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Three essays on urban freight transport: models and tools for effective city logistics projects

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INDEX

FIGURES LIST

TABLES LIST

Executive summary

Background

With the increase of the urban population, the fragmentation of the demand for goods, the increase in the frequency of deliveries linked with the decreasing of the time between order and delivery (also due to an increasingly widespread of e-commerce), the demand for goods in the city is steadily rising. The increase in demand for goods raises traffic and congestion of urban roads which causes a consequent increase in the air pollution and noise. To reduce these negatives aspects caused by urban freight transport, city logistic initiatives have emerged since the year 2000 and have also been aimed at optimizing operations related to freight transport in the city and reducing the number of heavy vehicles circulating in urban centres.

Despite this kind of initiative, in which researchers, industries and government have interest, city logistics projects are still far from achieving full effectiveness and dissemination across Europe. In particular, despite the presence in Europe of many projects related to the optimization of urban logistics, there are only few of them that last efficiently over time.

Objectives

The main purpose of these three years of research was to investigate the obstacles to the development of the city logistics initiatives by seeking solutions to overcome them through model and framework coming from management and transportation engineering. In particular, following a first analysis of a collection of European projects and a systematic analysis of scientific literature, three main gaps in city logistics have been identified: the lack of the stakeholders' involvement, the need for data sharing platforms to overcome the current lack of data and the need to define city logistics solutions within the urban ecosystem, making consistent design choices coherently with what is already existing in terms of infrastructures, rules and stakeholders in the context. From these three gaps, three main research questions have arisen:

(RQ1) Is it possible to support stakeholders in analysing CL solutions fitting their necessities applying some already existing and consolidate decision-making methods?

(RQ2) Is it possible to define a database platform in which it is possible to collect, consult and update as many existing data as possible regarding urban freight transport?

(RQ3) How is it possible to optimize city logistics infrastructures in a harmonious and coherent way with respect to the entire city logistics ecosystem?

Methodology

To answers to the research questions, a collection of articles is illustrated in this thesis work. From time to time different methodologies are used and illustrated, derived from the field of management and transport engineering, these different methodologies, such as the Systematic Literature Review, the House of Quality, a framework for building a data sharing platform, the city logistics Ecosystem and a decision-making support model (based on both a covering model and a Monte Carlo simulation) are described in detail in the various chapters and summarized in the next section of this abstract.

Results

(RQ1) Is it possible to support stakeholders in analysing CL solutions fitting their necessities applying some already existing and consolidate decision-making methods?

The House of Quality, an instrument derived from production engineering, thanks to the immediate graphic visualization of results, is a tool that enables stakeholders to understand which kind of city logistics solution can best meet their operational needs. One of the strengths of this tool is the speed and the lower cost for its implementation: it is sufficient to create a focus group or realize some interviews to define the stakeholders' requirements and the importance that they assign to each of these requirements (in terms of weight) to define the most part of the House of Quality matrix. The remaining part of the matrix can be later filled up by researchers who require experience to determine which city logistics solutions are best suited to solving each stakeholder requirement. In this also resides the main weakness of the method: part of the evaluation will be subjective and will depend on the sensitivity and the level of experience of the researcher. However, compared to other existing methods, it has proved to be easy to apply and can provide good arguments during its application to the Bergamo case study (Bergamo Logistica under the Bergamo smart city project 2.035).

(RQ2) Is it possible to define a database platform in which it is possible to collect, consult and update as many existing data as possible regarding urban freight transport?

In this case, no existing platform was referred to, but attempts were made to create a repeatable, continuously integrated and updateable platform starting from a retrieving data framework for gathering the data needed to design city logistics solutions. This platform has a threefold purpose: to gather all existing city-wide data on urban freight transport in one place, to allow to understand what data are needed to implement different solutions and to help stakeholders understand what elements are involved in the different solutions.

In order to achieve the data framework, on which the platform is based, a first bibliographic search of the elements present in cities that can be involved in the urban transport of goods was performed, then for each element a source has been identified from which to take the necessary data and finally the data available from the various sources have been grouped into layers viewable on a GIS-type platform.

This solution has many positive aspects, much of the sources are in fact the same in every European country (in the article illustrated in this thesis the framework was applied both in Bergamo and in Luxembourg) consequently the procedure for the collection of data is easily replicable. GIS-based software also allows for quick collection and integration of different data sources in different formats, so it is possible to collect data from digitized public administration maps at various levels (municipal, regional, national) and integrate them with data coming from open source archives (i.e., Open street map).

However, this type of solution has a couple of limitations: some data are difficult to find except with a great deal of cost and time (i.e., localization of all commercial activities, number of deliveries received by each shop); moreover, data needs to be updated at a certain frequency, taking into account also the constantly increasing of the level of technological innovation.

(RQ3) How is it possible to optimize city logistics infrastructures in a harmonious and coherent way with respect to the entire city logistics ecosystem?

To answer this question, it was first necessary to define the city logistics ecosystem. If in other areas, such as economics, IT engineering or transport (where systemic transport is concerned), this kind of vision is consolidated, there is not much literature about it in urban logistics. In fact, urban logistic solutions go into a very wide system, the city, the one where many subsystems (e.g., the energy system, the health system) co-exist, have contacts and influence each other. Urban freight transport, in particular, uses infrastructures and is governed by rules shared by people's mobility. Consequently, when designing a city logistics solution, is fundamental consider what elements of the ecosystem are involved (infrastructures, rules, actors) and how they can be impacted by the solution taken into account. Failure to do so could mean the failure of the entire initiative itself. This thesis illustrates the case of the optimization of loading and unloading areas in a district of Bergamo. The sizing and decision support model enables a sensitivity analysis on how to improve loading and unloading operations by increasing the number of stalls available for carriers, but in which the margin of decision is still left to the final decision maker, in this case, the municipality.

Conclusions

In this dissertation work for the first time, the main obstacles to the development of city logistics initiatives, that are the lack of involvement of stakeholders, the lack of data, and the lack of an ecosystem vision of urban transport, have been identified and addressed at the same time.

Even if literature sometimes offers some possible solutions to these gaps, few are simple to understand for those who work in the urban freight transport industry, easy to apply and replicable. Both in identifying the gap and in seeking solutions, the solutions showed in this thesis sought to address to those who work in the industry, mainly carriers, retailers, shop owners and public administration representatives, trying to combine scientific research with the search for solutions that can be implemented in practice as requested by such a practical research topic. For this reason, each proposed solution and methodology in this thesis has been implemented and experimented using as a case study the city of Bergamo (and testing its replicability in other European cities such as Saint-Etienne, Luxemburg and Amsterdam). In particular, the initial experience in the "*Bergamo Logistica"* project, part of the Bergamo 2.035 smart city research program, gave me the opportunity to understand the main critical issues found by the main actors who work in this field (i.e., carriers, couriers, retailers and institutions), to confirm some evidences that I found in the theory (i.e., main research gaps which originates the research questions) and to search for solutions that could both solve research gaps and optimize the daily logistics activities of the operators.

Introduction

The constant growth of the urban population, the presence of different actors with different and often conflicting interests, the fragmentation of the demand linked to a reduction in the delivery times and an increase in the frequency of deliveries due to the increase of the e-commerce purchases have stimulated an increasing demand for goods in the urban centres.

This rise of the demand for goods in the city has consequently led to an increase in the traffic congestion and in the occupation of the ground. In turn, this is due both to the increase of the warehouses number for the storage, even temporary, of goods in the city, and the need to have parking places for the loading and unloading areas near the shops. Moreover, the rise of the demand caused also an increasing of the environmental and acoustic pollution, and an increasing of the transport costs; indeed, the necessity of high delivery frequencies and reduced delivery times have in fact caused an increment in the number of freight transport vehicles, that often travel not fully loaded.

Because of these many issues, urban freight transport has become a topic that has increasingly attracted both academic researchers and practitioners working in the field of transport and logistics. The interest in optimizing freight transport in urban areas has increased since the year 2000, when the Institute for City Logistics was born in Tokyo, following the climate and CO_2 mitigation measures. City logistics has been defined by the Institute as the "*optimization and rationalization process of logistics and transport by private companies in urban areas, considering traffic conditions, congestion problems and fuel consumption in order to reduce the number of vehicles circulating in the city.* " (Anand, Quak, Van Duin, & Tavasszy, 2012). However, over the years, other definitions of city logistics have also been given, which are more focused on the optimization and engineering perspective (Taniguchi et al., 2001), on the socio-economics perspective (Gonzalez-Feliu et al., 2014) or to the descriptive and geographical perspective (Dablanc & Rodrigue, 2014).

Since 2000, therefore, the production of scientific articles related to the optimization of urban freight transport, as well as the number of projects started to promote and implement city logistic initiatives, has been steadily increasing.

However, despite the great amount of existing literature and the large number of projects carried out at European level (mainly as a result of funding from the European Union), city logistics initiatives still have not reached a huge spread. Existing scientific literature is in fact fragmented, ranging from articles that seek to frame the theme of urban logistics in broader areas such as decision-making support, supply chain management or project management, and articles aimed at solving very detailed and punctual problems, such as the optimization of the vehicles routing for the goods deliveries from a warehouse or the dimensioning of an urban distribution warehouses. Even with regard to European projects concerning city logistics initiatives, the number of projects over the past twenty years that have passed the pilot phase, and are still active is, in fact, relatively small.

As soon as this research on city logistics started, after a preliminary analysis of both the scientific literature and of city logistics European project reports, the following issue became evident as a critical one: city logistics solutions are generally defined as a necessary tool for optimizing urban logistics, which is one of the major causes of urban pollution; however, city logistics solutions are not really widespread, and municipal administrations are sceptical about their implementation. Municipalities are not sure about the benefits of the city logistics initiatives compared with a great economic effort to finance any new infrastructures. Moreover, retrieve data, modify existing rules and search for compromise solutions that could fit interests of the different actors operating in the sector could be time expensive activities as learned in *"Bergamo Logistica"* project, part of the Bergamo smart city project, Bergamo 2.035, regarding urban freight transport.

Given the above issue emerged from literature and project analysis and from a direct experience in a city logistics project, some interesting questions arose: what are the major problems that hindered the spread of city logistics initiatives by relegating the topic to a little more than a niche topic? Why after a few years of experimentation, city logistics projects are interrupted? What are the elements that hinder the search for innovative city logistic solutions or for the optimization of the existing ones?

These are the main questions emerged starting the research about city logistics and these are the main questions that are faced by this research thesis. The answers to these questions and the results of the research carried out during the PhD are contained in this thesis made up of the collection of papers realized, presented and published in these three years.

Particularly, Chapter 1 describes in detail the context of freight transport in urban areas, paying a particular attention to the description of the main problems that led to the emergence of city logistics initiatives mentioned in this introduction, and to the solutions that these initiatives propose. In this chapter, a first analysis of existing city logistics projects in Europe is also illustrated.

Chapter 2 describes the results of a systematic review of the literature that was initiated at the beginning of the doctoral research with the aim of unifying existing, fragmented, and varied scientific literature. The literature review allowed identifying the major research trends, the main hindering factors that researchers have found in these first twenty years of research into urban logistics, and defining the main research gaps.

Chapter 3 describes the structure of the doctoral research by clarifying the research path. In particular, in this chapter the research questions have been formulated starting from the gaps identified from the analysis of European projects and the literature analysis. The research questions investigate the three gaps identified in the literature and the analysis of European projects, namely the involvement of stakeholders in city logistics activities, the scarcity of data and the consequent need for a shared data platform for urban transport, and finally the need to frame every city logistics solution in the wider context of urban transport by defining an ecosystem of urban freight transport. This chapter also illustrates how the research questions have been dealt with over the years through local, national and international experiences, producing several articles presented at international conferences or published in major journals in the field. For this thesis, only the most significant research products for each research question are discussed, whereas the remaining products are briefly reported.

Chapter 4 addresses the issue of stakeholders' engagement in city logistics projects in order to support the development and eventually the success of these initiatives. In particular, in this chapter a model used in the product design, the House of Quality, is proposed to provide stakeholders with an immediate and understandable decision support tool. This chapter presents a model application applied to the city of Bergamo.

In Chapter 5, one of the main obstacles to the diffusion of research and implementation of city logistics solutions is addressed: the lack of data. To design city logistics solutions that are both effective and sustainable from the economic and environmental point of view, many data are needed. Retrieving these data requires both financial resources and time-consuming efforts; moreover, data need to be updated at a certain frequency, for example every year or even more frequently. In this chapter, a framework for the creation of a data sharing platform is proposed. To test its potentiality and replicability, the framework has been applied to the cities of Bergamo and Luxembourg.

Chapter 6 deals with the theme of the city logistic ecosystem, understood as a single framework that takes into account all elements such as infrastructures, people, and rules, included in city logistics solutions or impacted by them. The framework allows taking into account all the possible impacts that city logistics solutions could have on infrastructures and spaces that are shared with other transport flows in the city. In particular, this chapter illustrates, as an example, the case of the optimization of the loading and unloading areas in a district of Bergamo.

Finally, Chapter 7 presents the conclusions of the work with the answers to the research questions, the research limitations, and possible future developments in the field of urban freight transport.

1. The urban logistics context

Freight transport has always been one of the most discussed problem in the engineering field. The Romans built roads that were more and more suited to being driven by freight wagons, and it was also due to the relative problem of freight transport to Napoleonic troops that arose the logistics as a matter of study and the first *École Polytechnique* in France (Servetto, 2006).

The problem related to the freight transport became increasingly important as a result of the first and second industrial revolutions in which, because of the production of series products, the quantity of goods to be transported was getting bigger, despite the increasing of available transport modes (e.g., trains and cars) (Szostak, 1991).

Nowadays, the problem of freight transport is still of great relevance. Indeed, with the advent of the globalization of the supply chains the problem has become even more complex: on the one hand, it is necessary that the goods travel longer distances, mainly due to the relocation of the production centres; on the other hand, because of to the increase of the population in urban areas, it becomes essential to distribute the goods in more punctual and capillary way (Hulme, 2009).

However, the growth in the demand for commodities in the urban areas has contributed to the growth of pollution and congestion in large cities. To investigate and understand how goods can be transported in urban areas in an increasingly optimized and efficient way, the study of the last-mile logistics emerged both in the academic and in the practitioners' fields. The term last-mile logistics, in particular, defines "*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: it is the very last section of the supply chain, starting from the moment that the goods or parcels leave the warehouse of the supplier or logistics provider*" (Macharis & Melo, 2011). Thus, considering the last-mile logistics from a supply chain management point of view, it consists in the very final link from the moment in which the goods are picked up from the warehouses to the moment when they are bought from the shop shelves by the customers or directly delivered to the customers' home (Figure 1-1). In particular, this research focus on last-mile logistics in urban context or urban freight transport.

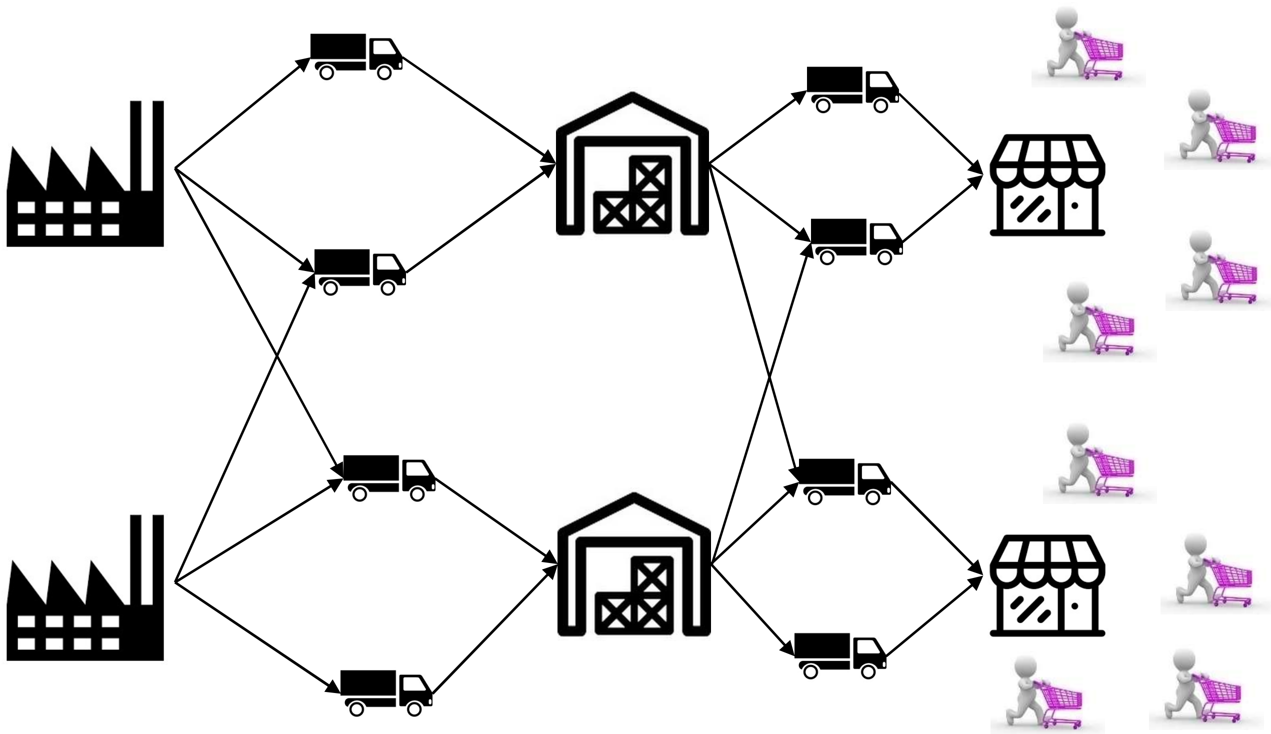

Figure 1-1 Transport in the supply chain.

