-2008

Average distance of warehouses to centre of gravity (most recent year) (**NB this doesn't apply to megaregional types of urban regions)**

33.15 km

Change in average distance of warehouses to centre of gravity (over the years)

+4.55 km

Change in average distance of warehouses to centre of gravity per year

0.45 km/year

Cluster indicator

Not available.

Type of land use control

Strictly local ☑

Some sort of metropolitan-wide land use control ☐

Some sort of region-wide (or state-wide) land use control ☐

Other comments/information

The average distance to the barycentre for all establishments increased by 2.1 km, from 25 km in 1998 to 27 km in 2008: ''relative sprawl'' in Atlanta Metropolitan Area.

Scientific or technical references

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

I.6.3 Belo Horizonte, Brazil

Name and size of studied metropolitan area

Belo Horizonte 331.4 km^2

(N.B. This study only considers the area of the city of Belo Horizonte – an additional study will consider the whole metropolitan area – ongoing. The Belo Horizonte Metropolitan Area (9,471.7km^2) represents 34 municipalities)

Type of metropolitan area

Monocentric or rather monocentric ☑

Polycentric or rather polycentric ☐

Megaregion ☐

Population

(2015) Belo Horizonte Metropolitan Area: 5.239 million

(2015) Belo Horizonte: 2.502 million

Population density

849.2/km^2

Name of warehouse data source and brief description

Municipal Register of Taxpayers Dataset (CMC)

National Classification of Economic Activities (CNAE) and economic activities related to warehouse (5250-8/05 –Multimodal transport operator; 5211-7/01 –Warehouse and 5211-7/99 – Warehouse To Third Parties).

Number of warehouses(specify year(s))

1994: 11

2014: 54

Number of warehouses per million people (specify year(s))

1994: 5.5

2014:21.6

Number of warehouses per 1000 km^2 (specify year(s))

1994: 33.19

2014: 162.65

Average size of warehouses (specify year(s)); can be any indicator such as m^2, m^3 or number of employees

1994: 2,073m^2

2014: 1,548 m^2

Time period studied for logistics sprawl analysis

1994-2014

Average distance of warehouses to centre of gravity (most recent year)(NB this doesn't apply to megaregional types of urban regions)

3.3 km

Change in average distance of warehouses to centre of gravity (over the years)

-0.92km

Cluster indicator

No cluster.

Type of land use control

Strictly local ☐

Some sort of metropolitan-wide land use control ☐

Some sort of region-wide (or state-wide) land use control ☐

Other comments/information

This analysis only considers Belo Horizonte city.

No land use control in Belo Horizonte.

Scientific or technical references

Oliveira, L. K., Santos, O. R., Nóbrega, R. A. A.(2016) The geography of warehousing in Belo Horizonte (Brazil). Proposed at WCTR 2016, Shanghai (China).

I.6.4 Berlin, Germany

Name and size of studied metropolitan area, number of municipalities

Berlin (891 km²) and surrounding municipalities of Brandenburg (in sum 3,778 km²)

Berlin has one municipality, 51 municipalities in the surrounding area of Brandenburg

Type of metropolitan area

- Monocentric or rather monocentric ☐
- Polycentric or rather polycentric ☑
- Megaregion ☐

Population

2014: 4.3 million (incl. 3.4 for Berlin)

Population density

Berlin: 3,840/km^2

Whole study area: 1,150 /km²

Name of warehouse data source and brief description

DLR (German Aerospace Centre) own data source of general cargo hubs in Germany, locations of 14 general cargo company networks in Germany

General cargo or break bulk cargo goods are goods that are loaded individually and not in one intermodal transport container. General cargo in road transport is also known as groupage, packaged goods, and piece goods. In road transport general cargo is typically shipped through networks of forwarding companies. In these networks for general cargo, the hubs are locations of forwarding companies. At these locations, goods are loaded and unloaded between lorries in the main run and lorries in pick-up and delivery-runs. There are currently (2015) 14 logistics networks for general cargo in Germany, each with locations in or close to Berlin. Altogether the general cargo networks in Germany serve 943 locations.

Number of warehouses (specify year(s))

Year 1994: 18 (general cargo networks only)

Year 2004: 19 (general cargo networks only)

Year 2014: 22 (general cargo networks only)

Number of warehouses per million people (specify year(s))

Year 2014: 5.0

Number of warehouses per 1000 km^2 (specify year(s))

Year 2014: 5.8

Average size of warehouses (specify year(s)); can be any indicator such as m^2, m^3 or number of employees

Not calculated

Time period studied for logistics sprawl analysis

1994-2004-2014

Average distance of warehouses to centre of gravity (most recent year) (NB this doesn't apply to megaregional types of urban regions)

15.7 km

Change in average distance of warehouses to centre of gravity (over the years)

+4.0 km (1994-2014)

Change in average distance of warehouses to centre of gravity per year

0.2 km/year

Cluster indicator

Not analysed

Type of land use control

- Strictly local ☑
- Some sort of metropolitan-wide land use control ☐
- Some sort of region-wide (or state-wide) land use control ☐

Other comments/information

Further indicators analysed:

- shift of barycentre
- logistics employment
- population development

The change in location for the general cargo hubs has been traced individually. Thirteen expert interviews on the reason for relocation were conducted.

Scientific or technical references

Klauenberg, J., Elsner, L.-A., Knischewski, Chr. (2016) Dynamics in the spatial distribution of general cargo hubs – the case of Berlin. *World Conference on Transport Research Submitted to WCTR 2016 Shanghai*.

I.6.5 Gothenburg metro, Sweden

Name and size of studied metropolitan area

Gothenburg Metropolitan Area (3694.86km^2)

12 municipalities

Type of metropolitan area

Monocentric or rather monocentric ☒

Polycentric or rather polycentric ☐

Megaregion ☐

Population (2014)

2014: 973 261

Population density (2014)

263.5 /km^2

Name of warehouse data source and brief description

Using the NACE code 52.1 from the SCB database was not relevant for the Gothenburg case, because we count only 51 warehouses in 2013 in this database so we used another method.

In order to measure the location of the warehouses, we used a database containing economic establishments of Sweden, with NACE codes, provided by SCB (*Statistiskacentralbyrån)*, providing exact addresses. This allowed us to geocode the establishments precisely, using a GIS system.

We cleaned the database to retain only actual logistics activities (some establishments, which are noted as logistics establishments, have no logistics activities whatsoever, such as company headquarters, or passenger transportation establishments). A number of filters were implemented.

The most important work was to gather information through the observation of satellite images of the addresses noted in the SCB database. Sometimes, observation of street photographs was also useful. We have checked for the morphology of the building, the

The logistics sprawl indicator has been weighted by the number of employees.