This chapter outlines the main open issues related to urban freight transport, giving particular attention to the importance of the problem addressing both the point of view of the efficiency of the last-mile freight transport operations, and the impact that a better transport of goods could have on the citizens' quality of life.

1.1. Main open issues in urban freight transport

1.1.1. Growing of urban population

Global population is forecasted to more than double by 2050, turning the human distribution across areas in the world into a crucial aspect to be considered in the urban freight transport field (Rutherford & Coutard, 2014). In addition to this, the percentage of population living in urban areas is expected to shift from the current 54 per cent to 66 per cent by 2050 (United Nations, 2014). This is inevitably leading cities around the world to face increasing challenges in terms of efficient transportation of people and goods, while controlling and ideally reducing its negative impacts (such as congestion, pollution, noises, accidents…) on the quality of life of their citizens, and without negatively affecting the city's economic, social, administrative, cultural, and touristic activities (Benjelloun, Crainic, & Bigras, 2010). In particular, the concentration of the population in urban areas brings along an increasing concentration of the demand for goods and products that should be transported to limited areas, often already heavily congested by people mobility traffic.

Considering pollution, it is estimated that road transports produces 73% of CO_2 emissions (Figure 1-2) 42% of which is due to freight transport (European Commission, 2014b). In turn, about 25% of the freight transport emissions is due to urban freight transport (Figure 1-3) (European Environment Agency, 2016) that also produces 37% of NO_x emissions, 12% of emissions of volatile organic compounds, and 40% of the total PM10 emissions pollutants in urban centres (European Environment Agency, 2015).

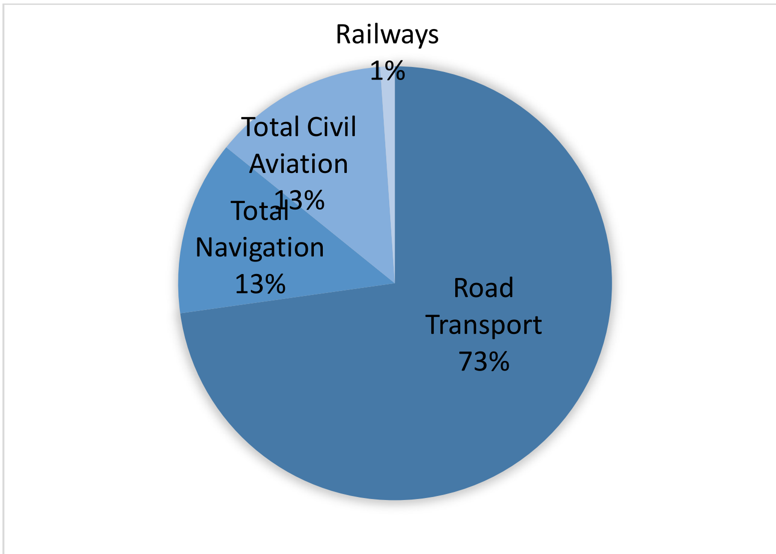

Figure 1-2 CO2 emissions for each mode of transport. Source: Reducing emissions from transport | Climate Action, European Commission, 2014.

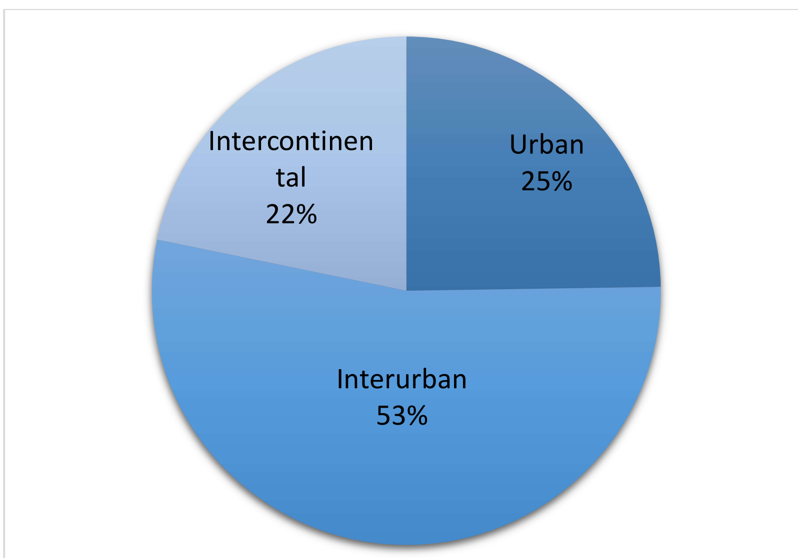

Figure 1-3 CO2 emissions for each typology of road freight transport. Source: NEC Directive reporting status, European Environment Agency, 2015.

1.1.2. Fragmentation of the demand

The distribution of goods in urban areas has become increasingly complex also because of other factors affecting it, such as the abovementioned government regulations, the traffic congestion, the high-frequency deliveries using lighter vehicles, and the environmental issues (Crainic, Ricciardi, & Storchi, 2004). Further, it is the same urban configuration and the land use of urban centres that makes demand for urban goods peculiar: despite at an aggregated level the demand is concentrated in a limited area (i.e. the city centre), at a detailed level the demand is extremely fragmented on a very large number of subjects, such as businesses and individual citizen. To some extent, this fragmentation effects can also be ascribed to the spreading of the e-commerce that brings along a proliferation of individualised deliveries to houses and businesses. As a result, the fragmentation of the demand produces a fragmentation of the transportation sector: in fact, there are third parties transportation companies of different sizes, who operate independently from each other (Kaplan & Sawhney, 2000). This fragmentation means that, often, there is a large portion of trucks that do not travel at full load, with a further loss of economic efficiency, excessive energy consumption, and related environmental impacts (Ljungberg & Gebresenbet, 2004).

A national analysis carried out in Italy estimates the urban freight traffic as the 25% of the total traffic, composed for the 70% by small vehicles, with load factors under the 30%. Often, small business owners do not use third-party transport operators, but carry out the transport on their own account, thereby further contributing to the fragmentation of transport: on the routes of up to 50 km, typical of the urban freight distribution, transport on own account regards about 40% of the total tonnes transported (ISTAT, 2015).
The fragmentation of the commercial exercises in cities, and the presence of commercial businesses of very limited size, may be considered as negative elements from the point of view of the costs and the complexity of the distribution. At the same time, however, these small businesses (often family owned and managed) represent a phenomenon to be safeguarded considering the benefits that they produce, especially compared to some segments of the population (European Union, 2001; Great Britain. Parliament. House of Commons. Treasury Committee., 2007). As a matter of fact, a neighbourhood shop could constitute a great service for the daily shopping for all the elder part of the population that is no more capable to drive or to walk for long distances.

1.1.3. Reduction of delivery time and increasing frequency of deliveries

The lead time reduction for deliveries and the increase in the frequency of delivery also plays a relevant role in urban freight transport. The dynamics of the market and the decline in consumer spending have led many channels / distribution points to reconsider the logic of managing their stock and supplies, intensifying the frequencies and consequently reducing the quantity ordered. Moreover, the great attention given to the aspect of "service" generated the consequent increase in deliveries and demands made on the same day in which the customer placed the order (e.g. Amazon Prime Now). Factors such as lead time and delivery frequency, for example, grow as a service differential, resulting in a proliferation of individualised deliveries to houses and businesses. Further, Continuous Inventory Replenishment (CIR) policies, adopted by segments of retailers because of the less available space inside stores and mainly aiming for the reduction of inventory, which allows more space for a greater variety of products available to customers, results in higher delivery frequencies to stores, although using freight vehicles with lower capacity or not efficiently saturated (de Magalhaes, 2010).

1.1.4.Stakeholders with conflicting goals

In the urban context, there are many types of different actors (stakeholders), often having conflicting goals. Even if carriers, retailers and couriers have the common goals in the urban freight context, that is to deliver or receive freight in the city in a safe, punctual and fast way, they have different necessities in terms of time windows, access restrictions, type of vehicles that make more complex make a share and compromising decision. Moreover, in the city context there is also the municipality, often the main decision-maker, that plays a great role: to guarantee a high liveability level for the urban citizens and to ensure that freight operations take place as efficiently as possible. The presence of many, very heterogeneous actors implies the need for a strong coordination between the parties, but this coordination is often absent or very limited (Dablanc, 2007). In fact, the lack of coordination between the parties has as its first consequence the imposition by the local government of more restrictive measures for access to the city centres, often already difficult to access because of the urban layout of many European cities. Moreover, it is possible to observe that involvement and participation are two very different things, it often happens that stakeholders are consulted, but rarely they take an active part in the decision-making process leading to the introduction of new rules and solutions for urban freight transport. As noted by (Ballantyne, Lindholm, & Whiteing, 2013), it is possible to differentiate between actors directly involved in the process and stakeholders who have interest in the subject but are marginally affected by changes in the industry. Often, public authorities make the mistake of involving some stakeholders neglecting those who work directly in the urban sphere but may not have the resources to attend meetings and projects.

1.2. City Logistics Solutions

To deal with the issues discussed so far, numerous projects are in progress in several countries for the establishment of sustainable urban freight systems in terms of environmental, social and economic development, making good use of new technologies to minimize the impact on people, and ultimately to improve the quality of the citizen's life. All these initiatives are grouped under the term City Logistics projects (also referred to as *urban logistics* or *urban freight transport*, encompassing the transportation of goods inside and across urban centres, thus concerning also the *last-mile distribution*). City Logistics is defined as "*The process for totally optimizing the logistics and transport activities by private companies in urban areas while considering the traffic conditions, congestion issues and combustible consumption, with a view to reduce the number of vehicles on the cities, through the rationalization of its operations*" (Thompson & Taniguchi, 1999).

As already mentioned in the Introduction paragraph of this thesis, there are several definition of City Logistics, but since this research focus in particular on the optimization and engineering aspects, the definition that takes this perspective has been chosen.

In many ways, City Logistics projects have as their main objective the improvement of the citizens' quality of life. However, also business actors – especially those located in the historical centres, often difficult to access and subject to ad hoc regulations – are often advantaged by the presence of more regular and efficient goods distribution services. In fact, City Logistics is not only about the distribution of goods to the final consumer. Projects in this field also address the flow of goods to retail outlets within the city, which operate according to different dynamics than those adopted by large distribution centres, even for the size of volumes processed. A typical case is that of the pharmacies, that receive deliveries several times per day in small batches (sometimes single units) to ensure the availability of products or respond to the specific needs of the customers.

To achieve their objectives, City Logistics projects usually focus on three aspects:

i) the reduction of traffic congestion and interference with the mobility of people;

ii) the reduction of pollution factors related to the distribution of goods, primarily (but not exclusively) through the use of low-emission or clean (i.e. Electric) vehicles;

iii) the reduction of indirect costs related to the distribution of goods, for example, reducing the risk of accidents through a reduction in the number of vehicles in circulation.

Figure 1-4 summarize the motivations and the expected goals of the city logistics solutions.

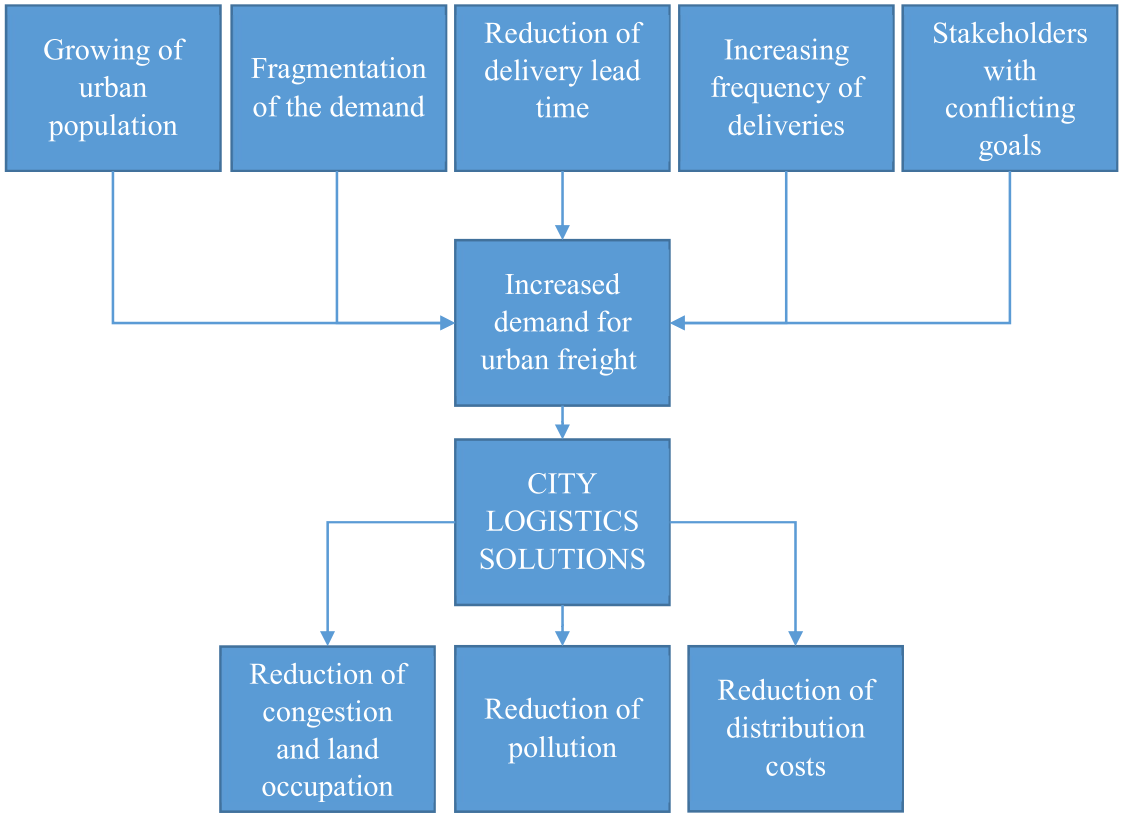

Figure 1-4 Motivations and the expected goals of city logistics solutions (author's elaboration).

From its first, formal appearance in the scientific sector in the late 90s, City Logistics context has spurred several initiatives to study, understand, implement, and realize the optimization of freight transport on an urban scale, according to several dimensions.

Many of these initiatives have as a result several solutions that are nowadays available to mitigate the negative impacts of logistics activities in urban contexts (such as congestion, air pollution, and noise), and the number is growing every day thanks to the current rates of technological development. The solutions that can be found in the literature vary from regulation (e.g., access restrictions) to time shifts (e.g., off-hour deliveries); from shifts in the transportation technology (e.g., electric vehicles, modal shifts) to changes in the supply chains (e.g., urban consolidation and distribution centres, delivery points for parcels). In order to understand the different types of city logistics solutions and their different applications initially, the projects in the main European network databases of projects DOROTHY (Pino, Nicolás, & Espinós, 2014) and CIVITAS (Van Rooijen & Quak, 2010) were analysed. The initial phase of this research focus on these two European network databases because of their aim is to show the different innovative transport solutions developed and deployed first-hand, and learn from peers and experts working in the field. All the projects in these databases are upload directly by the municipalities that have managed these projects making the available information more clear and completed.

From this first part of the research, a map (Figure 1-5) of the main European city logistics solutions has been developed with a data sheet for each project (available on:

https://www.google.it/maps/@50.610941,5.3221534,5z/data=!4m2!6m1!1s12kYmWGtMyjiOhb-HqjOK2j-e3LY?hl=it&authuser=0).

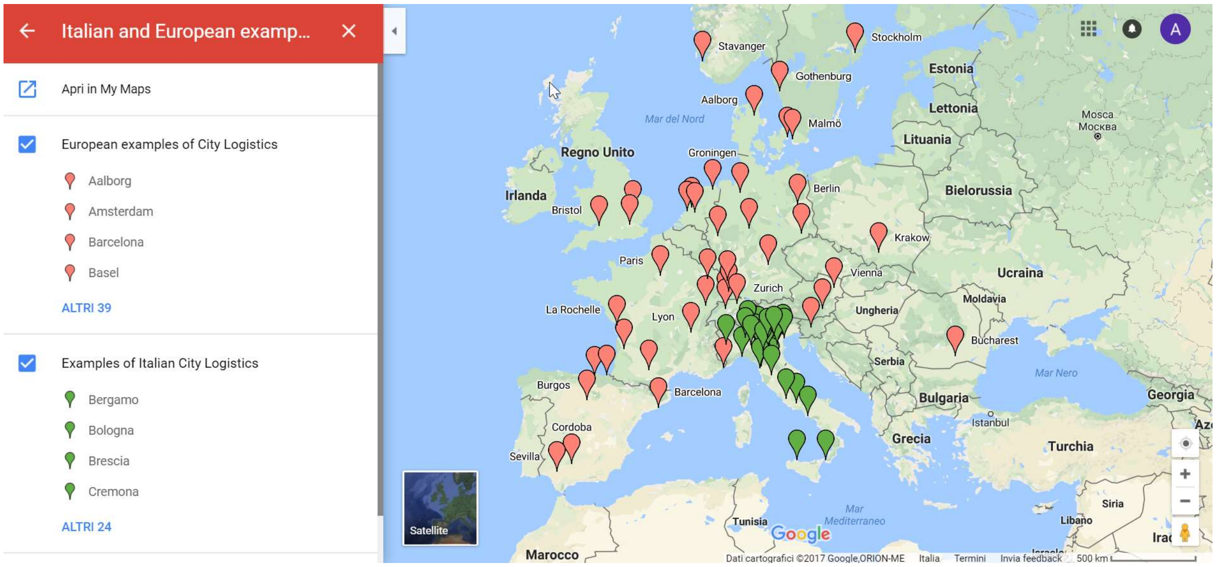

Figure 1-5 Maps of the main European city logistics projects (author's elaboration).

In particular, for each initiative within the databases a sheet has been drawn up (Figure 1-6) defining the starting date, the project status (i.e., active, pilot, failed), and a brief description using the secondary data (i.e., European projects reports and networks reporting database such as Civitas, Eltis, Citylog, Bestfus, C-Liege, the Internet sites of local administrations, or articles from magazines and newspapers).