Number of warehouses (specify year(s))

2000: 138

2014: 205

Number of warehouses per million people (specify year(s))

2000: 134.4

2014: 199.5

Number of warehouses per 1000 km^2 (specify year(s))

2000: 51

2014: 75.8

Average size of warehouses (specify year(s)); can be any indicator such as m^2, m^3 or number of employees

Code	Class Employees	Number of warehouses in 2014
1	0	5
2	1-4	12
3	5-9	36
4	10-19	66
5	20-49	46
6	50-99	24
7	100-199	7
8	200-499	7
9	500-999	1
10	1000-1499	1
11	1500-1999	0
12	2000-2999	0
13	3000-3999	0
14	4000-4999	0
15	5000-9999	0
16	10000	0

Time period studied for logistics sprawl analysis

2000-2014

Average distance of warehouses to centre of gravity (most recent year) (**NB this doesn't apply to megaregional types of urban regions)**

2000: 9.1 km

2014: 13.3 km

Change in average distance of warehouses to centre of gravity (over the years)

+4.2 km (+46.2%)

Change in average distance of warehouses to centre of gravity per year

0.3 km/year

Cluster indicator

There is a clustering, and increased concentration of warehousing activity in the Gothenburg region.

Type of land use control

Strictly local	☐
Some sort of metropolitan-wide land use control	☒
Some sort of region-wide (or state-wide) land use control	☐

Other comments/information

Scientific or technical references

Heitz A., Dablanc L., Olsson J., Woxenius Y. (2016) *Logistics sprawl patterns in Gothenburg, Sweden*, Submitted to World Conference on Transport Research, Shanghai, China.

I.6.6 Gothenburg region, Sweden

Name and size of studied metropolitan area

Västra Götalands County (Gothenburg region)
22,752 km^2

48 municipalities

Type of metropolitan area

Monocentric or rather monocentric ☒

Polycentric or rather polycentric ☐

Megaregion ☐

Population (2014)

2014: 1.6 million

Population density (2014)

68.58 /km^2

Name of warehouse data source and brief description

Using the NACE code 52.1 from the SCB database was not relevant for the Gothenburg case, because we count only 51 warehouses in 2013 in this database so we used another method.

In order to measure the location of the warehouses, we used a database containing economic establishments of Sweden, with NACE codes, provided by SCB (*Statistiskacentralbyrån)*, providing exact addresses. This allowed us to geocode the establishments precisely, using a GIS system.

We cleaned the database to retain only actual logistics activities (some establishments, which are noted as logistics establishments, have no logistics activities whatsoever, such as company headquarters, or passenger transportation establishments). A number of filters were implemented.

The most important work was to gather information through the observation of satellite images of the addresses noted in the SCB database. Sometimes, observation of street photographs was also useful. We have checked for the morphology of the building, the

Number of warehouses (specify year(s))

2000: 263

2014: 382

Number of warehouses per million people (specify year(s))

2000: 224

2014: 236.5

Number of warehouses per 1000 km^2 (specify year(s))

2000: 11.4

2014: 16.6

Average size of warehouses (specify year(s)); can be any indicator such as m^2, m^3 or number of employees

Code	Class Employees	Number of warehouses
1	0	12
2	1-4	21
3	5-9	86
4	10-19	113
5	20-49	85
6	50-99	40
7	100-199	10
8	200-499	9
9	500-999	1
10	1000-1499	1
11	1500-1999	0
12	2000-2999	0
13	3000-3999	0
14	4000-4999	0
15	5000-9999	0
16	10000	0

Time period studied for logistics sprawl analysis

2000-2014

Average distance of warehouses to centre of gravity (most recent year) (**NB this doesn't apply to megaregional types of urban regions)**

2000: 79.3 km

2014: 82 km

Change in average distance of warehouses to centre of gravity (over the years)

+2.7 km

Change in average distance of warehouses to centre of gravity per year

0.19 km/year

Cluster indicator

There is a clustering, and increased concentration of warehousing activity in the Gothenburg region.

Type of land use control

Strictly local ☐

Some sort of metropolitan-wide land use control ☐

Some sort of region-wide (or state-wide) land use control ☐

Other comments/information

The presence of the port located in Gothenburg is an important factor in keeping a low sprawl indicator, as terminals over time have concentrated in the vicinity of the port.

Scientific or technical references

Heitz A., Dablanc L., Olsson J., Woxenius Y. (2016a) Logistics sprawl patterns in Gothenburg, Sweden, proposed at World Conference on Transport Research, Shanghai, China.

I.6.7 Los Angeles, USA

Name and size of studied metropolitan area

Los Angeles Combined Statistical Area (87,940 km^2)

185 municipalities

Type of metropolitan area

Monocentric or rather monocentric ☐

Polycentric or rather polycentric ☑

Megaregion ☑

Population

2014: 18.5 million

Population density

210/km^2

Name of warehouse data source and brief description

County Business Patterns, category 493 (Warehouse & Storage) of NAICS (North American Industrial Classification System)

"Warehouse" defined as: "Industries in the Warehousing and Storage subsector are primarily engaged in operating warehousing and storage facilities for general merchandise, refrigerated goods, and other warehouse products. These establishments provide facilities to store goods. They do not sell the goods they handle. These establishments take responsibility for storing the goods and keeping them secure. They may also provide a range of services, often referred to as logistics services, related to the distribution of goods. Logistics services can include labelling, breaking bulk, inventory control and management, light assembly, order entry and fulfilment, packaging, pick and pack, price marking and ticketing, and transportation arrangement. However, establishments in this industry group always provide warehousing or storage services in addition to any logistic services. Furthermore, the warehousing or storage of goods must be more than incidental to the performance of services, such as price marking." (NAICS)

Number of warehouses (specify year(s))

1998: 220

2013: 946

Number of warehouses per million people (specify year(s))

1998: 13.4

2013: 51

Number of warehouses per 1000 km^2 (specify year(s))

1998: 2.5

2013: 10.7

Average size of warehouses (specify year(s)); can be any indicator such as m^2, m^3 or number of employees

Not calculated

Time period studied for logistics sprawl analysis

1998-2009

Average distance of warehouses to centre of gravity (most recent year) (**NB this doesn't apply to megaregional types of urban regions**)

51.4 km

Change in average distance of warehouses to centre of gravity (over the years)

+9.7 km

Change in average distance of warehouses to centre of gravity per year

0.88 km/year

Cluster indicator

None available

Type of land use control

Strictly local ☑

Some sort of metropolitan-wide land use control ☐

Some sort of region-wide (or state-wide) land use control ☐

Other comments/information

Logistics sprawl has been compared with sprawl of economic activities in general. Average distance of all establishments from their barycentre remained stable, changing from 41.748 to 41.714 miles. Showing a huge discrepancy: LS indicator much higher, while the indicator for economic activities is very stable overtime.