One of the main obstacles in building this map was the difficulties in finding information on the current state of the project. In fact, many initiatives have been interrupted or concluded, but no information on the motivation for this interruption of experimentation can be found. In particular, it is difficult to understand if a project finished because it was a pilot with a limited life span (i.e. with termination already planned) or because of other reasons, such as lack of funds, incorrect cost overruns, incorrect dimensioning of the infrastructure, or lack of stakeholders' interest.

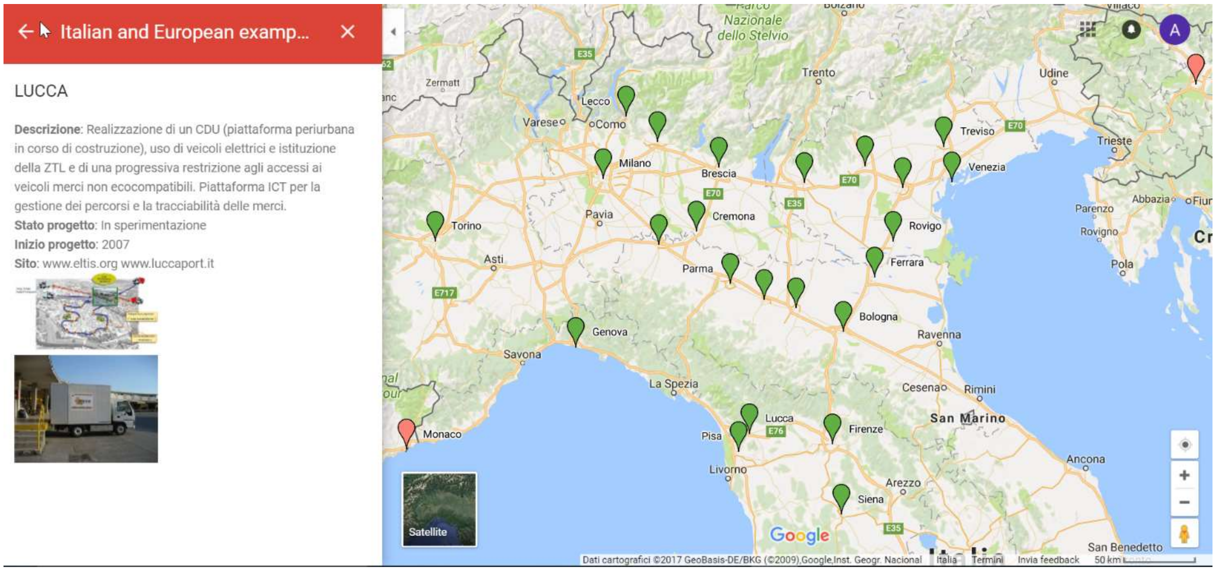

Figure 1-6 Example of the information sheet of an Italian city logistics project

According to the previous outputs of the main European projects databases, to the scientific literature review (Muñuzuri, Larrañeta, Onieva, & Cortés, 2005) and also to the practitioners (Regione Lombardia, 2014) the solutions that found larger application belong to four main categories:

- **Access restrictions:** access restriction measures include actions to prevent or restrict access to the city or to certain areas of the city (typically the historic centres). Restrictions can be imposed on the size (i.e. height and width), weight or type of fuel of the vehicle engine (i.e. gasoline, methane, electric). The appealing of this type of intervention is their relatively low investment, which relates essentially to communication initiatives, the update of road signs and billboards. However, if the control is automated (i.e. via cameras), the investment may be substantial. On the other hand, however, it should be noted that the costs are not negligible relative to the human, technological and financial resources necessary for the supervision of the activities, the authorization procedures (if present), and checks of the compliance with the limitations.

- **Infrastructures:** infrastructure measures include interventions to increase the endowment of physical structures available for the activities of urban freight distribution (i.e. city warehouses, urban consolidation centres, terminals for modal shift or infrastructural solutions for the e-commerce such as the parcel lockers). The construction of new facilities (i.e., warehouses) or the conversion of existing structures for freight intended use, usually aimed at those involved in different processes from the urban distribution of goods. These measures are intended to increase the level of efficiency and potential of urban freight distribution.

- **Regulations:** this category includes measures and initiatives activated by local governments to regulate different aspects of the movement of commercial vehicles, aiming at changing the preferences of the users concerning the use of infrastructure and urban transport. The final goal is to reduce congestion in urban centres through a more efficient use of available infrastructure. The definition of some limited traffic zones in which the access to the freight vehicles is limited (e.g., time windows, weight restrictions, type of fuel restrictions) or the payment of a toll are typical regulations solutions.

- **Technologies:** technological measures include initiatives based on the use of innovative technologies, both in the ICT applied to urban mobility (info-mobility), and in the propulsion systems of commercial vehicles (hybrid or electric vehicles). About info-mobility, technology today offers possibilities that were unthinkable a few years ago. With the opening of information systems in public administrations and municipal companies it will be possible to have access to a vast amount of data that will enable a systemic perspective in decisions making process, and not only local optimization. Connected to this, it is possible to create solutions and adaptive rules, that take advantage of forecasts based on historical data and real-time decision making (for example, on routes, traffic times, etc.).

In addition to the analysis of European projects above described, articles within the scientific literature describing city logistics solutions in more detail have been identified. In particular, for each solution different articles were selected. Table 1-1 shows the result of this initial bibliographic search.

Type of solutions	Solution	References
Access Restrictions	Limited traffic zones, Time windows, Fuel/vehicle type restrictions, Limited traffic zones, Weight/height/width restrictions	Anderson, Allen and Browne, 2005; Quak and de Koster, 2009; Deflorio *et al.*, 2012; Stathopoulos, Valeri and Marcucci, 2012; Qureshi *et al.*, 2014; Ghilas, Demir and Woensel, 2016
Infrastructures	Urban Consolidation Centres (UCC) / Urban Distribution Centres (UDC)	Marcucci and Danielis, 2008; Chwesiuk, Kijewska and Iwan, 2010; Van Rooijen and Quak, 2010; Browne, Allen and Leonardi, 2011; Allen *et al.*, 2012; Muñuzuri *et al.*, 2012; Olsson and Woxenius, 2014; Tozzi, Corazza and Musso, 2014
	Use of naval / railway / airport terminals for modal shift	Regué and Bristow, 2013; Engström, 2016
	B2C Solutions (e.g. pick-up points, parcel lockers)	Ducret, 2014; Morganti, Dablanc and Fortin, 2014; Cepolina and Farina, 2015;

		Wang and Zhou, 2015
Regulations	Road pricing	Friesz *et al.*, 2008
	Night/off-peak deliveries	Holguín-Veras, 2008; Sathaye, Harley and Madanat, 2010; Bjerkan, Sund and Nordtømme, 2014; Sánchez-Díaz, Georén and Brolinson, 2017
	Multifunctional lanes	Yang and Moodie, 2011
	Loading-unloading bays	Dezi, Dondi and Sangiorgi, 2010; Boussier *et al.*, 2011; McLeod and Cherrett, 2011; Alho and de Abreu e Silva, 2014; Gatta and Marcucci, 2016
Technology	ITC / ITS management systems for freight transport	Ambrosini and Routhier, 2004; Crainic, Ricciardi and Storchi, 2004; Taniguchi and Shimamoto, 2004; Sheu, 2006; Crainic, Gendreau and Potvin, 2009; Giannopoulos, 2009; Toh, Nagel and Oakden, 2009; Flamini, Nigro and Pacciarelli, 2011; Anand *et al.*, 2012; Schau *et al.*, 2016
	Electric vehicles	Delaître and De Barbeyrac, 2012; Roumboutsos, Kapros and Vanelslander, 2014; Lebeau, Macharis and Van Mierlo, 2016
	Cargo-bikes	Gruber, Kihm and Lenz, 2014; Sadhu, Tiwari and Jain, 2014; Schliwa *et al.*, 2015; Heinz *et al.*, 2016

Table 1-1 Main examples of city logistics solutions in literature.

This table is not exhaustive of all the city logistics solutions existing in literature, it only suggests, for each different solution, some examples in order to show the diversity of action and solutions. Furthermore, this preliminary research of different examples of city logistics solutions immediately highlighted the great fragmentation and the complexity of the problem, as well as the variety of scientific approaches to address them. The necessity to better clarify these aspects, led to the decision to start a systematic literature review on this topic (Chapter 2).

2. Literature review on urban freight transport

Even though urban logistics has been investigated for several years, the subject is still evolving because of the continuous changes in citizens' habits, such as e-commerce, the greater sensitivity to environmental issues, and the unceasing technological evolution enabling new delivery scenarios, such as electric vehicles with greater autonomy, drones and driverless vehicles. However, despite its importance and increasing relevance, the literature on urban logistics is quite fragmented, thus hindering a holistic understanding of the topic and making it difficult to highlight the gaps that must be addressed.

The projects review showed in the paragraph 1.2 revealed a lack of a comprehensive and systematic literature analysis that consolidates the knowledge on urban logistics and that analyses the development of the discipline. On the contrary, there are many contributions in many different fields, and a considerable number of papers that refer to very specific problems such as the distribution of drugs in pharmacies or specific typologies of food such as milk in urban centres, schools, and hospitals as well as other urban logistics problems related to temporary construction sites or large events. Moreover, the above-mentioned projects review highlighted many city logistics projects that have not gone beyond an experimental stage.

Therefore, in this research it was necessary to perform a systematic literature review (SLR) on urban logistics from a logistics and management perspective trying to consolidate the existing literature, and to identify the gaps and barriers. A SLR allows for a detailed longitudinal analysis of literature, and thus enables the consolidation of the knowledge on urban logistics and the analysis of the development of the discipline to provide potential directions for future research development. Gathering information from 104 papers published in peer-reviewed journals for the period 2000 to 2015 (the complete list of paper is reported in the Appendix 1), the performed SLR provides an overview of the main topics and their evolution over time as well as a review of the main methodologies employed.

In the next paragraphs, the SLR research method, the results of the systematic literature review, and the trends and gaps emerged from the study are discussed.

2.1. The SLR research method

This Systematic Literature Review (SLR) has been performed because of the very fragmented literature about city logistics, in which it is difficult identify the main research topics, the trends and the gaps of the research in this field.

The SLR has already been used to consolidate emerging topics in other areas, such as the role of logistics in achieving agility (Gligor & Holcomb, 2012), the extensions of sustainability codes to suppliers (Gimenez & Tachizawa, 2012), and the servitization of manufacturing (Lightfoot, Baines, & Smart, 2013).

A review earns the adjective "systematic" if it is based on clearly formulated questions, identifies relevant studies, appraises their quality and summarizes the evidence by use of explicit methodology (Khan, Kunz, Kleijnen, & Antes, 2003). In this way, a SLR overcomes the perceived weaknesses of a narrative review and become more reliable and repeatable by other researchers (Tranfield, Denyer, & Smart, 2003). In particular, an SLR provides a replicable research protocol (Denyer & Tranfield, 2009), and the detailed documentation of the performed steps within the SLR enables in-depth evaluation of the conducted study (Kupiainen, Mäntylä, & Itkonen, 2015) .

This study followed the guidelines provided in the most prominent articles (Kitchenham & Charters, 2007; Kitchenham & Brereton, 2013; Touboulic & Walker, 2015; Tranfield et al., 2003) to devise a robust and replicable study. In particular, a three-step protocol was developed to identify a valid procedure for performing an automated research, so the SLR can be replicated by other researchers (Kitchenham & Charters, 2007).

Step 1: Inclusion/exclusion criteria

First, a preliminary list of the keywords and inclusion criteria were identified, and the concept of urban logistics was defined by its various synonyms (e.g., urban freight transport, urban delivery) in the keywords, making this research as much comprehensive as possible (Wong, Wong, & Boon-itt, 2015). Moreover, the research focused on papers published in refereed journals in the field of logistics, transportation, management and economics for the period 2000 to 2015. The starting year (i.e., 2000) was selected because, even though the term "city logistics" first appeared in the 1990s (Nemoto, 1997; Wissmann, 1994), the major push in the scientific literature began around the year 2000.

Conference proceedings and grey literature (i.e., technical reports and works in progress) were excluded from the corpus of investigated papers. Therefore, this review was limited to peer-reviewed publications to gain consistency between themes and sources (Touboulic & Walker, 2015) and to ensure the quality of the selected papers (Burgess, Singh, & Koroglu, 2006). Although excluding grey literature or relevant conference proceedings from the sample can limit the assessment of recent, ongoing research efforts, this approach has often been followed by other researchers to ensure the level of quality of the included material (Gimenez & Tachizawa, 2012; H. Netland & Aspelund, 2014).

The search was launched based on a first set of criteria reported in Table 2-1. Major publishers' databases and library services, such as Elsevier, Sciencedirect, Emerald, Springer, and Wiley, were selected for the analysis. Following this, a double-blind control test was performed (Tranfield et al., 2003) on 50 papers to verify and refine the selection criteria. At this point of the analysis, it was essential to involve other supporter researchers in order to ensure, as far as possible, the objectivity of the paper selection made, the repeatability and the avoidance of possible bias given by a subjective interpretation of the literature review topics (Touboulic & Walker, 2015). More specifically, a manual selection of the articles was carried out at first to verify their coherency with the inclusion and exclusion criteria. Each paper that met disagreement regarding inclusion/exclusion criteria was carefully read and discussed with other supporter researchers until agreement was reached. This led to the definition of the final selection criteria as reported in Table 2-1. The query was then launched again, which resulted in the extraction of 298 papers (Figure 2-1).

Inclusion Criteria	Description
Keywords	urban logistics, city logistics, urban freight, last mile delivery, urban delivery
Language	English
Document types	Articles
Source types	Peer-reviewed journals
Time Interval	2000 – 2015

Table 2-1 Inclusion criteria for paper selection during the Step 1.

Step 2: Selection based on title and abstract

Each researcher reviewed the titles and abstracts of selected papers. Following a discussion among the researchers, papers out of the research scope were removed from the corpus. In particular, 161 papers that did not focus strictly on urban logistics but focused instead on issues such as health, urban planning, climate change or social aspects and papers that adopted an approach other than logistics or management, such as mathematical, chemical, energy, or an environmental approach, were excluded.

Step 3: Selection based on full text and snowballing

The last step of the protocol involved the refining of the list of selected papers. After reading the full versions of candidate papers, 34 papers were not in the scope of this research (i.e., engineering management approaches to urban logistics) and were excluded.

Then, the references of all selected papers have been checked according to a backwards snowballing approach, and the most cited papers (i.e., those with more than five citations from other papers already selected) were identified. If these most cited papers were missing from the corpus and coherent with inclusion criteria, they were added (Browne et al., 2011), leading to a final corpus of 104 papers.

The results in terms of the number of papers resulting from the selection protocol in the SLR are summarized in Figure 2-1. The complete list of papers is available in the appendix 1 of this thesis.

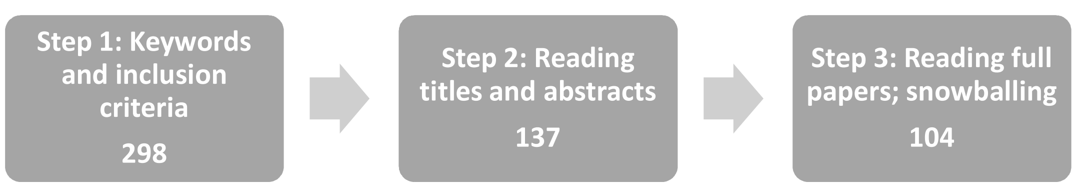

Figure 2-1 Systematic literature review results according to the selection protocol.

Considering the corpus of 104 papers, some descriptive statistics were first calculated. The details of these analyses, and an explanation of how they were performed, are reported in the next sections of this chapter.

2.2. Descriptive analysis of the corpus

Figure 2-2 presents the distribution by year of the papers in the corpus. Despite some fluctuations in the considered time interval, it is possible to appreciate the steady increment of contributions regarding urban logistics in the last five years, thus confirming the current relevance of the subject.

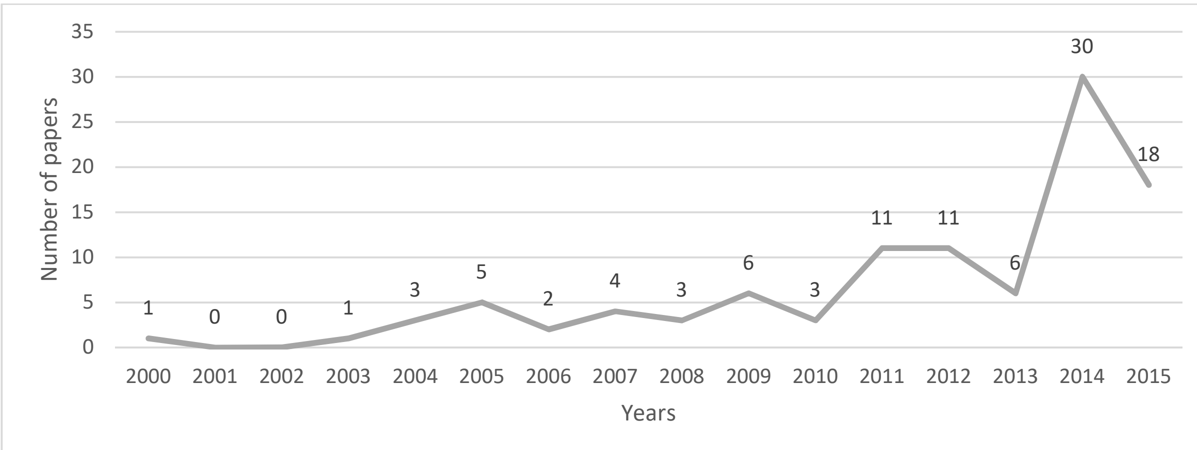

Figure 2-2 Papers distribution by year of publication.

The peak in the number of papers in 2014 is partially due to a special issue titled "Managing Freight in Urban Areas", which appeared in the journal, "Research in Transportation Business & Management" (Volume 11, July 2014). In fact, 12 papers of the corpus appeared in this special issue (which accounts for 15 papers in total). However, as the scope of the special issue was exceptionally broad and featured a wide range of topics, it did not bias the subsequent analyses. Moreover, even excluding the papers published in this special issue, there would still be a peak of 18 articles in 2014, again confirming the growing trend in the articles published on urban logistics through the years. Altogether, the corpus includes 24 different journals (Figure 2-3), and there is no dominant journal, even if urban logistics is primarily addressed by journals focus on transportation as their main subject of investigation. Despite this, the corpus also comprises journals focusing on management, operations and logistics disciplines.

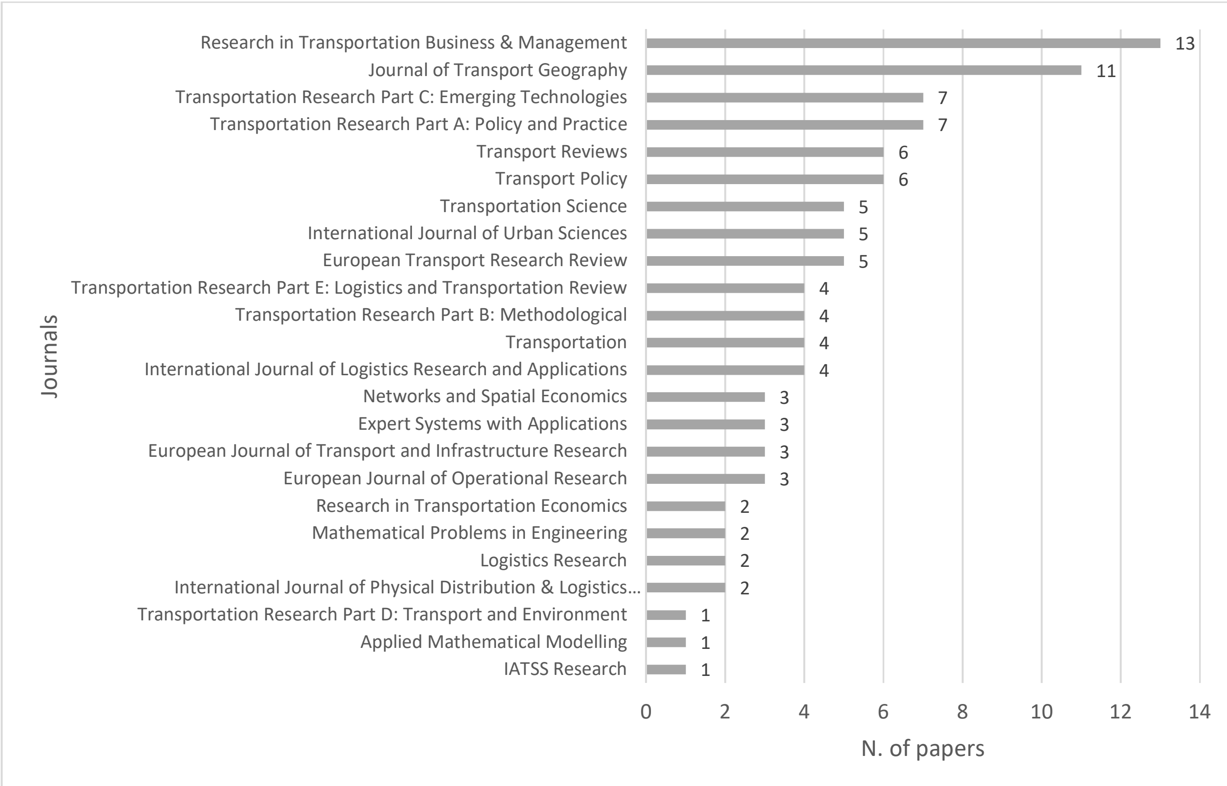

Figure 2-3 Number of papers for each journal in the corpus.

2.3. Main research trends

Figure 2-4 displays the frequencies of the various topics as they appeared in the papers. Each paper can address more than one topic. The three most frequently addressed topics resulted the following:

- *Vehicle Routing Problems Solutions:* adaptation of VRP models to urban logistics problems (e.g., the location of a UCC, location of loading/unloading bays, optimal vehicle routing from the UCC, etc.)
- *Stakeholder involvement:* as stakeholders are fundamental to the success of city logistic projects, several papers describe how to engage stakeholders in the development of city logistic projects (Gatta & Marcucci, 2014; Macharis, Milan, & Verlinde, 2014).
- *Solutions Performance Assessment and Comparison:* definition and assessment of quantitative (e.g., CO_2 emissions and other air pollutants, congestion, load factors, delivery times, etc.) and qualitative (e.g., liveability, accessibility, etc.) indicators to measure the impact or compare city logistics projects.

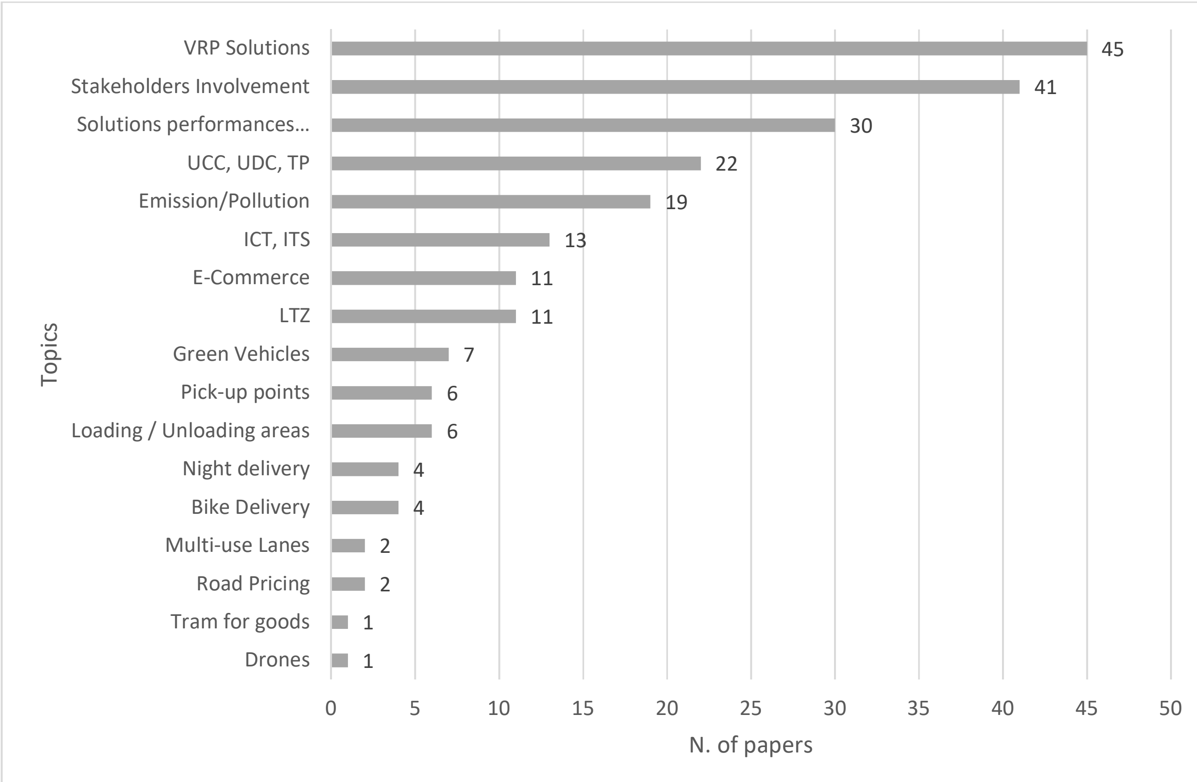

Figure 2-4 Number of papers addressing each topic (each paper may refer to more than one topic).

The research efforts devoted to the different topics has changed over the years (Figure 2-5). At the beginning of the considered time period (2000 to 2005), only certain topics were being explored, such as, VRP solutions, ICT (especially on-board GPS instruments), emissions, and performance and solutions comparisons.

In a second phase (2006 to 2010), there was a growing interest in topics such as stakeholder involvement, LTZ, UCC, and VRP on a more complex level than those considered in the first phase and also encompassing time window problems and stakeholder behaviour. In recent years (2011 to 2015), the focus on some topics, such as road pricing and reserved lanes, has diminished whereas many new topics have surfaced, such as bike delivery, pick-up point deployment, e-commerce and drone deliveries, among others, while the interest related to stakeholders, VRP and evaluation of urban logistics solutions performances has remained substantially unchanged.

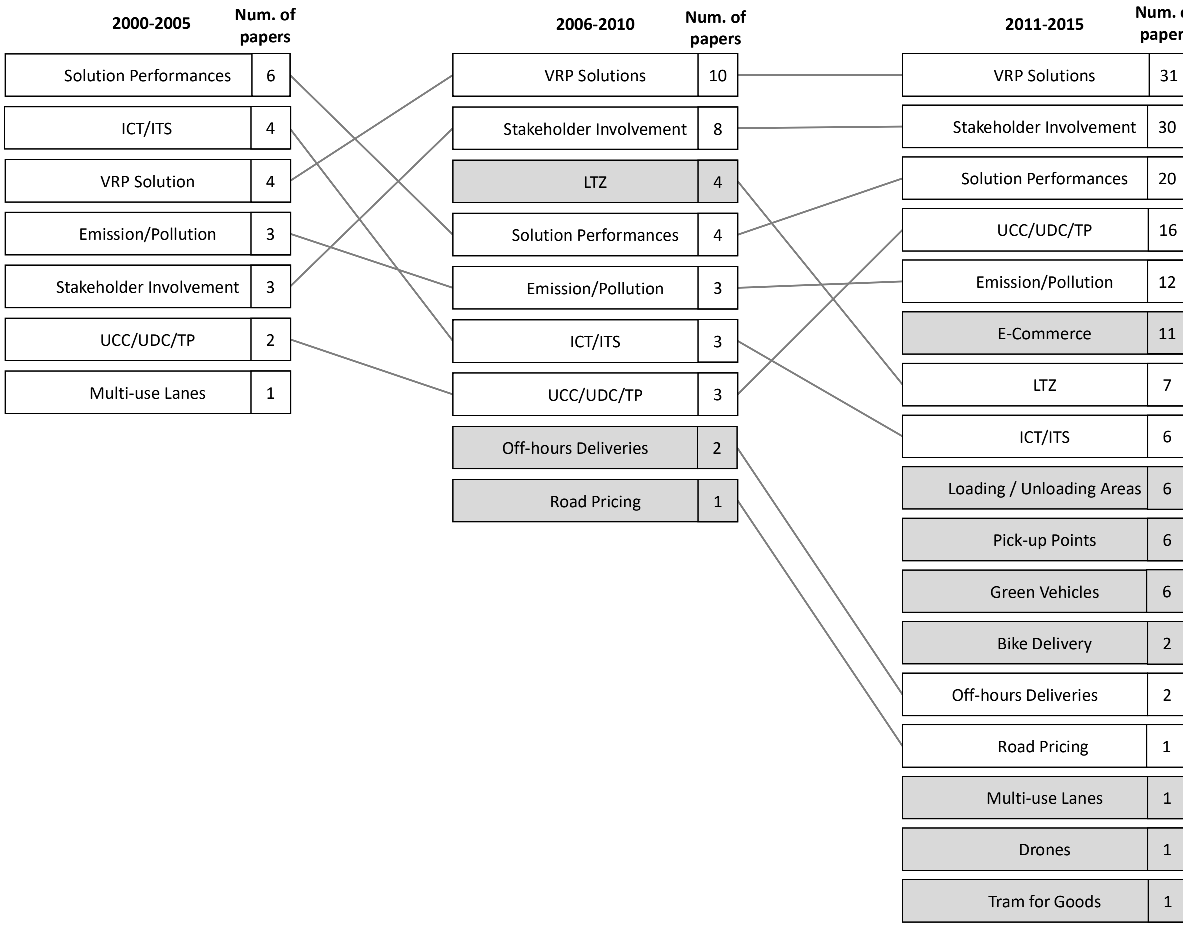

Figure 2-5 Topic relevance over time (grey background = new topics addressed during the studied period).

2.4. Main research methodologies employed and relationship with the main topics

To classify the research methodologies, the analysis followed an inductive approach similar to the one previously discussed for the classification of the topics. Each researcher independently classified the methodologies used in the papers based primarily on his/her own experiences. Then, following a discussion, a common classification table was developed by revising and grouping the various methodologies identified. For instance, case studies (single or multiple) and interviews were merged because they are always used jointly in the corpus.

The resulting classification is reported in Figure 2-6, where each paper could adopt more than one methodology, although the maximum number of methodologies per paper in the corpus is two.

In addition to the research methodology, it is important to consider the type of data collected and used in the study. Therefore, the analysis distinguished between qualitative (or unstructured) and quantitative (or structured) data. Quantitative data can be quantified and verified and are amenable to statistical manipulation. Such data include traffic flows, flows of goods, distances covered by a vehicle, orders from a store or from e-commerce customers. Conversely, qualitative data, such as opinions of stakeholders, cannot be measured directly. More simply, quantitative data define whereas qualitative data describe.

By using the two types of data together, a more complete examination of the phenomena being studied can be conducted (Creswell, 2009). The results of the classification of data are reported in Figure 2-7.

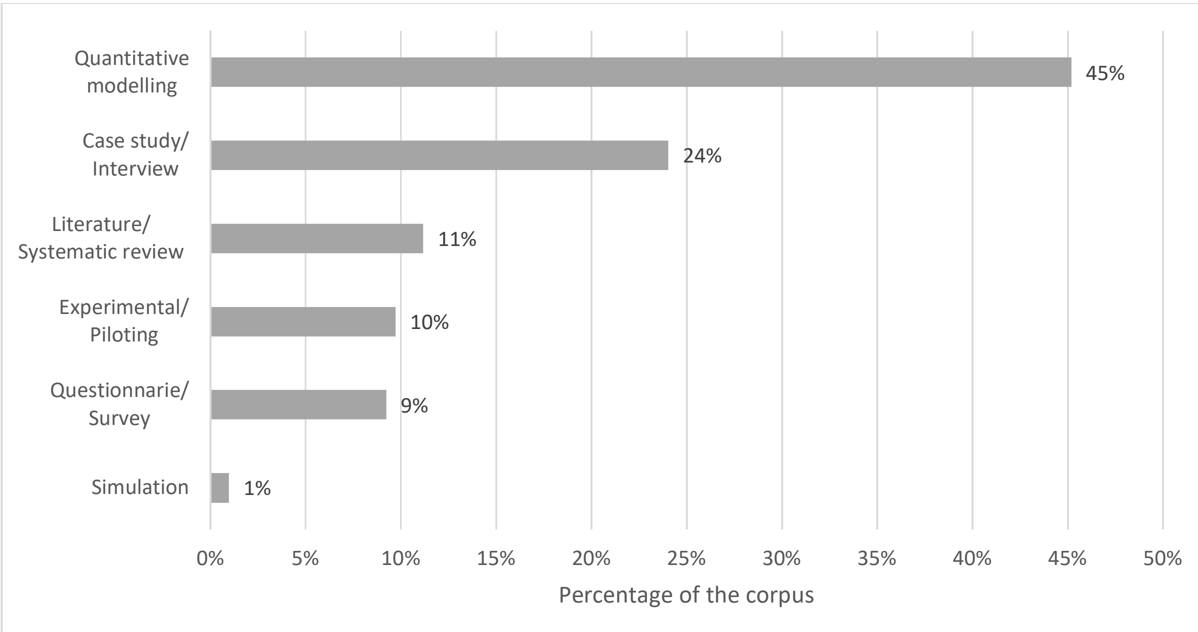

Figure 2-6 Types of research methods in the corpus

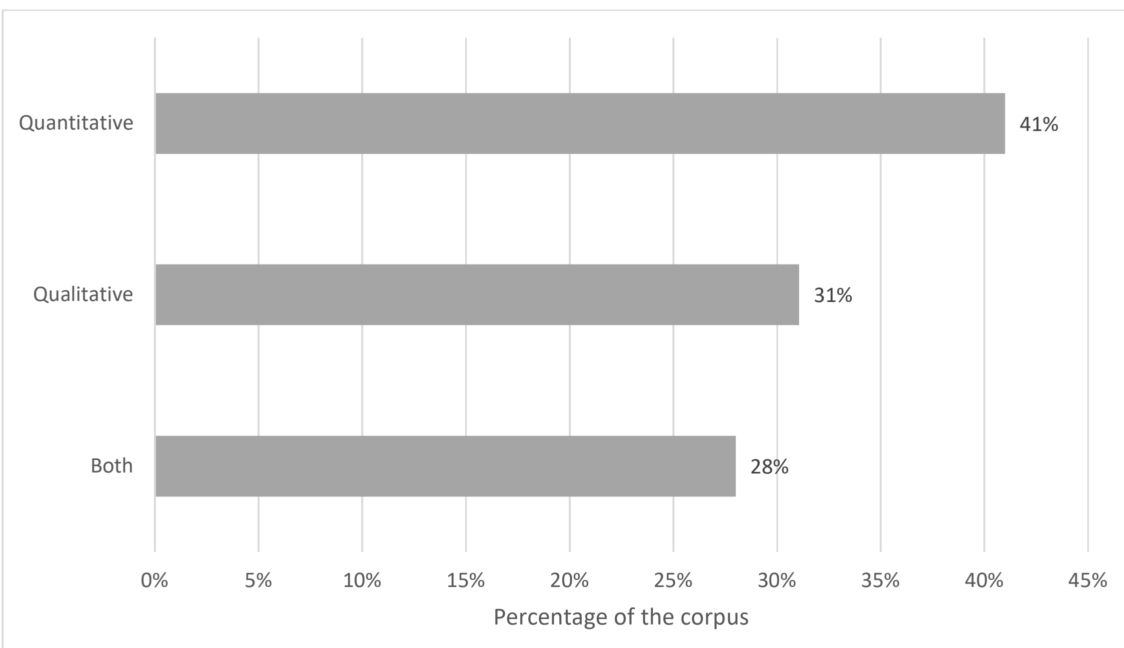

Figure 2-7 Types of data used

Finally, linking the research methods with the topics covered in each paper, the results are displayed in Table 2-2 (the numbers are referred to the paper that are numbered and listed in Appendix 1). It is observed that there has been little use of experimental or piloting projects, surveys or literature review. As expected, quantitative models are mainly used for routing and scheduling problems to optimize deliveries (Taniguchi and Shimamoto, 2004), identify the optimal location of UDCs (Yang and Moodie, 2011) or predict the behaviour of the actors involved through agent-based decision-making methods (Baindur & Viegas, 2011). Similarly, interviews and case studies are more often used to assess the potential effectiveness of urban logistics solutions (Himanen, Lee-Gosselin, & Perrels, 2005), to make comparisons between cities (Ballantyne et al., 2013) and to understand the views of the stakeholders involved in the decision-making process (Lindawati et al., 2014). Questionnaires and surveys, however, are adopted to a lesser extent compared to the previously discussed methodologies. These findings reveal potential areas for the application of surveys to extend and generalize findings resulting from the interviews and quantitative models. Only a few cases of reviews were found, and they are mainly reviews of projects rather than reviews of literature (Allen et al., 2012) and are, for the most part, related to the ITS or e-commerce sector (Giannopoulos, 2009; Vanelslander, Deketele, & Van Hove, 2013). This result highlights the applied rather than the theoretical character of urban logistics as a discipline that focuses on solving specific problems rather than on developing a shared vision of the key concepts. This last finding supports the contribution of this SLR by providing a solid foundation of knowledge regarding urban logistics, as this analysis did not find evidence of literature reviews with a broad or longitudinal perspective of urban logistics.