Scientific or technical references

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

I.6.8 Paris, France - all warehouses

Name and size of studied metropolitan area

Paris Region (Ile-de-France)

12 058 km^2

1300 municipalities

Type of metropolitan area

Monocentric or rather monocentric ☒

Polycentric or rather polycentric ☐

Megaregion ☐

Population (2014)

2014: 11 786 400

Population density (2014)

977.5/km^2

Name of warehouse data source and brief description

NACE 52.1 Warehouse and Storage

The Statistical Classification of Economic Activities in the European Community, commonly referred to as NACE, is the industry standard classification system used in the European Union. The current version is revision 2 and was established by Regulation (EC) No 1893/2006. It is the European implementation of the UN classification ISIC, revision 4.NACE is similar in function to the SIC and NAICS systems.

This item includes: This class includes:
- operation of storage and warehouse facilities for all kinds of goods:
- operation of grain silos, general merchandise warehouses, refrigerated warehouses, storage tanks etc.

This item also includes: This class also includes:
- storage of goods in foreign trade zones
- blast freezing

This item excludes: This class excludes:
- parking facilities for motor vehicles, see 52.21
- operation of self-storage facilities, see 68.20
- rental of vacant space, see 68.20

Number of warehouses(specify year(s))

2000: 714

2012: 955

Number of warehouses per million people (specify year(s))

2000: 65

2012: 81

Number of warehouses per 1000 km^2 (specify year(s))

2000: 59

2012: 79

Average size of warehouses (specify year(s)); can be any indicator such as m^2, m^3 or number of employees

Forthcoming information

According to DRIEA (2009), about 20% of the warehouses in the Paris region are less than 500m².

Time period studied for logistics sprawl analysis

2000-2012

Average distance of warehouses to centre of gravity (most recent year)(NB this doesn't apply to megaregional types of urban regions)

2000: 17.5 km

2012: 21 km

Change in average distance of warehouses to centre of gravity (over the years)

+3.5 km

Change in average distance of warehouses to centre of gravity per year (km/year)

0.29

Cluster indicator

In general, the Paris region consists of a constellation of medium-sized specialized logistics clusters. The development of medium-sized concentrated clusters in the west increases in proportion. In the east, we can observe the movement of successive fronts of medium-sized clusters which push metropolitan boundaries ever further outwards. In 2000 and 2012 we can observe two moving clusters to the north and to the south of Paris, in the inner suburban ring where warehousing activities seem to be particularly prone to locate. These concentrations covered fairly large areas in 2000, which corresponded to the former industrial areas (as Pantin or La Courneuve, in the north). The growth of logistics activities is based on a diffuse polarization in the inner suburbs, reinforcing logistics sprawl and lengthening distances from the historical Paris centre. Warehouse clusters also appear at the fringe of the first ring of suburbs. These clusters are located around specific multimodal transport infrastructure such as ports and airports. The cluster formed byRoissy CDG airport also seems to have grown in 2012. The three main clusters in the inner suburban ring (Gennevilliers to the north, Roissy to the north-east, and Orly-Rungis to the south) are also major national and regional freight gateways. These clusters have excellent transportation infrastructure: port terminals, container terminals, airports and good highway connections.

Type of land use control

Strictly local ☒
Some sort of metropolitan-wide land use control ☐
Some sort of region-wide (or state-wide) land use control ☐

Other comments/information

Ile-de-France is the largest consumption area in France, which demands an efficient logistics organization. The region contains approximately 20% of France's total warehousing space. The transportation and logistics sectors account for almost 10% of employment in the region (about 400,000 jobs). Between 2000 and 2012, the Paris region experienced a 33% increase in the number of its warehousing facilities.

At the megaregional scale of the "Paris Basin", which contains the Paris region, the number of warehousing facilities has increased by 30% in twelve years. Between 2000 and 2012, the mean distance from the centre of gravity fell from 155 km to 110 km: there is clearly an inward movement around the Paris region. The Paris region is "encircled" by logistics clusters, located at its edges. The clusters located in the east and the south have become considerably larger. The regions to the north and east seem to have become specialized in this type of logistics between 2000 and 2012 which has been confirmed in the specialized press as well as from the interviews we have conducted.

Scientific or technical references

Heitz A., Dablanc L.(2015) "Logistics Spatial Patterns In Paris: The Rise of The Paris Basin as a Logistics Megaregion", *Transportation Research Record: Journal of the Transportation Research Board*, 2477, pp. 76-84.

I.6.9 Paris, France – parcel and express transport terminals

Name and size of studied metropolitan area

Paris Region (Ile-de-France)

12 058 km^2

1300 municipalities

Type of metropolitan area

Monocentric or rather monocentric ☒

Polycentric or rather polycentric ☐

Megaregion ☐

Population (2014)

2014: 11,786,400

Population density (2014)

977.5/km^2

Name of warehouse data source and brief description

Parcel and express transport operators' terminals.Comprehensive collection of terminals by use of the Yellow Pages. Data then grouped by municipality.

Number of warehouses(specify year(s))

1974: 31

2010: 90

Number of warehouses per million people (specify year(s))

2010: 7.5

Number of warehouses per 1000 km^2 (specify year(s))

2010: 7.5

Average size of warehouses (specify year(s)); can be any indicator such as m^2, m^3 or number of employees

Not calculated

Time period studied for logistics sprawl analysis

1974-2010

Average distance of warehouses to centre of gravity (most recent year)(NB this doesn't apply to megaregional types of urban regions)

1974: 6.3 km

2010: 18.1 km

Change in average distance of warehouses to centre of gravity (over the years)

+11.8 km

Change in average distance of warehouses to centre of gravity per year (km/year)

0.33

Cluster indicator

Not calculated

Type of land use control

Strictly local ☒

Some sort of metropolitan-wide land use control ☐

Some sort of region-wide (or state-wide) land use control ☐

Other comments/information

An analysis of sprawl for jobs was also conducted. From 1975 to 2006, the average distance of jobs to their barycentre has increased by two kilometres. This is a sign of a much faster growth pattern for logistics activities than for all economic activities in general.

Scientific or technical references

Andriankaja, D. (2014) Le « desserrement logistique », quelle responsabilité dans l'augmentation des émissions de CO_2 des activités de messagerie? (*Logistics sprawl, what responsibility in CO_2 emissions from the parcel and express transport sector?*). PhD Thesis, IFSTTAR/University of Paris-East, June.