	Case study/ Interview	**Quantitative Modelling**	**Questionnaire / Survey**	**Experimental / Piloting**	**Literature / Systematic Review**	**Simulation**
VRP Solutions	19, 20, 32, 50, 51, 64, 67, 71, 73, 90, 99	1, 2, 4, 11, 12, 15, 20, 21, 22, 25, 26, 29, 30, 34, 36, 37, 39, 42, 57, 59, 61, 66, 74, 84, 95, 98, 99, 103	10, 45	32, 44, 52, 59, 71, 72	24, 70	83
Stakeholder Involvement	7, 16, 19, 33, 40, 41, 49, 51, 62, 67, 69	2, 9, 13, 17, 18, 21, 25, 31, 34, 35, 37, 42, 46, 48, 58, 65, 68, 82, 86, 91	14, 63, 87, 101	13	43, 75, 78, 93, 94	-
Solution Performance Assessment and Comparison	7,8,19,41,49,55	1,2,5,15,17,21,34,58,65, 89	63,80,101	5, 47, 52, 72	3, 43, 93	-

UCC/ UDC/ TP	50,64,67,100, 104	5,13,25,30, 37,42,48,98,103	10,45,97	5,13,28,52,85	70,92	-
Low Emission and Pollution Technologies	7,33,50, 56,81,88, 104	1,2,12,35,36, 59,82,88,96	-	27,28,44,59	92	-
ICT/ITS	32, 64	2, 4, 12, 29, 39, 57, 59	10	32, 59	3, 23, 24	-
LTZ	19, 20, 41, 64	20, 22, 25, 48, 57	-	47, 52	75	-
E-Commerce	76, 81, 88, 102	53, 60, 61, 74, 77, 84, 88	102	76, 85	-	-
Loading / Unloading Areas	32, 33	35	45, 80	32, 85	-	-
Pick-up Point	81, 88	53, 61, 74, 88	-	85	-	-
Green Vehicles	33, 104	82, 95, 96	38	-	-	83
Off-hours Deliveries	67	17, 46	-	27	-	-
Bike Delivery	56,79,100, 104	-	-	-	100	-
Road Pricing	-	17,48	-	-	-	-
Multi-use Lanes	-	6	38	-	-	-
Drones	90	-	-	-	-	-
Tram for Goods	-	95	-	-	-	-

Table 2-2 Topics and methods used in the corpus

2.5. Main contributions driving the development of the literature

To complement the analysis illustrated in the previous sections, a citation network analysis was performed to provide a better and deeper understanding of the literature in the field of urban logistics. Citation Networks (CNs) are directed, acyclic networks whose nodes represent existing papers and whose edges connect citing papers to cited ones. A CN enables the analysis of the links between papers to discover relationships and to support the identification of connected topics. Furthermore, citation networks can also direct researchers to specific knowledge areas and related subfields/communities.

The assumption underpinning a CN analysis is that researchers in the same field tend to cite each other to better position their work in the field (Hummon & Doreian, 1989). Intuitively, the papers most recognized as key contributors in the field are those receiving many citations from other authors.

The CN in Figure 2-8 was built from the corpus of the 104 papers resulting from the SLR and from analysing the respective citations. This paper adopted the convention according to which each arrow goes from the cited document to the citing document, thus representing the "is cited by" relationship. The CN comprises a large, well-connected portion of the collection as well as a set of isolated nodes, those listed on the right of the figure. These papers are those that neither cite nor are cited by the rest of the papers in the collection.

Among these, approximately two-thirds are relatively recent works (published after 2012), for which the citation count can be influenced by their reduced exposure on the research stage. Regarding the less recent contributions, some do not focus exclusively on urban logistics, and others are based on grey literature (e.g., reports, projects, conferences) or are extremely focused on niche topics. Still, as all of these isolated papers do not cite any other paper in the corpus, they will likely not become nodal works in the development of the discipline (Lucio-Arias & Leydesdorff, 2008; Yin, Kretschmer, Hanneman, & Liu, 2006). Therefore, they were disregarded in the following analyses.

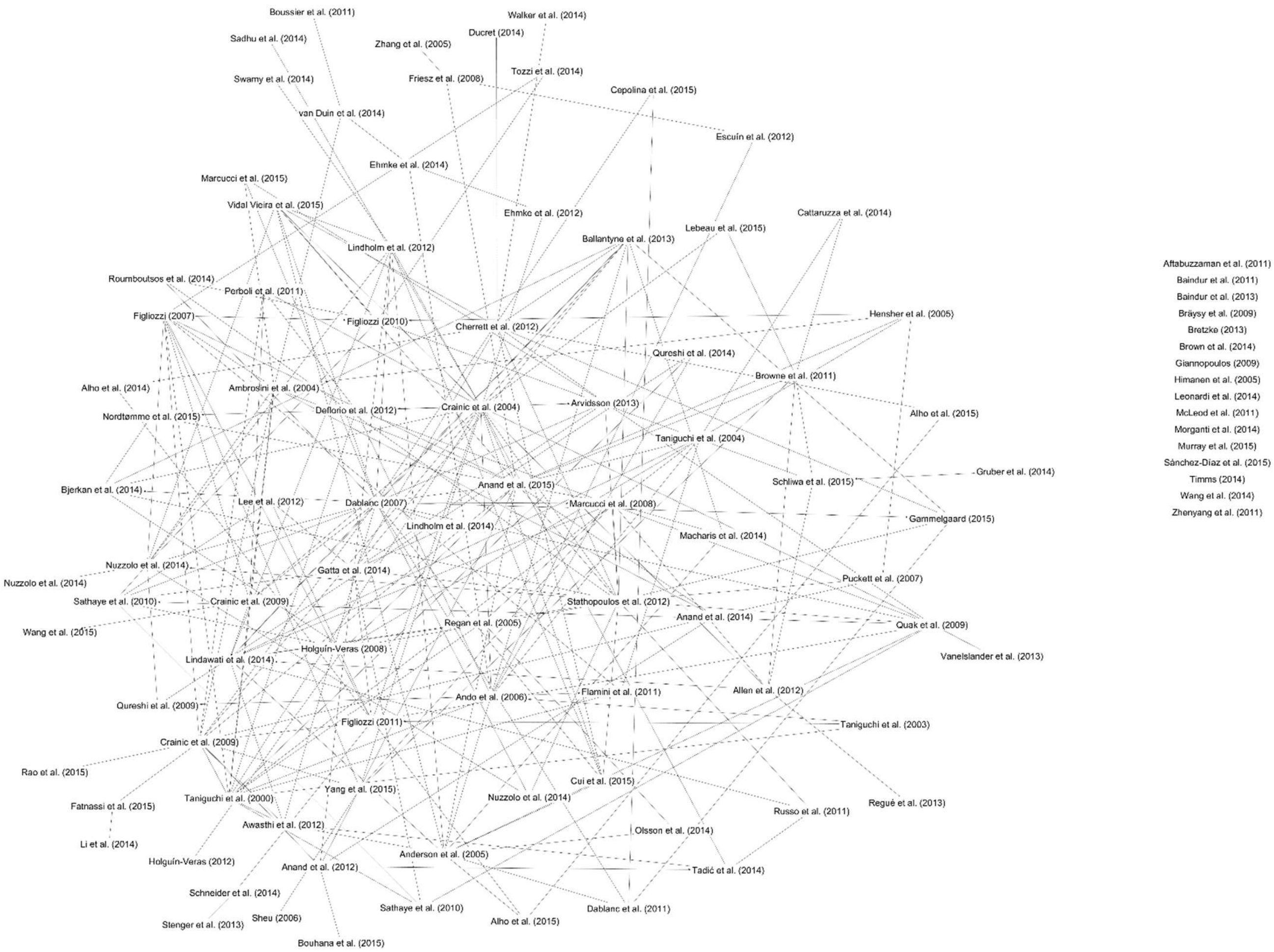

Figure 2-8 Citation network from the corpus

To summarize the relevance of the papers in the corpus using the CN analysis, three indicators for each paper were computed:

1. Global Citation Score (GCS): total number of citations as in Scopus (i.e., from other papers within or outside the CN); the GCS measures the overall relevance of the paper in the literature.
2. Local Citation Score (LCS): number of citations only from other papers in the CN; the LCS measures the relevance of the paper in the corpus.
3. Closeness Centrality (CC) within the CN (Sabidussi, 1966): measured as the average distance in terms of the number of nodes to cross, as computed using the Pajek software, to reach all other papers; the CC identifies those papers that are highly cited or are cited by other highly cited papers and are therefore assumed to provide a relevant contribution to the theory (Colicchia & Strozzi, 2012).

Table 2-3 reports the ten most frequently cited papers according to the GCS, and it also reports the related LCS and CC values. As displayed in Table 2-3, the values of the different indicators are not always coherent with each other. For example, a highly cited paper can have a lower CC than a paper cited fewer times. The discrepancy in the consequent rankings can be attributed to the fact that the LCS and GCS consider only direct citations, whereas CC considers all the citation links within the CN (Colicchia and Strozzi, 2012).

Title	Authors & Year	Journal	GCS	LCS	CC
Advanced freight transportation systems for congested urban areas	(Crainic et al., 2004)	Transportation Research Part C: Emerging Technologies	100	20	0.3062
Goods transport in large European cities; difficult to organize, difficult to modernize	(Dablanc, 2007)	Transportation Research Part A: Policy and Practice	99	22	0.2678
Intelligent freight-transportation systems; assessment and the contribution of operations research	(Crainic et al., 2009)	Transportation Research Part C: Emerging Technologies	77	3	0.0310
Intelligent transportation system based on dynamic vehicle routing and scheduling with variable travel times	(Taniguchi et al., 2004)	Transportation Research Part C: Emerging Technologies	76	5	0.0662
Urban logistics - How can it meet policy makers' sustainability objectives?	(Anderson et al., 2005)	Journal of Transport Geography	73	12	0.1714
An evaluation methodology for city logistics	(Taniguchi & Heijden, 2000)	Transport Reviews	58	14	0.3185
Travel time reliability in vehicle routing and scheduling with time windows	(Ando & Taniguchi, 2006)	Networks and Spatial Economics	58	6	0.0618
Objectives, methods and results of surveys conducted in the field of urban freight transport: An international comparison	(Ambrosini & Routhier, 2004)	Transport Reviews	47	9	0.1811
Dynamic game theoretic model of multi-layer infrastructure networks	(Zhang, Peeta, & Friesz, 2005)	Networks and Spatial Economics	46	1	0.0174

Table 2-3 Top 10 most frequently cited documents in the corpus (ranked by GCS)

2.6. Main path analysis

A main path analysis (MPA) highlights the structural backbone in the development of a scientific field and thus provides a dynamic perspective by analysing the chronological network of citations (Colicchia and

Strozzi, 2012). In fact, the main path in a CN highlights those papers that build on prior papers, and it continues to act as an authority in reference to later works (Yin et al., 2006; Lucio-Arias and Leydesdorff, 2008). Indeed, citing previous works and being cited by subsequent literatures positions a paper in relation to other papers (Hummon and Doreian, 1989), and by defining these positions, main path algorithms make the structural backbone of a literature visible (Lucio-Arias and Leydesdorff, 2008).

The main path is built by calculating the connectivity of the links in terms of their degree centrality and outlining the path formed by the nodes with the highest degree. In terms of a CN, this degree measure considers the number of citations a paper receives (out-degree, according to our convention of arrow direction) as well as the number of cited references in the paper (in-degree). The main path is then constructed by selecting the papers with the highest scores until an end document is reached, that is, a paper that is no longer cited or one that contains no further references within the considered set (Batagelj, 2003). The main path resulting from the CN built from the considered collection is depicted in Figure 2-9 (using the Pajek software).

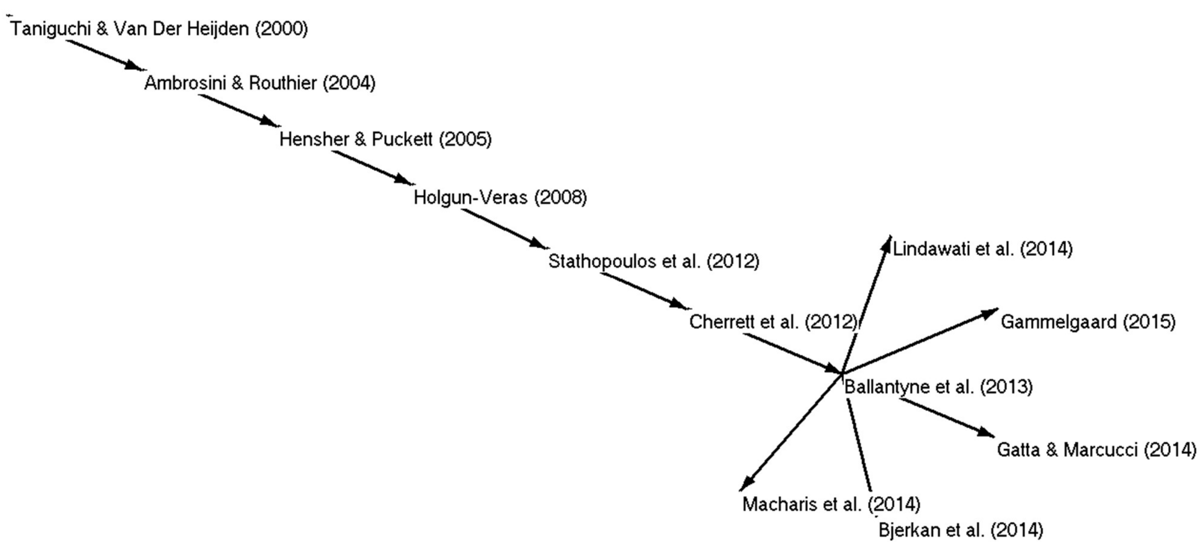

Figure 2-9 Main path in the corpus

Analysing the main path, it is possible to conclude that the early research on urban logistics focused mainly on the evaluation of different methods to minimize adverse impacts on the environment and on the cost of freight transport in urban areas (Taniguchi and Van der Heijden, 2000; Ambrosini and Routhier, 2004). Later, it was realized that one of the main factors for the effective implementation of new solutions in urban freight was collaboration with stakeholders (Holguín-Veras, 2008; Puckett, Hensher, Rose, & Collins, 2007). In urban logistics, there are various stakeholders (traders, traditional transporters, couriers, eco-friendly trucking companies) who, while pursuing the same objective, that is, the on-time delivery of goods to the destination point, have different operating characteristics and interests that make collaboration complex. For instance, (Holguín-Veras, 2008) investigate the acceptability of off-hour deliveries by stakeholders and highlight the negative elements as well as the benefits of delivery over time for both carriers and traders. Later, among the various stakeholders, the role of public authorities is analysed (Stathopoulos et al., 2012) as is the need to consider the characteristics of the different flows (Cherrett et al., 2012). Finally, Ballantyne et al. (2013) analyse the studies conducted in different countries, specifically, Sweden, the UK, and the Baltic region, and find that public authorities do not have a good understanding of urban logistics issues because they have not yet found an assessment method that simultaneously considers the complexity of the different solutions and the conflicting interests of the stakeholders. From this point, the main path shows the various ways different authors have tried to find this assessment method for decision making. (Macharis et al., 2014) proposed a multi-actor multi-criteria analysis (MAMCA). According to Bijerkan et al. (2014) and Lindawati et al. (2014), the solution lies in overcoming barriers to collaboration among industry players so they can support themselves in the implementation of new green solutions. Gatta and Marcucci (2014), however, suggest the use of an agent-specific approach that takes into account the specific characteristics of each stakeholder. Finally, (Gammelgaard, 2015) emphasizes that the implementation of new urban logistics solutions follows the same dynamics as those of the change process by alternating dialectical processes and purposes. Accordingly, this finding implies that the correct implementation of urban logistics solutions does not follow a linear path from start to finish but instead proceeds by trial and error.

2.7. Main research gaps

Reading the paper that constitute the main corpus of the SLR many gaps have been highlighted by the researchers. These gaps are put in evidence as some barriers that obstacle the efficiency of the existing city logistics models and solutions. These are the same barriers also emerged analysing the previous European city logistics project, interviewing the operators in the city logistics field (i.e., carriers and retailers) during the *Bergamo Logistica* projects and discussing with other researchers during the international conferences. These gaps could be summarized as follow.

2.7.1 Stakeholders' involvement

An element that emerges from the different analysis in literature and practice is that there is not yet a shared and final perspective on how to involve stakeholders in the making of decisions related to urban logistics. While recent research has begun to address this issue (Gatta & Marcucci, 2014; Macharis et al., 2014), still much research in urban logistics is focused on improving the technical aspects of the existing solutions or on proposing new solutions. Scholars seem to forget that many cities are still in the beginning phase of their urban logistics journey and are thus more focused on solving conflicts among stakeholders or that urban logistics solutions may sometimes appear simple from a technical perspective but be difficult to implement in a context where there are many stakeholders, none of whom wield sufficient power to enforce decisions (Leonardi, Browne, Allen, Zunder, & Aditjandra, 2014).

Consequently, greater attention must be given to the development of new methods to support decision making for the ex-ante evaluation of the possible solutions and must taking into account the interests and preferences of the different stakeholders. Because stakeholder management has been addressed in numerous areas, such as corporate social responsibility and project management, it may be possible, from both the theoretical and practical perspective, for urban logistics researchers to inherit from the large body of research already available (Bryson, 2004; Fassin, 2012). For example, the literature suggests different ways to identify, classify, prioritise and engage the stakeholder based on certain key characteristics, such as power, interest, and legitimacy (Mitchell, Agle, & Wood, 1997). Such an approach should be complemented by a toolkit for stakeholder management actions, such as approach, communication, and involvement, that are able to bring on board the key stakeholders (Stathopoulos et al., 2012).

In this way, rather than passively include the opinion of all stakeholders, the project owner, for example, the municipality, can attempt to proactively influence and orient the attitude of the key stakeholders, thus enhancing the value and the acceptability of an urban logistics solution (Dablanc, Diziain, & Levifve, 2011). (Pinto, Golini, & Lagorio, 2016), for example, on the basis of the interactions with stakeholders, explain how a progressive approach that begins with data sharing and then moves towards easier solutions, such as loading/unloading bays optimization, and finally to more complex solutions, such as the UDC, can result in greater commitment from the stakeholders.

2.7.2 Common frameworks and data sharing platforms

As emerged from the analysis there is great interest regarding the comparison of different urban logistics solutions. Several papers based on in-depth case studies performed on single cities can be found, thus generating a useful library of experiences (Hesse, 2007) . Nevertheless, these case studies are difficult to compare, as the time frame, data collection methods and contexts of the cities are often quite different. To overcome this problem, it would be useful to develop common frameworks to collect and analyse data. For instance, the creation of shared platforms, such as the Smart City Logistic (http://smartcitylogistics.org/), can help not only to create a common framework of analysis of urban logistics cases but also to incentive public and private stakeholders to provide data that, when combined, can prove to be extremely valuable to them (Golini & Landoni, 2014). Through these platforms, researchers and policy makers can collect, analyse and visualize relevant urban logistics data for policy development (Merchán et al., 2015). Moreover, it would be possible to consider simultaneously the different characteristics of the urban ecosystem, such as the distribution of the population (Marcucci, Gatta, & Scaccia, 2015) or the presence and extent of historical centres that feature a higher tourist concentration and narrow streets (Muñuzuri et al., 2005), a combination that can heavily affect the distribution of goods. Finally, the possibility to access and visualize the data (e.g., Public Participatory Geographic Information Systems) can create the conditions for an effective stakeholder engagement process (White, Kingston, & Barker, 2010).

The creation of data-sharing platforms would also solve another problem that emerged from the analysis, specifically, the lack of data concerning vehicle traffic flows and deliveries (i.e., delivery points, times, routes and frequencies, and load factors). Furthermore, privacy and confidentiality issues, such as license plates of

vehicles being subject to privacy regulations and data sharing, which increases the risk of information spill-over to competitors, may also negatively influence the availability of data. Consequently, models are rarely tested extensively and with sufficient sample sizes. Moreover, some models require real-time data (e.g., dynamic vehicle routing) that are often unavailable.
However, given the increasing availability of sensors spread throughout the cities (e.g., cameras, ground sensors, user provided data) as well as the progress of the Internet of Things (IOT) applications, data should become increasingly more available over time. In a matter of a few years, the problem of a lack of data could be completely reversed, becoming, instead, an excess of data issue. New analytical competences, such as those related to data manipulation and data mining, will be required of scholars in the urban logistics field. Accordingly, it may be relevant to introduce new tools and methods typical of big data analysis to exploit additional information regarding deliveries and traffic flows.

2.7.3 Urban logistics ecosystem

It is also possible to observe that there is a lack of studies analysing urban logistics as a whole and comprehensive issue. An urban logistics solution, in fact, does not live in isolation, but rather, it represents a system within a larger system of systems, for example, a city. Nevertheless, exploring the literature, researchers usually adopt a traditional analytical or reductionist approach, which aims at decomposing all systems into ultimately simple indivisible parts to be investigated separately. Although effective in general descriptions, the main drawback of reductionism is that it neglects the reciprocal effects that the separated parts can have on each other as well as the circular feedbacks involving the different parts (Daellenbach, McNickle, & Dye, 2012).

According to a systemic view, the interaction among these parts (including stakeholders, as discussed in the previous section) yields the actual performance of the whole system; therefore, the critical factors or the success/failure of an urban logistics solution, particularly from the economic point perspective, should sometimes be sought outside the solution itself. For example, (Rose, Mollenkopf, Autry, & Bell, 2016) contend that understanding the interactions between urban logistics providers and the urban environment can allow for better management both of urban space and transportation firms.
In this respect, the interaction of two key components of an urban logistic ecosystem, namely, people and technology (together referred to as socio-technical systems), can be an interesting and relevant focus for future research. In particular, rather than taking a technology-centred approach, researchers could examine how people are influenced by and react to different technologies (Nam & Pardo, 2011), which may lead to systems that are more acceptable to end users and deliver better value to stakeholders (Baxter & Sommerville, 2011). In (Lagorio, Pinto, & Golini, 2017) the urban logistics ecosystem is described starting form a biological-

economical approach to better analyse all the components and their reciprocal interactions, with a focus on stakeholders' interactions.

Maybe the investigation of the impact of urban logistics solutions should be conducted using a systemic (or holistic) approach as such a perspective allows for focusing on the interactions between the elements rather than on the elements themselves (Senge, 2006) . For example, the integration of a UDC and the related freight activities should consider the effects on other solutions that are either directly or indirectly related to urban logistics to highlight the reciprocal benefits and drawbacks and to identify potential synergies. In particular, this could be fundamental when infrastructures are involved in the CL solutions. In fact, infrastructures are used both by mobility and freight transport, so a decision taken regarding infrastructure could affect also the other transport flows that used the same infrastructure. For example, if the Municipality decides to change some parking destination from private car parking to loading-unloading areas this decision could affect the traffic congestion in that area. So, it could be very important to consider all the interactions in the city logistics ecosystem before planning a city logistics solution: models supporting the decision-making in city logistics have to take these aspects in consideration.

3. The research

3.1. Objectives of the research and research questions

As explained in the previous chapter, transport of goods in urban areas is a very complex topic. Complexity, in addition to being linked to the causes described in the previous chapters (e.g. increased urban population, increased fragmentation of demand, and frequency of deliveries, mainly due to the spread of e-commerce) is also connected to other factors, such as the lack of data on transport flows, the lack of a common systemic vision, the presence of a large number of stakeholders with different, and often conflicting, interests and goals. These factors, also identified as research gaps, emerged from both the literature and the analysis of the European projects, and are at the core of the complexity of urban freight transport, posing challenges and obstacles to design and implement solutions to optimize the delivery process.

These three gaps, and the possible ways to overcome them, are the core of this research work (Figure 3-1).

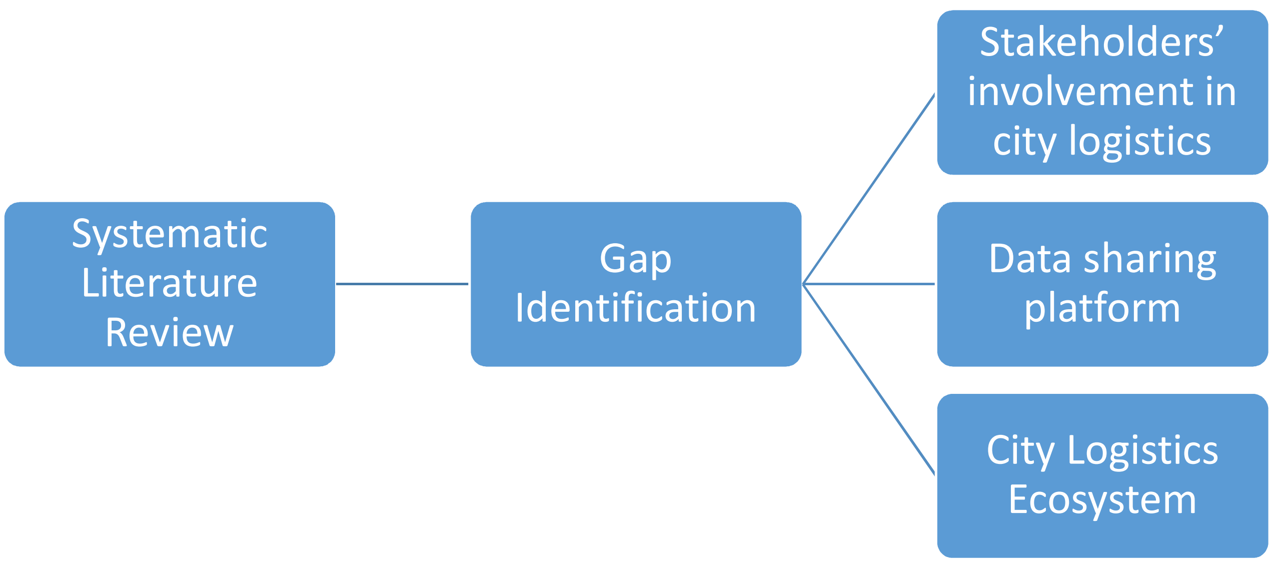

Figure 3-1 The research structure

In particular, the presence of a high number of stakeholders involved in city logistics initiatives (i.e. traders, transporters, traditional couriers, innovative and "green" transport companies) with contrasting interests (Lindawati, van Schagen, Goh, & de Souza, 2014) makes more complex the definition of a unique, shared and compromised set of optimized solution for urban freight transport. Furthermore, stakeholders' commitment is fundamental with respect to the success of any city logistics initiative (Holguín-Veras, 2008). However, even when all the relevant stakeholders are involved, they might not have all the correct information or skills to understand the nature and complexity of the problems, and tend often to overlook fundamental aspects

(Lindholm & Behrends, 2012). To overcome these issues, several approaches dealing with stakeholder engagement have been proposed (e.g., MAMCA) (Macharis et al., 2014) with the aim of evaluating different stakeholders' opinions in the decision-making process. However, before starting the decision-making process, stakeholders need a help in understanding and managing the complexity of their business ecosystem (Adner, 2013). Indeed, without having proper data about the flow of goods passing through the city and the incidence that this has on the mobility of people already present in the urban streets, it could be complex for the actors operating in the field to think about a global optimization of the entire urban transport system and not just of the operations parts that directly concern their daily work. Thus, to address these gaps, a decision-making support tool could be useful to stakeholders to use the few data available to understand the solutions that best fit the urban context in which they operate. These considerations led to the first research question:

(RQ1) Is it possible to support stakeholders in analysing CL solutions fitting their necessities applying some already existing and consolidate decision-making methods?

The second gap is one of the most evident in the city logistics field. Data are necessary in the freight urban transport context because before start reasoning about urban freight optimization it is necessary to understand the entity of the problem: how many shops are there in the city? How are they located in the city? Are there any commercial districts and residential districts? How many deliveries each shop receives every day and every week? From how many suppliers? Which are the regulations and restriction applied to the freight transport such as limited traffic zones, time windows and access restrictions?

The freight demand estimation as well as the urban logistics infrastructures (i.e., road networks, loading/unloading areas, warehouses) are certainly the most complex part in designing a city logistics solution. In this case, the complexity is mainly due to the lack of data. In order to be able to estimate in the most possible correct way the demand, it is not only necessary to have the answers to the previous questions. A substantial quantity of additional data is necessary, such as data and information regarding the quantity of goods for each delivery, the type of vehicles used for the deliveries, the duration of the delivery operations, the size of the store, the number of employees and the number of suppliers. All these data are also necessary for a long observation period to avoid the effects of seasonality. These data are not easy to collect because it would require a great effort from retailers who often do not have the time to collect this information and often, if the business is run by employees, they do not even know these data. Moreover, the information should be updated annually in order to record any eventual business cuts and estimate long-term demand trends. In order to do this data collecting, the effort in economic terms and dedicated time is huge. However, most of the forecasting methods of demand, from the more general (e.g. moving average method, trend projection method, exponential smoothing method) to the specific ones for the urban freight transport described in the previous paragraph, are based on historical series or, in any case, start to foresee future demand from previous real data.

However, in the smart cities context, in fact, there are lots of new technologies for real-time traffic monitoring (Hancke, Silva, & Hancke, Jr., 2012) that enable to apply modern high-tech technologies such as sensors and big data techniques, but that, in the specific case of the urban freight transport, is not of great help at the moment. That is because the main technologies and sensors applied in the city could give lots of information about traffic flows, sensors could detect all the freight vehicles and distinguished them from the mobility flows, but as explained in the chapter 1, to have information about urban freight transport is not sufficient to know only the dimension of the freight traffic flows, but more data are necessary about the number of deliveries that each shop received.

Thus, even if there are many fixed devices (all-weather, all-day, and fixed location) that have been proposed to obtain traffic information in the field of sensor technology, such as inductive loop detectors, infrared instruments, ultrasonic arrays, microwave radars, magnetic sensors and video image processing systems (Bao et al., 2016), these could give very poor information for the freight traffic.

In the absence of data, information about freight traffic flows could be useful, especially when it is necessary to not planning detailed city logistics solutions, but it is necessary to have a rough estimate of the number of heavy vehicles circulating in the city or in a part of it. For example, a rough demand estimation may be very useful in the early stages of designing an urban distribution centre: it is crucial to find the demand to serve to keep the centre's costs below the possible gains. Many European distribution centres have failed because they have not been able to reach the number of participants needed to meet the minimum demand necessary to ensure the distribution centre's livelihood (Lagorio, Pinto and Golini, 2016b). Thus, it necessary to define all the elements that could be involved in the freight urban context and collect information regarding them. Doing this it could be useful to include in the elements both the urbanistic aspects (e.g., road networks, warehouses and shop location, parking) both the regulations aspect (e.g., limited traffic zone, access restrictions, time windows) in order to have a global view of all the urban logistics context.

(RQ2) Is it possible to define a database platform in which it is possible to collect, consult and update as many existing data as possible regarding urban freight transport?

The third gap emerged from the literature review is the absence of a common frame, an urban logistics "ecosystem", a context definition in which is possible to take into consideration all components of urban freight transport. Urban transport of goods is only a part of a huge transport systems in which all the specific transport sub-systems (e.g., mobility, freight transport, transit) coexist and interact among them.

This aspect become particular important when solutions take in consideration element of the city that are used by different actors such as infrastructures (i.e., road networks, parking, warehouses). Thus, when a city logistics solution is planned, it is necessary to take in consideration all the elements of the city that this solution could affect in order to realize a solution as much efficient as possible. Therefore, a third research question addressed in this research is as follows:

(RQ3) How is it possible to optimize city logistics infrastructures in a harmonious and coherent way with respect to the entire city logistics ecosystem?

Figure 3-2 shows how the research questions fit into the research structure.

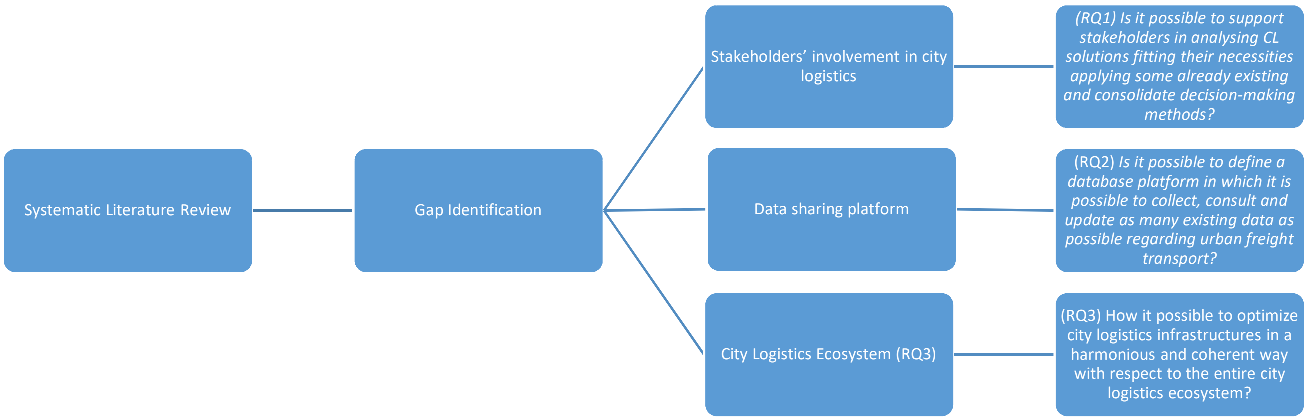

Figure 3-2 Research questions over the research structure

3.2. Research workflow

As showed in paragraph 3.1, the main goal of this thesis is to find solutions to fill the main gaps emerged in the city logistics field. The importance of these gaps does not emerged only from the literature review showed in the chapter 2: the interaction with some operators and practitioners carried out in the last recent years (i.e., the carriers, couriers, retailers and municipality representatives), the exchange of viewpoints about projects and research with foreign researchers studying this topic, as well as the participation into international conferences, have contributed to substantiate the identified gaps.