I.6.10 Randstad, The Netherlands

Name and size of studied metropolitan area

The Randstad Region (14,668 km^2)

170 municipalities

Type of metropolitan area

Monocentric or rather monocentric ☐

Polycentric or rather polycentric ☒

Megaregion ☒

Population (2014)

2014: 8,595,855

Population density (2014)

586.1/km^2

Name of warehouse data source and brief description

NACE 52.1

The Statistical Classification of Economic Activities in the European Community, commonly referred to as NACE, is the industry standard classification system used in the European Union. The current version is revision 2 and was established by Regulation (EC) No 1893/2006. It is the European implementation of the UN classification ISIC, revision 4. NACE is similar in function to the SIC and NAICS systems.

This item includes: This class includes:
- operation of storage and warehouse facilities for all kinds of goods:
- operation of grain silos, general merchandise warehouses, refrigerated warehouses, storage tanks etc.

This item also includes: This class also includes:
- storage of goods in foreign trade zones
- blast freezing

This item excludes: This class excludes:
- parking facilities for motor vehicles, see 52.21
- operation of self-storage facilities, see 68.20
- rental of vacant space, see 68.20

Number of warehouses (specify year(s))

2007: 628

2013: 631

Number of warehouses per million people(specify year(s))

2007: 81.1

2013: 73.4

Number of warehouses per 1000 km^2(specify year(s))

2007: 42.9

2013: 43.2

Average size of warehouses (specify year(s)): can be any indicator such as m^2, m^3 or number of employees

Forthcoming information

Time period studied for logistics sprawl analysis

2007-2013

Average distance of warehouses to centre of gravity (most recent year)(NB this doesn't apply to megaregional types of urban regions)

Agglomeration	2007	2013
Flevoland (incl. The Hague)	17.7 km	21 km
Noord Holland (incl. Amsterdam)	21.6 km	19.6 km
Zuid Holland (incl. Rotterdam)	16.3 km	15.3 km
Utrecht	12.3 km	12.8 km

Change in average distance of warehouses to centre of gravity (over the years)

Agglomeration	Change
Flevoland (incl. The Hague)	+18.6 %
Noord Holland (incl. Amsterdam)	-9.5%
Zuid Holland (incl. Rotterdam)	-6.2%
Utrecht	+4%

Cluster indicator

Forthcoming calculations

Warehouses establishments are clustered around the four main metropolitan areas of the Randstad.

Type of land use control

Strictly local ☐

Some sort of metropolitan-wide land use control ☐

Some sort of region-wide (or state-wide) land use control ☒

Other comments/information

The Randstad region experienced a dispersion of logistics activities in the 1970s when they moved from clusters to peripheral regions within the Netherlands (Davydenko et al., 2013).

Nevertheless, our analysis measures these patterns in more detail and also seems to suggest a coordinated move of centres of gravity towards the “Groene Hart”, i.e. sprawl into the heart of the ring-shaped Randstad area, along the direction of the main highways connecting the cities. This is indicated by a convergence of the centres of gravity. The observed geographic patterns of change may be a result of both centripetal forces and centrifugal ones *at the Randstad level*, which are superposed on the forces at city level. The net effect for cities may be concentration or deconcentration. However, if we observe the evolution of the location of warehouses in the last fifteen years, we can see that the deconcentration of warehouses is a permanent dynamic in the provinces of Utrecht and Flevoland. The province of Utrecht is small and biased by the city of Utrecht. Flevoland Province is slightly different from the others: it does not include major cities such as Amsterdam and Rotterdam, and in historical terms is a fairly recent creation. It cannot therefore be considered to be an urban centre in the same way as the others, but it is the subject of many proactive development policies, particularly for its new town of Almere. The deconcentration of warehouses is taking place in the provinces of Flevoland and Utrecht, although the intensity of the process is not the same, being relatively low in the province of Utrecht compared to Flevoland. We can hypothesize that the significant deconcentration taking place in the Flevoland province is linked to the recent nature of its development.

Scientific or technical references

Heitz A., Dablanc L., Tavasszy L. (2016), Logistics sprawl in monocentric and polycentric metropolitan areas: the case of Paris, France and the Randstad, paper submitted to the WCTRS Shanghai 2016.

I.6.11 Rotterdam, The Netherlands

Name and size of studied metropolitan area

Rotterdam Metropolitan Area: Zuid Holland province (3,418 km^2)

68 municipalities

Type of metropolitan area

Monocentric or rather monocentric ☒

Polycentric or rather polycentric ☐

Megaregion ☐

Population (2014)

2014: 3 563 860

2007: 3 455 097

2000: 3 397 744

Population density (2014)

1043/km^2

Name of warehouse data source and brief description

NACE 52.1

The Statistical Classification of Economic Activities in the European Community, commonly referred to as NACE, is the industry standard classification system used in the European Union. The current version is revision 2 and was established by Regulation (EC) No 1893/2006. It is the European implementation of the UN classification ISIC, revision 4. NACE is similar in function to the SIC and NAICS systems.

This item includes: This class includes:
- operation of storage and warehouse facilities for all kinds of goods:
- operation of grain silos, general merchandise warehouses, refrigerated warehouses, storage tanks etc.

This item also includes: This class also includes:
- storage of goods in foreign trade zones
- blast freezing

This item excludes: This class excludes:
- parking facilities for motor vehicles, see 52.21
- operation of self-storage facilities, see 68.20
- rental of vacant space, see 68.20

Number of warehouses (specify year(s))

2007: 168

2013: 185

Number of warehouses per million people (specify year(s))

2007: 48.8

2013: 52

Number of warehouses per 1000 km^2 (specify year(s))

2007: 81.1

2013: 73.4

Average size of warehouses (specify year(s)); can be any indicator such as m^2, m^3 or number of employees

No information

Time period studied for logistics sprawl analysis

2007-2013

Average distance of warehouses to centre of gravity (most recent year)(NB this doesn't apply to megaregional types of urban regions)

2007: 16.3 km

2013: 15.3 km

Change in average distance of warehouses to centre of gravity (over the years)

-6.2%

Cluster indicator

Warehouses are mainly concentrated in the municipality of Rotterdam with 35.7% of the total number of the warehouses. The second major concentration is in 'S-Gravenzande with 7.1% of the total number of warehouses.

Type of land use control

Strictly local ☐

Some sort of metropolitan-wide land use control ☐

Some sort of region-wide (or state-wide) land use control ☒

Other comments/information

The Port of Rotterdam and its entire region are integrated in a port regionalization dynamics, which means that logistics activities spread out into the region (Strale, 2013). Many activities are functionally linked to the port, and spread over a region that stretches from Dordrecht to Venlo through Tilburg (Priemus, Visser, 1995) crossing the boundaries of municipalities and provinces (Van der Burg, Vink, 2008). However, it seems that this dynamic has been reversed at local scale in the provinces of Zuid Holland in the last years. This observation allows us to appreciate how quickly the location of warehouses can change.