This thesis, and the outcomes achieved are also the results of the participation in the following projects:

- some local project experiences (Bergamo 2.035, Smarter Citizens),
- some international visiting experience and collaboration (Instiut Henry Fayol of the École des Mines de Saint-Étienne, Luxembourg Institute of Science and Technology (LIST), Amsterdam University of Applied Sciences, Harvard Graduate School of Design),

Table 3-3 shows all the scientific contributions written and published in these years. The results of these works are described and organised in this thesis in order to answer to the three research gaps illustrated in the paragraph 3.1.

Topic	RQ	Collaboration	Reference
City Logistics in Smart Cities	-	Bergamo 2.035	Lagorio, A., Pinto, R. Golini, R. (2014). Cap. 6 Bergamo Logistica (pp. 136-171), Bergamo 2.035, a new urban concept, ISBN 978-88-89555-36-1 .
City Logistics in Smart Cities	-	Bergamo 2.035	Lagorio, A., Pinto, R., Golini, R. (2014). City logistics issues in small-medium cities: an overview of the Bergamo case from an industrial engineering perspective. Proceeding of the XIX Summer School "Francesco Turco", Senigallia (AN), 9-12 September 2014.
Systematic Literature Review on City Logistics	-		Lagorio, A., Pinto, R., Golini, R. (2015). City logistics research streams: a systematic literature review. Proceeding of the XX Summer School "Francesco Turco", Napoli (NA), 16-18 September 2015.
Systematic Literature Review on City Logistics	-		Lagorio, A., Pinto, R. and Golini, R. (2016) 'Research in urban logistics: a systematic literature review', *International Journal of Physical Distribution and Logistics Management*, 46(10), pp- 908-931.
Stakeholders' Involvement	**RQ1**		**Lagorio, A., Pinto, R. & Golini, R. (2015). Urban freight transport in an Italian mid-sized city: The Bergamo case from inception to stakeholders' involvement. Proceeding of URBE (URban freight and BEhaviour change) Conference 2015, ROMA, 1-2 October 2015.**
Data support	RQ2	LIST – Tudor Research Center (Luxembourg)	Golini, R., Guerlain, C., Lagorio, A. & Pinto, R. (2015). An assessment framework for city logistics in mid-sized towns. Proceeding of URBE (URban freight and BEhaviour change) Conference 2015, ROMA, 1-2 October 2015.
Data support	**RQ2**	**LIST – Tudor Research Center (Luxembourg)**	**An assessment framework to support collective decision-making on urban freight transport. Submitted to: TRANSPORT (ACCEPTED).**
Urban Distribution Centers	RQ3		Lagorio, A., Pinto, R., Golini, R. (2016). Urban distribution centers: Doomed to fail or optimal solutions for last mile deliveries? Proceeding of the XX Summer School "Francesco Turco", Napoli (NA), 13-15 September 2016.
Loading/unloading areas location	**RQ3**		**Pinto, R., Golini, R. and Lagorio, A. (2016) 'Loading/unloading lay-by areas location and sizing: a mixed Analytic-Monte Carlo simulation approach', *IFAC-PapersOnLine*, 49(12).**
Decision-making support	RQ3		Lagorio, A., Pinto, R., Golini, R. (2017) "Urban Logistics Ecosystem: A system Framework for stakeholders in urban freight transport Projects". Proceeding of the 20th IFAC World Congress, Toulouse, France, 9-14 July 2017.

Loading/unloading areas location	RQ3		Urban freight loading/unloading lay-by areas location and sizing. **Submitted to: International Journal of Production Research.**

Figure 3-3 Research contributions

In particular, Chapter 4 addresses the RQ1, reporting the results discussed in the paper "Lagorio, A., Pinto, R. & Golini, R. (2015). Urban freight transport in an Italian mid-sized city: The Bergamo case from inception to stakeholders' involvement. Proceeding of the URBE (URban freight and BEhaviour change) Conference 2015, ROMA, 1-2 October 2015". This paper illustrates the application of a tool for decision support typical of the product development field, the House of Quality (HoQ), to the stakeholder theory in the field of goods transportation in urban areas. The HoQ allows taking into account both the needs of the stakeholders and the possible city logistics solutions. This method also allows viewing the priorities between the demands of the stakeholders in order to understand which solutions are best suited to solve the most urgent needs.

The RQ2 is addressed in Chapter 5, which reports the results discussed in the paper "Golini, R., Guerlain, C., Lagorio, A. & Pinto, R. (in press). An assessment framework to support collective decision-making on urban freight transport. Transport". This paper proposes a framework that supports the collection and classification of information about the features of a city relevant to urban freight transport. The information is organized in a framework of 28 different layers that are then stored in a Geographical Information System (GIS) tool to enable efficient data retrieval and effective information graphical display. The resulting GIS tool thus represents a decision support system for urban freight transport problems, providing decision makers and stakeholders with a wide range of easy to understand information aimed to support the identification and preliminary evaluation of city logistics solutions. The framework is repeatable, reliable and applicable to other European cities. To illustrate the benefits attainable, prototypical real-scale tests based on the framework have been realized in two mid-sized European cities: Bergamo (north of Italy) and the city of Luxembourg. For both cities, data were mainly collected from publicly available sources and organized according to the framework. The data and information collected have been used in collaboration with the stakeholders in order to identify the priorities of intervention and evaluate alternative city logistics solutions.

Regarding the RQ3, in these years several papers were presented: one regarding the city logistics ecosystem treated as a global decision-making support framework and others regarding particular city logistics solutions involving infrastructures where the ecosystem aspect is fundamental to evaluate the impact that these solutions could have on the other elements and actors of the city. This latter aspect is particularly relevant because it directly involves the operations activities and consequently could arise great interest among the practitioners that operated in this field. To illustrate one of the possible answer to the RQ3 in chapter 6 the paper "Pinto, R., Golini, R. and Lagorio, A. (2016) 'Loading/unloading lay-by areas location and sizing: a mixed Analytic-Monte Carlo simulation approach', IFAC-PapersOnLine, 49(12)." is presented. An improved version of this article was also submitted to International Journal of Production Research. In this paper, the focus is on the location and sizing of commercial loading/unloading parking in urban centres, where it is possible to park for a limited amount of time to perform loading/unloading operations and deliveries. The problem has been formulated and addressed with reference to a central district in the city of Bergamo, with a strong commercial presence, and characterized by significant problems of traffic congestion. The paper presents a mixed Analytic-Monte Carlo simulation approach in order to find an optimal distribution and relative sizes of the lay-by areas according to the demand and location of the business activities. The same model was also applied to the Oude Pijp neighbourhood of Amsterdam giving positive results (these are not included in this thesis).

4. Stakeholders' involvement in city logistics

City logistics projects inherently involve many logistics-related decisions along several dimensions: from the definition of the best place for locating logistics activities (such as urban distribution centres), to the last-mile delivery planning and execution; from the definition of limited traffic zones (LTZ) to the deployment of environmentally sustainable fleets of vehicles. Because of this, it is not always immediate and straightforward for stakeholders to attain shared and consensus-based decisions. In fact, this aspect constitutes one of the main gaps in the city logistics context, as discussed in chapter 2 and 3. This aspect also led to the *(RQ1) Is it possible to support stakeholders in analysing CL solutions fitting their necessities applying some already existing and consolidate decision-making methods?*

and constitutes the first topic analysed by this research thesis (Figure 4-1).

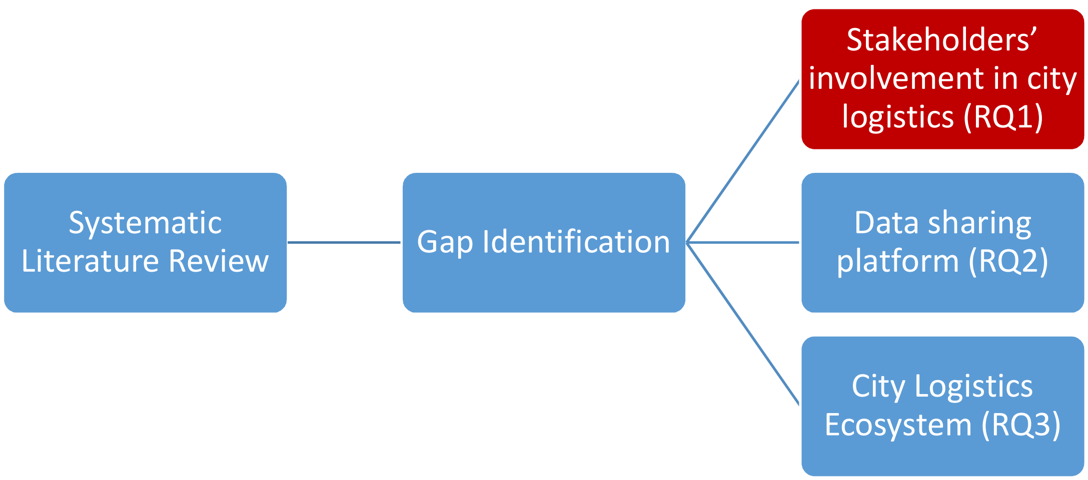

Figure 4-1 Research question 1 over the research structure

This chapter includes the results of the paper "Lagorio, A., Pinto, R. & Golini, R. (2015). Urban freight transport in an Italian mid-sized city: The Bergamo case from inception to stakeholders' involvement. Proceeding of URBE (URban freight and BEhaviour change) Conference 2015, ROMA, 1-2 October 2015". In particular, it illustrates the Bergamo case study. The focus is on the stakeholders' involvement in city logistics projects and the resulting initiatives that emerged from a co-creation process involving public authorities and private stakeholders, associations at different levels, research centres and common citizens, among the others (Stathopoulos et al., 2012).

This chapter also aim to provide a contribution in the area of decision-making support in the context of a city logistics project by illustrating the preliminary implementation of a specific method: The House of Quality (HoQ) method, first step of the Quality Function Development (QFD). The main reasons underpinning the adoption of the

HoQ are related to the empirical verification that, because of stakeholders with conflicting interests, the identification of the main hindering factors and priority actions to implement within a city logistics project could be very complex. Therefore, considering the well-known necessity to take into account the conflicting interests of the various stakeholders involved, the HoQ provides a replicable method for supporting decision-making processes in such a context. In particular, the HoQ method has been applied to the Bergamo case study to prioritize city logistics solutions, taking into account both the needs of the stakeholders involved and the characteristics of the available solutions.

4.1. Stakeholder theory in City Logistics Projects

Stakeholders' involvement at different stages of decision processes regarding urban freight transport is pivotal in order to provide applicable, effective and sustainable city logistics solutions (Da Blanc et al., 2011). Therefore, there are many difficulties to overcome when trying to set up working groups on these issues. Rare are not the cases in which, despite the presence of all the relevant actors, the city logistics initiatives do not go beyond the experimental stage because "stakeholder involvement required long-term perspective, time and careful effort to maintain interest among stakeholders" (Lindholm, 2014). A failure can happen also because both decision makers (i.e. public administrations, municipalities) and transport companies, do not have all the skills to understand the nature and complexity of the freight transport problem in urban areas, and tend often to minimize some of the issues that turn out to be fundamental (Lindholm and Behrends, 2012). In urban freight, transport have different stakeholders (traders, traditional transporters, couriers, eco-friendly trucking companies) that, while pursuing the same objective (the delivery of the goods on time to the destination point), have different operating characteristics that make collaboration complex (Lindawati et al., 2014). The differences in the management of transport operations determine different - and often conflicting - needs. For example, the interviews conducted for writing the case study discussed in this research show that bike couriers want stricter rules for the access in urban centres, and oppose the delivery time-windows. On the other hand, traditional carriers are favourable to the definition of time slots, in order to reduce the overlap with the urban traffic; still, they oppose restrictions on the weight and type of vehicle fuel.

To satisfy these major needs, there are different recent proposals in literature on approaches to stakeholder engagement (Macharis et al., 2014; Gatta and Marcucci, 2014). Even if any different city has different characteristic from a urbanistic and architectural point of view, there are some characteristics of freight transport in urban areas (presence of many stakeholders, time and space constraints of the access to the city center, the presence of many businesses in a confined space) that does not depend to the internal structure of cities but to the freight transport operations (Da Blanc, 2007); therefore, it seems possible to find methods replicable in other cities. To do so, however, applicable, feasible and effective city logistics solutions are needed: these solutions require a decision support system that take into account all aspects and all the needs of the stakeholders involved.

In the literature there are many examples of decision support systems, but they are often complex systems that require high technical and scientific competence (that the government and the stakeholders usually do not have. The application of the HoQ method could be an easier and an immediate way to take into account stakeholders needs giving more attention to the aspects that allow finding a compromise between the different requirements. The method of HoQ is also easy to understand for those who participate in decision-making, and can be replicated in other cases.

4.2. Methodology

Given the multitude of stakeholders involved with different goals, the various requirements they have and the different solutions that could be implement, a single case study was deemed as the right approach to investigate the phenomenon within its real-life context leveraging on multiple sources of evidence to understand its key success factors (Yin, 1994, Eisenhardt, 1989). Moreover, the single case study research method is particularly appropriate for exploratory studies discovering relevant constructs in areas where theory building is at the formative stages and for studies where the experiences of participants and context of actions are critical (Bhattacherjee, 2012), such as city logistics projects. Like other methodologies, the analysis of a single case study has its limitations. In particular, single case study methodology is less generalizable and it is more complex to verify the external validity than other methodologies, such as multiple case studies. However, these limitations are also positive factors because this methodology "sacrifices generalizability in favour of more in-depth analysis" (Lopes et al., 2017).

More in detail, as discussed in the previous paragraph, a decision method capable to take into account the conflicting interests of different stakeholders is needed. To this end, the Quality Function Deployment (QFD), in particular the first step of this process, the House of Quality (HoQ) method, was applied. In this research, HoQ is not used as a dominant methodology compared to potential alternative method, it was selected because it is a consolidate method already easily used by stakeholders in the product management field (Judi & Boon, 2010).

The QFD method, born in the 1972 for the design of an oil tanker by Mitsubishi Heavy Industries (Hauser & Clausing, 1988) is commonly used as a procedure that provides a visual tool for developing a product or process design based on customers' requirements (Judi & Boon, 2010). QFD, as a well-known method, has a large application area also within the sustainability framework, such as sustainable product development, improvement analysis and design process. Recently, it has been widely used also in the development of green supply chain to identify the priority actions to perform to make industrial processes and logistics more sustainable (Buyukozkan & Berkol, 2011).

In particular, the first part of QFD was applied in this research: the creation of a House of Quality that allows the evaluation of customer requirements and possible product changes to implement. In this case, the customer requirements are the stakeholders needs, what they would like to introduce or improve in the urban transport of goods to help and facilitate their work. Therefore, changes to implement in the product in this case are replaced by the possible city logistics solutions that fulfil the stakeholders' necessities in different ways and with different instruments.

It is also established that "*HoQ is a team-based method that draws upon the expertise of the group members to carefully integrate the voice of the customer in all activities of the company. (...) The true value of the House of* *quality is not the diagram. Rather, the true value lies in the group decision making, which requires that the team discuss and ultimately obtain a common understanding of the design problem.*" (Ulrich & Eppinger, 2012).

From its inception, the HoQ has been used for different purposes: in particular, three categories of HoQ functional fields have been identified (Sharma, Rawani, & Barahate, 2008):

- Primary functional field including HoQ usage in product development, customer requirement analysis and quality management system;
- Secondary functional field including HoQ usage in concurrent engineering, management sciences, planning, operation research, education, software and expert systems (including artificial intelligence, artificial neural network and fuzzy logic);
- Tertiary functional field including HoQ's functions such as construction, cost, food, the environment and decision-making.

Based on this final application in the tertiary field of the House of Quality as a method of analysis of a process and decision support, the HoQ was applied to the Bergamo case study in an innovative way as a tool to accompany the stakeholder theory in urban freight transport.

4.3. House of Quality Matrix

Relating the needs of the stakeholders and the possible city logistics solutions, a key element of the HoQ process is the definition of the HoQ Matrix. The definition of the various parts that compose the HoQ matrix (Table 4-1) is a complex procedure that is often carried out gradually in order to be better controlled. The main steps for the HoQ Matrix definition are reported in Table 4-1.

Step	Description
1: Customer Requirements	Customer requirements are information usually gathered through interviews with the customers in which they are encouraged to describe their needs and problems (Voice of the Customer).
2: Customer Importance weight	Adjacent to the requirements column is the importance weights column. Using values between 0.0 and 1.0, the weights establish how important the customer considers each requirement with respect to the other requirements. The importance weight sum to 1.0. This is a fundamental fact in order to derive the priority to give to technical requirements under. This formation is obtained through interviews or surveys.