The port of Rotterdam is one of the most important logistics clusters in the Randstad (OECD, 2007) and therefore naturally has a high concentration of warehouses and other logistics

activities. In Zuid Holland in recent decades the port of Rotterdam has sought to limit its spatial expansion. The port of Rotterdam has decided to focus on land use in the vicinity of port infrastructure for the development of logistics activities rather than to spread outside the port area. The Havenplan 2010 Port Development Plan emphasized the importance of limiting the space taken up by port development with the construction of the Second Maasvlakte, a polder in the North Sea near Rotterdam, and the relocation of activities (Priemus, Visser, 1995). The decision to build this landfill was taken in 2004 and the facility was opened in 2013. It should make it possible to concentrate activities in a limited area, thereby halting the expansion of the port towards the city and allowing re-urbanization of industrial areas. In anticipation of increased activity in the port, logistics activities have been redistributed around the port in recent years. The intensification of logistics we have observed reflects the existence of a new clustering of logistics activities.

Scientific or technical references

Heitz A., Dablanc L., Tavasszy L. (2016), Logistics sprawl in monocentric and polycentric metropolitan areas: the case of Paris, France and the Randstad, paper submitted to WCTRS Shanghai 2016.

I.6.12 Seattle, USA

Name and size of studied metropolitan area

Seattle Metropolitan Area (15,209.3 km^2)

77 municipalities

Type of metropolitan area

Monocentric or rather monocentric ☑

Polycentric or rather polycentric ☐

Megaregion ☐

Population

2014: 3.5 million

Population density

230.12/km^2

Name of warehouse data source and brief description

County Business Patterns, category 493 (Warehouse & Storage) of NAICS (North American Industrial Classification System)

"Warehouse" defined as: "Industries in the Warehousing and Storage subsector are primarily engaged in operating warehousing and storage facilities for general merchandise, refrigerated goods, and other warehouse products. These establishments provide facilities to store goods. They do not sell the goods they handle. These establishments take responsibility for storing the goods and keeping them secure. They may also provide a range of services, often referred to as logistics services, related to the distribution of goods. Logistics services can include labelling, breaking bulk, inventory control and management, light assembly, order entry and fulfilment, packaging, pick and pack, price marking and ticketing, and transportation arrangement. However, establishments in this industry group always provide warehousing or storage services in addition to any logistic services. Furthermore, the warehousing or storage of goods must be more than incidental to the performance of services, such as price marking." (NAICS)

Number of warehouses (specify year(s))

1998: 85

2009: 212

Number of warehouses per million people (specify year(s))

1998: 28.0

2009: 60.6

Number of warehouses per 1000 km^2 (specify year(s))

1998: 5.59

2009: 13.94

Average size of warehouses (specify year(s)); can be any indicator such as m^2, m^3 or number of employees

Not calculated

Time period studied for logistics sprawl analysis

1998-2009

Average distance of warehouses to centre of gravity (most recent year) (**NB this doesn't apply to megaregional types of urban regions)**

19.3 km

Change in average distance of warehouses to centre of gravity (over the years)

-1.3 km

Change in average distance of warehouses to centre of gravity per year

-0.12 km/year

Cluster indicator

There is a clustering, and increased concentration of warehousing activity in the Puget Sound region.

Type of land use control

Strictly local ☐

Some sort of metropolitan-wide land use control ☐

Some sort of region-wide (or state-wide) land use control ☑

Other comments/information

There was a high concentration of warehouses near the barycentre in 1998, and additional warehouses were constructed in those zip codes (central area) by 2009.

Distance of all establishments from the barycentre was 16.3 miles in 1998, compared to 16.5 in 2009.

Scientific or technical references

Dablanc, L., Ogilvie, S., Goodchild, A. (2014) Logistics Sprawl: Differential Warehousing Development Patterns in Los Angeles and Seattle. *Transportation Research Record: Journal of the Transportation Research Board*, 2410, Freight Systems 2014, Vol. 1: Planning Modelling, and Logistics.

I.6.13 Tokyo, Japan

Name and size of studied metropolitan area

Tokyo Metropolitan Area (14,034 km^2)

Tokyo Metropolis is a metropolitan prefecture comprising administrative entities of special wards and municipalities. There are 23 wards, 26 cities, 5 towns and 8 villages.[13]

Type of metropolitan area

Monocentric or rather monocentric ☐

Polycentric or rather polycentric ☑

Megaregion ☑

Population

2003: 34.5 million

Population density

1,971/km^2

Name of warehouse data source and brief description

2003 Tokyo Metropolitan Freight Survey (TMFS). TMFS was conducted in 2003 and targeted (1) all factories and logistics facilities with storage and (2) a random sample of shops, restaurants and business offices. Logistics facilities consist of establishments that include distribution centres, truck terminals, warehouses, intermodal facilities and oil terminals. Only the data from the logistics facilities (a total of 4,109 responses) were used since the focus of the investigation is on the logistics facilities. The authors used a subset of the data that includes 2,803 logistics facilities that have floor area of at least 400 square meters. While such facilities represent 63% of the respondents, they cover approximately 90% of the shipments in terms of both shipment weights and vehicle trips associated with logistics facilities. In this analysis, the authors exclude inland facilities that are located less than 1.5 km from the coastal line (30% of logistics facilities with over 400 m^2 of floor area).

Number of warehouses (specify year(s))

1980: 420

2003: 209

Number of warehouses per million people (specify year(s))

1980: 14.6

2003: 6.1

Number of warehouses per 1000 km^2 (specify year(s))

1980: 29.93

2003: 14.89

[13] http://www.metro.tokyo.jp/ENGLISH/ABOUT/HISTORY/history02.htm

Average size of warehouses (specify year(s)); can be any indicator such as m^2, m^3 or number of employees

Not available

Time period studied for logistics sprawl analysis

1980-2003

Average distance of warehouses to centre of gravity (most recent year) (**NB this doesn't apply to megaregional types of urban regions)**

30.7 km

Change in average distance of warehouses to centre of gravity (over the years)

+4.2 km

Change in average distance of warehouses to centre of gravity per year

0.18 km/year

Cluster indicator

None available

Type of land use control

Strictly local ☑

Some sort of metropolitan-wide land use control ☐

Some sort of region-wide (or state-wide) land use control ☐

Other comments/information

The authors find that the average distance of the inland logistics facilities from the urban centre (as a different point of comparison from the barycentre) also increased by roughly 4 km between 1980 and 2003.

Scientific or technical references

Sakai, T., Kawamura, K., Hyodo, T. (2015) Logistics facility distribution in Tokyo Metropolitan Area: Experiences and policy lessons. In: 9th International Conference on City Logistics, Tenerife.

I.6.14 Toronto, Canada- Greater Toronto Area

Name and size of studied metropolitan area

Greater Toronto Area (7,124 km^2)

25 municipalities

An analysis was also made for a larger area (GGH, pop 8.7 million in 2011 – see below)

Type of metropolitan area

Monocentric or rather monocentric ☑

Polycentric or rather polycentric ☐

Megaregion ☐

Population

2012: 6.1 million

Population density

849.2/km^2

Name of warehouse data source and brief description

Enhanced Points of Interest (EPOI) dataset by DMTI, a Canadian provider of geographic and marketing data.DMTI's data included a 2002 dataset with businesses listed in SIC (Standard Industrial Classification) format and a 2012 dataset with businesses listed in NAICS(North American Industrial Classification System). Categories surveyed for the study: SIC 422(very similar to NAICS 493) and NAICS 493 businesses. The 2002 SIC 422 Public Warehousing and Storage list of businesses was converted to NAICS 493 businesses.

As mini-storage units have been found to be quite incorrectly classified as warehouses, the database was cleaned accordingly.

NAICS 493 represents the following types of warehouses: "*"Warehouse" defined as: "Industries in the Warehousing and Storage subsector are primarily engaged in operating warehousing and storage facilities for general merchandise, refrigerated goods, and other warehouse products. These establishments provide facilities to store goods. They do not sell the goods they handle. These establishments take responsibility for storing the goods and keeping them secure. They may also provide a range of services, often referred to as logistics services, related to the distribution of goods. Logistics services can include labelling, breaking bulk, inventory control and management, light assembly, order entry and fulfilment, packaging, pick and pack, price marking and ticketing, and transportation arrangement. However, establishments in this industry group always provide warehousing or storage services in addition to any logistic services. Furthermore, the warehousing or storage of goods must be more than incidental to the performance of services, such as price marking*." (Source: NAICS).

Number of warehouses (specify year(s))

2002: 165

2012: 228

Number of warehouses per million people (specify year(s))

2002: 28.1

2012: 37.7

Number of warehouses per 1000 km^2 (specify year(s))

2002: 23.16

2012: 32.0

Average size of warehouses (specify year(s)); can be any indicator such as m^2, m^3 or number of employees

Not calculated

Time period studied for logistics sprawl analysis

2002-2012

Average distance of warehouses to centre of gravity (most recent year) (NB this doesn't apply to megaregional types of urban regions)

17.9 km

Change in average distance of warehouses to centre of gravity (over the years)

+1.2km

Change in average distance of warehouses to centre of gravity per year

0.12 km/year

Cluster indicator

Not available.

Type of land use control

Strictly local ☐

Some sort of metropolitan-wide land use control ☐

Some sort of region-wide (or state-wide) land use control ☑

Other comments/information

In GTA, the distance of all establishments from the barycentre was 17.7 km in 2002, and 18.7 km in 2012 (+ 1km).

Another analysis was made for a larger area than GTA: the Greater Golden Horseshoe (GGH) region that contains the GTA, the Greenbelt, and other satellite communities that lie outside of the greenbelt. There were 217 warehouses in 2002, and 350 in 2012 (increase of 61%). The distance of all warehouses from the barycentre was 29.6 km in 2002 and 39.1 km in 2012 (change +9.5 km, or 0.95 km/year). For all establishments, it was 34.6 km in 2002, and 38 in 2012 (change +3.4km).

Scientific or technical references

Woudma, C., Jakubicek, P.,Dablanc, L. (2015) Logistics sprawl in North America: methodological issues and a case study in Toronto. In: 9th International Conference on City Logistics, Tenerife (Spain).

I.6.15 Toronto, Canada- Greater Golden Horseshoe

Name and size of studied metropolitan area

Greater Golden Horseshoe (GGH) region contains the Greater Toronto Area (GTA), the Greenbelt, and other satellite communities that lie outside of the greenbelt

31,562km^2

An analysis was also made for GTA (see above)

Type of metropolitan area

Monocentric or rather monocentric ☑

Polycentric or rather polycentric ☐

Megaregion ☐

Population

2011: 8.7 million

Population density

276/km^2

Name of warehouse data source and brief description

Enhanced Points of Interest (EPOI) dataset by DMTI, a Canadian provider of geographic and marketing data.DMTI's data included a 2002 dataset with businesses listed in SIC (Standard Industrial Classification) format and a 2012 dataset with businesses listed in NAICS(North American Industrial Classification System). Categories surveyed for the study: SIC 422(very similar to NAICS 493) and NAICS 493 businesses. The 2002 SIC 422 Public Warehousing and Storage list of businesses was converted to NAICS 493 businesses.

As mini-storage units have been found to be quite incorrectly classified as warehouses, the database was cleaned accordingly.

NAICS 493 represents the following types of warehouses: "*"Warehouse" defined as: "Industries in the Warehousing and Storage subsector are primarily engaged in operating warehousing and storage facilities for general merchandise, refrigerated goods, and other warehouse products. These establishments provide facilities to store goods. They do not sell the goods they handle. These establishments take responsibility for storing the goods and keeping them secure. They may also provide a range of services, often referred to as logistics services, related to the distribution of goods. Logistics services can include labelling, breaking bulk, inventory control and management, light assembly, order entry and fulfilment, packaging, pick and pack, price marking and ticketing, and transportation arrangement. However, establishments in this industry group always provide warehousing or storage services in addition to any logistic services. Furthermore, the warehousing or storage of goods must be more than incidental to the performance of services, such as price marking*." (Source: NAICS).

Number of warehouses (specify year(s))

2002: 217

2012: 350

Number of warehouses per million people (specify year(s))

2002:

2012: 40.2

Number of warehouses per 1000 km^2 (specify year(s))

2002:

2012:

Average size of warehouses (specify year(s)); can be any indicator such as m^2, m^3 or number of employees

Not calculated

Time period studied for logistics sprawl analysis

2002-2012

Average distance of warehouses to centre of gravity (most recent year) (NB this doesn't apply to megaregional types of urban regions)

39.1 km

Change in average distance of warehouses to centre of gravity (over the years)

+9.5km

Change in average distance of warehouses to centre of gravity per year

0.95 km/year

Cluster indicator

Not available.

Type of land use control

Strictly local ☐

Some sort of metropolitan-wide land use control ☐

Some sort of region-wide (or state-wide) land use control ☑

Other comments/information

The distance of all establishments from the barycentre was 34.6km in 2002, and 38 km in 2012 (+ 3.4km).

Scientific or technical references

Woudsma, C., Jakubicek, P. Dablanc, L. (2015). Logistics sprawl in North America: methodological issues and a case study in Toronto. In: 9th International Conference on City Logistics, Tenerife (Spain).

Appendix 3. Detailed calculations for Section I.3

The duration of a round is limited by *H*. This determines the otherwise unknown number of stops in the round *x*:

$$x = \frac{H - \frac{2l}{v_a}}{h + \frac{\delta}{v_z}}$$

This requires that $H > 2l/v_a$.Remember that$H_r = H - 2l/v_a$, the duration of the round excluding the duration of the approach and return movements; and that$h_o = h + \delta/v_z$ denote the duration of an operation including the travel time between two consecutive customers.

Then:

$$x = \frac{H_r}{h_o}$$

Denote by *L* the average length of a round: it is then $L = 2l + \delta x$, or:

$$L = 2l + \frac{\delta H_r}{h_o}$$

Denote by *R* the average number of rounds necessary to deliver the *F* customers. It is then $R = F/x$ or:

$$R = \frac{F h_o}{H_r}$$

The transport cost function is:

$$C^t = c_l RL + c_h HR$$

Remind that $c_R = 2c_l l + c_h H$\$ denotes the ``fixed" part of the transport cost, i.e. the part which does not depend on δ.By making explicit all the terms of the transport cost function and adding the platform cost function, the total cost function becomes:

$$C = c_w F + (2c_l l + c_h H)\frac{h + \frac{\delta}{v_z}}{H - \frac{2l}{v_a}} F + c_l \delta F$$

Replacing δ gives:

$$C = c_w F + (2c_l l + c_h H)\frac{hF + \frac{k\sqrt{AF}}{v_z}}{H - \frac{2l}{v_a}} F + c_l k\sqrt{AF}$$

Equivalently:

$$C = \left(c_w + \frac{c_l l + c_h H}{H - \frac{2l}{v_a}}\right)F + \left(\frac{1}{v_z}\frac{2c_l l + c_h H}{H - \frac{2l}{v_a}} + c_l\right)k\sqrt{AF}$$

which is, then, equivalent to Equation (1).

Equation (2) can be derived as follows. Let us differentiate the cost function *C* with respect to *l*, all other variables fixed. Remind that $dc_R = 2c_l dl$, and $dH_r = -(2/v_a)dl$:

$$C_l dl = c'_w F dl + \frac{2c_l h_o}{H_r} F dl + \frac{c_R h_o}{H_r^2 v_a} F dl$$

If *l* is an optimal interior solution, then *dC* = 0. This yields the condition on *l*.

In order to derive Equation (3), let us differentiate the cost function *C* with respect to *F*. Remind that $dh_o = d\delta/v_z$ and that $d\delta = -(\delta/2F)dF$.

Then:

$$dC = c_w dF + \frac{c_R h_o}{H_r} F + \frac{c_R h_o}{H_r} dF + c_l d\delta + c_l \delta dF$$

or:

$$dC = c_W dF - \frac{\left(\frac{c_R}{H_r v_z} + c_R\right) F\delta}{2F} dF + \left(\frac{c_R h_o}{H_r} + c_l \delta + c_w\right) dF$$

Finally:

$$dC = c_W dF + \frac{1}{2} c_l \delta dF + \frac{c_R}{H_r}\left(h_o - \frac{\delta}{2v_z}\right) dF$$

Note that $h_o = h + \delta/v_z$ so that$h_o - \delta/2v_z = h + \delta/2v_z$.

Now, in order to analyse how the optimal location, solution of Equation (2), varies with the parameters, denote by Γ its LHS divided by *F*. The full differential of Γ is:

$$d\Gamma = c''_w(l) + \frac{2h_o}{H_r} dc_l + \frac{2c_l dh_o}{H_r} - \frac{2c_l h_o^2}{H_r^2 dH_r} + \frac{2h_o}{H_r^2 v_a} dc_R + \frac{2c_R}{H_r^2 v_a} - \frac{4c_R h_o}{H_r^3 v_a} - \frac{2c_R h_o}{H_r^2 v_a} dv_a$$

and the total differential of h_o is:

$$dh_o = dh + \frac{1}{v_z} d\delta - \frac{\delta}{v_z^2} dv_z$$

the total differential of H_R is:

$$dH_r = dH - \frac{2}{v_a} dl + \frac{2l}{v_a^2} dv_a$$

and the total differential of c_R is:

$$dc_R = 2l dc_l + 2c_l dl + H dc_h + c_h dH$$

It is now possible to analyse the behaviour of the optimal location of the warehouse.Analyzing the second derivatives of *C* is analogous to analyzing the first derivatives of Γ.

$$\Gamma_l = c''_w + \frac{8c_l h_o}{H_r^2 v_a} + \frac{2c_R h_o}{H_r^2 v_a}$$

If the rent is a convex function of the distance to the centre, then c_w'' is positive.Besides, in the vicinity of an equilibrium point, c_w''should be positive. As a consequence: $\Gamma_l > 0$.The other differentials are as follows:

$$\Gamma_{c_l} = \frac{2h_o}{H_r} + \frac{4lh_o}{H_r^2 v_a} > 0$$

and:

$$\Gamma_h = \frac{2c_l}{H_r} + \frac{2c_r}{H_r^2 v_a} > 0$$

$$\Gamma_\delta = \frac{2c_l}{H_r v_z} + \frac{2c_R}{H_r^2 v_a v_z} > 0$$

$$\Gamma_{v_z} = -\frac{2c_l \delta}{H_r v_z^2} - \frac{2c_R \delta}{H_r^2 v_a v_z^2} < 0$$

$$\Gamma_H = -\frac{2c_l h_o}{H_r^2} + \frac{2c_h h_o}{H_r^2 v_a} - \frac{4c_R h_o}{H_r^3 v_a}$$

Note that:

$$\frac{2c_h h_o}{H_r^2 v_a} - \frac{4c_R h_O}{H_r^3 v_a} = \frac{1}{(H_r^2 v_a)(2H_r c_r h_o - 4c_R h_o)}$$

and, given the fact that $c_R = 2c_l l + c_h H$ and $H_r = H\text{-}2l/v_a$, that:

$$2H_r c_r h_o - 4c_R h_o = 2H_r c_h h_o - 8c_l l h_o - 4c_h H h_o$$
$$= 2(H_r - H)c_h h_o - 8c_l l h_o - 2c_h H h_o < 0$$

so that $\Gamma_H < 0$. Finally:

$$\Gamma_{v_a} = -\frac{4c_l h_o l}{H_r^2 v_a^2} - \frac{8c_R h_o l}{H_r^3 v_a^3} - \frac{2c_R h_o}{H_r^2 v_a} < 0$$

and:

$$\Gamma_{c_h} = \frac{2h_o H}{H_r^2 v_a} > 0$$

From the implicit equation theorem, the sign of the variation of the optimal location *l* with respect to the other model parameters is the sign of the ratio of the corresponding partial derivatives of Γ, hence the conclusions.

Appendix 4. Table of e-commerce indicators

	E-COMMERCE GENERAL FIGURES (European countries)							
Source	ecommerce-europe.eu- 2014 Key E-commerce	ecommerce-europe.eu-2014 Key E-commerce	ecommerce-europe.eu-2014 Key E-commerce	ecommerce-europe.eu-2014 Key E-commerce	ecommerce-europe.eu-2014 Key E-commerce	ecommerce-europe.eu-2014 Key E-commerce	e-commerce manager.com	e-commerce manager.com
	Total B2C e-commerce (goods and services) turnover-€billion	**Total B2C e-commerce (goods & services) increase (% increase compared to year before)**	**E-commerce % on total GDP**	**Share of goods purchased on line (% in total retail of goods)**	**Share of services purchased on line(% in total retail of services)**	**Average spending per e-shopper (€)**	**Total grocery e-commerce turnover (€ billion)**	**Share of grocery e-commerce in total grocery commerce (%)**
Austria	11.7	8%	3.56%	7.20%		3 034		
Belgium	6.1	13.7%	1.53%	6.40%		1 234		
CzechRepublic	3.1	15.5%	2.02%	7.10%		845		
Denmark	9.9	18.1%	3.84%	20%		2 721		
Estonia	0.15	15.4%	0.77%			283		
Finland	6.6	14.2%	3.23%	9.80%		2 145		
France	56.8	11.2%	2.67%	4.60%		1 600	6.51 (2014)	3.1 (2014)
Germany	63.4	26.8%	2.3%	9%		1 585		
Greece	3.9	20.4%	2.15%	2.90%		1 624		
Hungary	0.9	24%	0.9%	3.70%		346		
Iceland	0.25	8.7%	1.95%			1 445		
Ireland	5.3	15.2%	2.86%			2 967		
Italy	13.3	17.5%	0.82%	1.90%		810		
Latvia	0.2	11.1%	0.83%			352		
Lithuania	0.41	12.2%	1.13%			630		
Luxembourg	0.5	13%	1.12%			1 574		
Netherlands	14	8.4%	2.13%	7.60%		1 100		
Norway	8.3	15.3%	2.20%	9.70%		2 608		

Poland	6.5	21.7%	1.59%	5.40%		618		
Portugal	2.9	13.3%	1.70%			1 330		
Romania	1.2	15.4%	0.8%	2.50%		317		
Russia	19.9	15.7%	1.42%	2.20%		767		
Spain	16.9	16.6%	1.60%	4.10%		1 174		
Sweden	8.9	7.20%	2.07%	3.50%		1 504		
Switzerland	12.7	16.10%	2.38%	5.50%		2 858		
Turkey	9.8	9.7%	1.63%	1.60%		1 245		
Ukraine	2.3	21.6%	2.27%	1.60%		662		
United Kingdom	127.0	14.7%	5.74%	13%		3 073		
Europe	423.0	13.6%	2.5%	6.40%		1 544		
Global	1938	24%		5.90%		1702		

	DELIVERY					LOGISTICS FACILITIES				
Source	Copenhagen Economic-2012		CopenhagenEconomic-2012			http://ecommercenews.eu/an-overview-of-pick-up-points-in-europe/-2015				Reuters
	Total shipments (express and non express)(B2B ; B2C, C2C)- (in million units)	**Share of B2C and C2C in total shipment parcels**	**Share of shipments delivered as express delivery by national postal operators (%)**	**National Postal Operator market share relative to B2C parcels and packets shipments (%)**	**If city case studies are available: share of e-commerce deliveries in total deliveries (%)**	**Number of pick up points**	**Number of pick-up-point per capita**	**Market share of pick-up points in total number of e-commerce deliveries (%)**	**Number of *automated* pick-up points**	**Number of "drives" (grocery e-commerce pick-up-points)**
Austria										
Belgium						4150				
CzechRepublic										
Denmark										
Estonia										
Finland										
France	780 (DGCCRF)-2011					19600	7 per 100 000 inhabitants (Morganti et al, 2014)	66% (FEVAD, juin 2015)	33 (Morganti et al, 2014)	2841 (mars 2014)
Germany						67800				
Greece										
Hungary										
Iceland										
Ireland										
Italy						13100				

Latvia										
Lithuania										
Luxembourg										
Netherlands						5885				
Norway										
Poland										
Portugal										
Romania										
Russia										
Spain						3308				
Sweden										
Switzerland										
Turkey										
Ukraine										
United Kingdom						6700 (Great Britain)				
Europe	6406		14%	35%						
Global										

	MARKET STRUCTURE		E-SHOPPERS					
Source			ecommerce-europe.eu-2014 Key E-commerce	ecommerce-europe.eu-2014 Key E-commerce	ecommerce-europe.eu-2014 Key E-commerce			
	National Postal Operator share of revenue due to e-commerce (%)	**Main alternative operators active in B2C deliveries**	**total residents (million)**	**internet users (million)**	**share of internet users (%)**	**Total urbanresidents(million)**	**urban internet users (million)**	**share of urban internet users(%)**
Austria			8.5	5.9	81%			
Belgium			11.2	7.9	85%			
CzechRepublic			10.5	7.1	80%			
Denmark			2.6	4.5	96%			
Estonia			1.3	0.931	84%			
Finland			5.5	4.2	92%			
France	32.1% (DGCCRF)-2011		65.8	44.8	84%	47.9 (INSEE-RGP 2010)		
Germany			82	70.5	86%			
Greece			10.9	5.9	63%			
Hungary			9.9	6.4	76%			
Iceland			0.326	0.254	98%			
Ireland			4.61	2.88	80%			
Italy			60.8	32.5	62%			

Latvia			2	1.53	77%			
Lithuania			2.94	1.81	72%			
Luxembourg			0.6	0.4	95%			
Netherlands			16.8	13.6	98%			
Norway			5.1	4	96%			
Poland			38	21.6	67%			
Portugal			10.4	5.7	65%			
Romania			19.9	9.2	54%			
Russia			143.7	84.4	71%			
Spain			46.5	30	76%			
Sweden			9.6	7.4	93%			
Switzerland			8.1	6	87%			
Turkey			76.7	29.2	51%			
Ukraine			45.2	16.7	43%			
United Kingdom			64.3	48.7	92%			
Europe			817	491	72%			