Step	Description
3: Technical Requirements or Engineering Characteristics	This section is referred to the "Voice of the Company" because of it describes the product in the terms of the engineering characteristics and of the basic technical requirements. The QFD design team, who identify all the measurable characteristics of the product that they perceive related to the specified customer requirements, generates this information. An additional row is often included in this section to illustrate the direction of change in each of these variables, which is considered to result in an improvement in product performance.
4: Interrelationships or Correlation rating matrix	At the intersection of a row and column is a cell that is used to indicate the amount of correlation between a customer requirement and engineering characteristics. It is task of the QFD team to identify where these interrelationships are significant. The level of interrelationship discerned is weighted usually on a three-point scale: 1 (low), 3 (medium), or 9 (high) for positive correlation and -1, -3, -9 for negative correlation. The cell is left blank for no discernible correlation. The numbers 1, 3, and 9 are frequently used in practice, although other number schemes have been used.
5: Roof or Coupling Matrix	The triangular roof of the HoQ called the coupling matrix is used to identify where the technical requirements support (+) or impede (-) one another. Uncoupled engineering characteristics can be optimized, one by one, without affecting other engineering characteristics. Inversely correlate characteristics indicate that compromises will need to be made.
6: Technical Priorities	The relative importance of each technical requirements of the product in meeting the customer's specified needs can be simply calculated from the weightings contained in the Customer Importance Weights and interrelationship matrix sections. Each interrelationships weighting is multiplied by the customer importance weight. These values are then summed down the columns to give a priority score for each technical requirement.

Table 4-1 HoQ implementation steps. Source*: Product Design and Development, Karl T. Ulrich and Steven D. Eppinger. 5th edition, McGraw Hill, 2012*

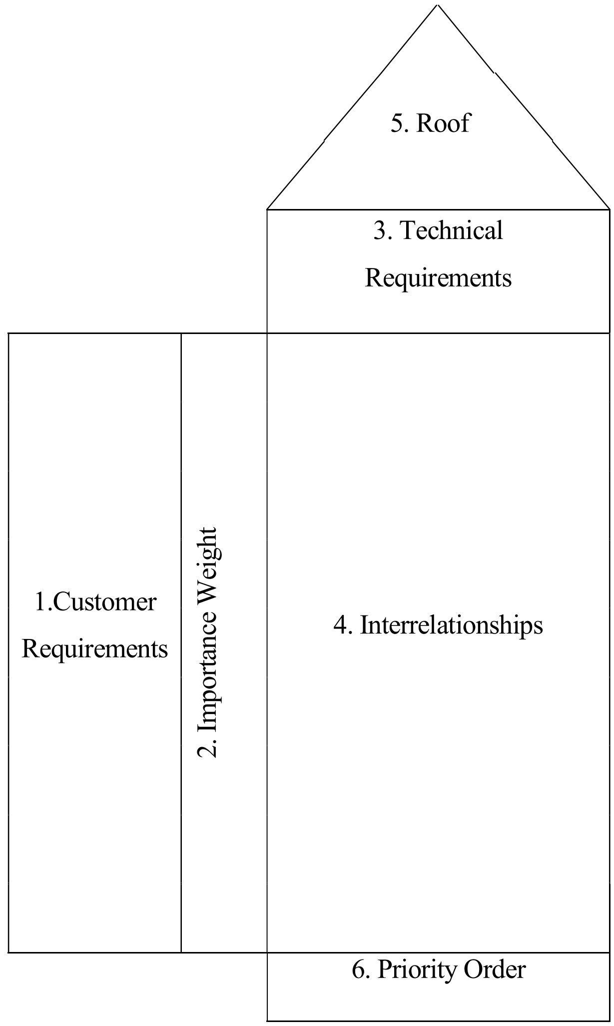

Figure 4-2 House of Quality Matrix Source: Product Design and Development, Karl T. Ulrich and Steven D. Eppinger. 5th edition, McGraw Hill, 2012

To apply the HoQ method to the Bergamo case, some considerations are needed. The customer requirements in this case became stakeholders' requirements: during the focus group with the actors operating in the sector realized for the Bergamo Logistica project and deeply described in the next paragraph, they explicate their needs to help, improve and facilitate their work related to the transport of goods in urban areas. Instead of the technical characteristics, in the matrix there are the different city logistics solutions results of a study on the main solutions proposed and experimented in literature, in European projects and in local projects already underway and discussed with stakeholders (Figure 4-2). Each solution also responds better to certain needs rather than others, and some solutions, if applied together, could generate trade-off.

The roof of the HoQ matrix is used to identify where the technical requirements support or impede one another (Table 4-1). In this case, instead of the roof an alternative system was used to highlight the solutions that could easily be implemented jointly. Next paragraphs illustrate how this model has been applied to the case study of Bergamo (Figure 4-3).

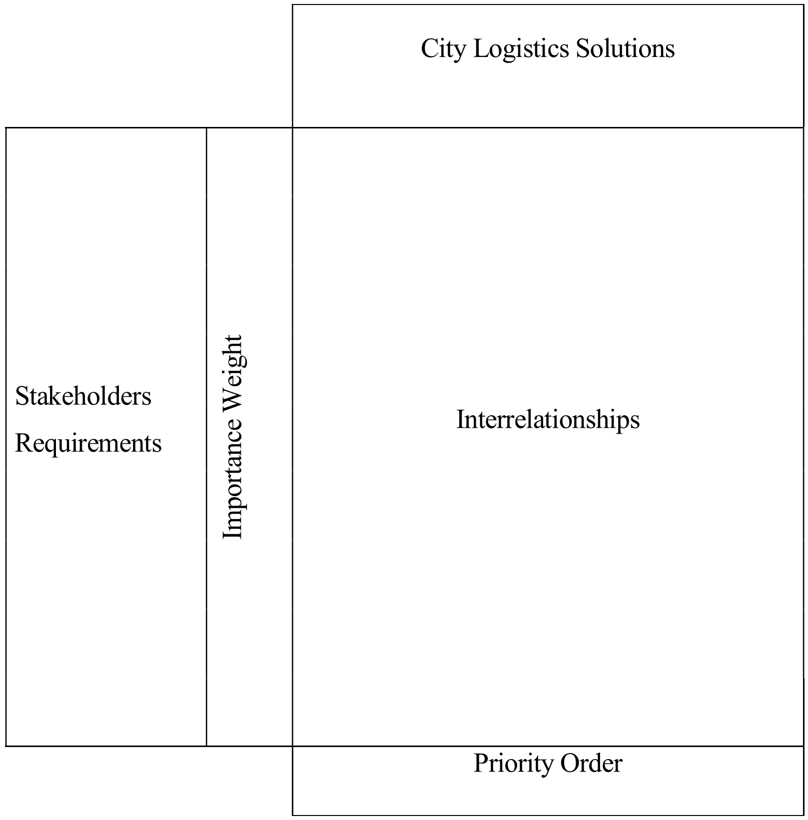

Figure 4-3 House of Quality Matrix adapted for Bergamo Case Study

4.4. Case Study: The Bergamo Logistica project

4.4.1. BG2.035, the status of Bergamo with respect to city logistics

Because at the time of the study no intervention on the transport of goods in urban areas was implemented (except for the presence of non-homogeneous and discontinuous LTZ), at the beginning of the Bergamo Logistica project a number of possible solutions, discussed with stakeholders, to improve urban freight within the city boundaries were identified. According to the defined city criteria by (Dijkstra & Poelman, 2012), Bergamo represents a good example of a mid-sized European city, due to its characteristics (population of 121.316) and for the constraints it is subject to (e.g. conformation of historical center, local regulations).

As a starting point, through a secondary data analysis, some general trends related to the transportation of goods in Bergamo were identified. The identification of these trends was based on several sources of secondary data (ISTAT, Transport White Paper, European Commission documents, extant literature, previous report by the Bergamo municipality, articles from local newspaper). Secondary data can be defined as data collected by others, not specifically for the research question at hand (Stewart & Kamins, 1993). In our case, with the term secondary data we refer to data collected by governmental and regulatory bodies (i.e., censuses, national and international reports and regulations, open databases, Chamber of Commerce's date) and companies (i.e., annual activities report,

financial data, official website). Moreover, we considered data from press (i.e., newspapers articles, websites) and grey literature (i.e., not published academic researches, reports, white papers).
The identified trends for Bergamo were the following:

- the slow but steady increase of the population in urban areas
- the fragmentation of demand (both geographically and over time)
- the diffusion of e-commerce with the related last-mile delivery issues
- the relatively high number of small and medium-sized shops in the city center
- the request for more flexible and timely delivery lead time
- the increase in the frequency of delivery (especially requested by small-shop owners that do not want to keep large inventory stocks)
- the increasing number of actors (stakeholders) in the sector.

Subsequently, the main and more recent city logistics solutions were revised. Both solutions proposed by different Italian actors (in particular, the Lombardy Region where Bergamo is located) and by European projects and networks like DOROTHY (Pino et al., 2014) and CIVITAS (van Rooijen and Quak, 2014) were considered. Further, solutions found in the literature were taken in consideration (Ambrosini and Routhier, 2004; Cherret et al., 2012). In the previous analysed sources, often the solutions were grouped into four main areas: Access restrictions, Infrastructures, Technology, and Regulations (Table 4-2). Within these areas, several unique solution proposals based on what already exists in Europe and in Italy were identified, as well as solutions that have a different level of complexity. A list with the explanation of each city logistics solution is showed in paragraph 1.2.

Access restrictions	**Regulations**
• Limited traffic zone (LTZ) • Time windows • Weight Restrictions • Restrictions on the type of vehicle power	• Road pricing • Multifunctional lane • Night and overtime deliveries
Technology	**Infrastructures**
• Automatic systems for LTZ control • Loading and unloading area management system • Electric vehicles	• Realization of Urban Distribution Centres (UDC) or Transit Point • Reserved lanes for freight transport

Table 4-2 Elaboration of Regional guidelines for the regulations of urban freight, European project and literature Source: Linee guida regionali per la mobilità delle merci nelle città, Regione Lombardia, 2014.

Then, several analyses in parallel were performed, especially interviews, involving local actors: in particular, several public (municipality and local public transport company) and private (courier, traders, transporters and associations) stakeholders were identified and involved through direct interviews to understand their critical viewpoint and their perceived issues in delivering goods in the city center. Furthermore, a questionnaire was administered to transporters and retailers to understand the viewpoint of operators in their day-by-day job concerning the characteristics of the urban distribution of goods (schedules and delivery times, number of suppliers, load factor ...).

To further address stakeholders' involvement, a working group composed of stakeholders and research members was established with the aim to discuss the main findings from the analysis. In particular, the stakeholders listed the main needs they found in urban freight transport and put them in order of importance according to their opinion. This working group represented a good opportunity to illustrate and discuss with the stakeholders the solutions previously found, actively involving them in the analysis and comparisons.

4.4.2. Steps of HoQ construction

At this point, a workshop with stakeholders was organized to show the partial results of the research, what was emerged from the interviews with stakeholders and citizens, and the results of the questionnaire to traders and transporters. The purpose of this workshop was to start a discussion in order to let emerge the critical aspects of the transport of goods in the city center of Bergamo according to the stakeholders involved, and understand what their needs really were.

Initially, the stakeholders identified their main needs to be satisfied in the freight transport in the Bergamo urban areas. Then, each stakeholder was asked to classify each request in order of priority on a Likert scale from 1 (least important) to 5 (most important), in order to have an average score for each requirement. At this stage, using stakeholders' priority order score, the importance weights presented in Table 4-3 that will form a part of HoQ matrix were allocated.

Stakeholder Requirements		Stakeholder Importance Weight						
Stakeholders		Traditional Transporters	Eco-friendly trucking companies	Couriers	Traders	Mean	Normalized Mean	Standard Deviation
Restrictions	*Accessibility*	5	5	5	4	5	0,23	0,50
Sustainability	*Low additional direct cost*	5	5	5	4	5	0,23	0,50
	Impact on citizens	2	4	3	2	3	0,13	0,96
	Congestion decreasing	4	5	4	3	4	0,19	0,82
Technological	*Information exchange*	4	5	5	5	5	0,23	0,50

Table 4-3 Stakeholders' importance weights in the Bergamo case study. Source: Elaboration of stakeholder workshop results

Later, to complete the matrix of interrelationships, the main city logistics solutions identified from the literature, from European and Italian CLP, and from international and local guidelines were considered again, and solutions interacting with stakeholders' requests were identified. In particular, the traditional HoQ scores system were used (Ulrich and Eppinger, 2012) to indicate the degree of interrelation between CL solution and stakeholders' requests (9 = strong interrelationship, 6 = interrelation, interrelationship 3 = weak, 0 = no interrelation). To indicate a negative interrelation a minus sign was used. The scores were assigned in response to a comparison between researchers. As previously mentioned, instead of the classical triangular-shaped roof, we have highlighted with different colours the city logistics solutions that may be applied jointly or pursuing similar purposes.

In particular, observing table 4-4:

- Orange: measures that seek to harmonize the freight traffic with the normal traffic in critical areas, possibly by means of payment (road pricing);
- Green: “green” measures;
- Blue: measures to strengthen the capacity of freight traffic through space and dedicated infrastructure.

After completing the matrix of interrelationships, it is possible to obtain the technical priorities as indicated in Table 4-5. For convenience, the results are shown as percentages.

4.5 Results discussion

The application of the House of Quality shows that the highest priorities are represented by the realization of an Urban Distribution Centre (15%), an automatic control system for the LTZ (13%), and a better management system platform of loading-unloading bays within the city center (10%). These solutions were further discussed with stakeholders and with the municipality to evaluate costs and related problems; a proposal for a path of gradual introduction of city logistics measures emerged from the study was then drafted (Table 4-6).

The results of the analysis show the relevance of the consultation-working group as an essential tool for the success of city logistics initiatives. Harmonization of decisions, activities and regulation may represent fundamental elements. Indeed, it is necessary to share common guidelines, in order to obtain real benefits. This point is very complex and very critical because, as often happens, it may induce a reduction of a possible local benefits in order to obtain a better result at the systemic level. Each stakeholder holding interests in the field of freight transport in urban areas has objectives that are often at odds with those of the other: this should not be an obstacle, but the starting point to find shared solutions of compromise.

Stakeholder Requirement \ Technical Requirement			Score	LTZ	Time Windows	Weight Restrictions	Fuel Type Restrictions	Automatic systems for LTZ control	Loading - unloading area management system	Electric vehicles	Road Pricing	Multifunctional Lane	Overnight Delivery	UDC / Transit point	Reserved Lanes
Restrictions	Accessibility	5	0,23	-9	-3	-6	-3	-9	3	0	0	3	3	9	6
Sustainability	Low additional direct cost	5	0,23	0	0	0	-9	0	0	-9	-3	0	-3	3	0
	Impact on citizens	3	0,13	0	6	6	0	6	3	3	-3	3	3	3	6
	Congestion Decreasing	4	0,19	0	0	0	0	0	0	0	3	6	3	3	6
Technological	Information exchange	5	0,23	0	0	0	0	6	9	0	0	0	0	6	0

Table 4-4 Complete House of Quality Matrix for the Bergamo Case study Source: Elaboration of stakeholder workshop results

Technical Priorities	2,0	1,5	2,1	2,7	4,2	3,1	2,4	1,6	2,2	2,3	5,1	3,3
	6%	4%	7%	8%	13%	10%	7%	5%	7%	7%	15%	10%

Table 4-5 Technical priorities for the CL solutions implementation in Bergamo Case Study. Source: Elaboration of stakeholder workshop results

Cooperation of private freight companies is essential for successful freight planning; however, it is sometimes difficult to get freight companies involved in the planning process. This may be because they want fast action that does not occur, or because they do not understand the time-consuming planning process of public agencies (Chatterjee, 2004).

Public and private stakeholders are more likely to adopt solutions that they can see applied in the short term; therefore, it is important to introduce city logistics solutions that are implementable and allow to gradually changing attitudes, behaviours and regulations. Given their constraints, the limited traffic zones (LTZ) in the upper and lower town can be an ideal starting point to develop and test new solutions (e.g. cargo bikes).

Stage	Suggested solution for Bergamo	Cost	Stakeholder perceived benefit
1. Enablers	Establishment of a permanent working group and creation of a Data Sharing Platform.	Low	High
2. Harmonization (orange group solutions)	Main project: Automated LTZ control system to be harmonized with: LTZ, time	Medium	High

	windows, road pricing, time and weight restrictions.		
3. Empowering (blue group solutions)	Phase 1: Loading and unloading area management system. Phase 2: UCD; to be harmonized with: reserved lanes.	Medium High	High High
4. Green (green group solutions)	Introduction of vehicles with low environmental impact by supporting use, purchase or rental of them.	High	Low

Table 4-6 Technical priorities for the CL solutions implementation in Bergamo Case Study

The HoQ proved useful to mediate the different stakeholders' requirements and consider them. It also provided a methodology to define what the priority actions to implement are. Organizing the process in different steps with different stages of meeting and discussion makes easier the mediation between the conflicting interests of stakeholders.

In contrast, the HoQ tends to level the contrasts to more converging decisions on the proposal chosen by the majority. This, however, could act against smaller stakeholders. It also ensures that if researchers want this method to provide useful results, stakeholders have to start at the same level of knowledge of the problem and the proposed solutions (Ballantyne 2013); this requires great efforts to exchange information and greater transparency on the part of decision makers.

The weakness of the procedure is the subjectivity of the allocation of the level of interaction between the different requirements: even if a technical-scientific team assigns the scores, it can never be totally objective. On the contrary, one of the strengths is that it allows a continuous discussion of the results and allows process replication even at more detailed levels. For example, after the first HoQ it is possible to take a specific solution, such as the introduction of Urban Distribution Center and verify technical and stakeholders' requirements to understand the feasibility and the necessary steps for its implementation.

4.6 RQ1 outcomes

In this chapter, an application of the House of Quality method to consider the conflicting interests of different stakeholders working in the field of urban freight transport was illustrated. In the Bergamo case study, first stakeholders' needs and their priorities were defined. In parallel, studying major European CLP, scientific literature and international, national and local guidelines, and the main trends of freight transport in downtown of Bergamo, a number of possible city logistics solutions were identified. These solutions were presented and discussed with stakeholders involved. In particular, the role of the researcher in this kind of project is to mediate between the stakeholders (traders, transporters, couriers) and the decision makers in public administration (municipality).

As for many other studies in the area, one limitation of this research lies in the lack of reliable data about freight movements that constrained the possibility to develop quantitative studies and precise cost-benefit analyses only to small portions of the city. Therefore, the innovative contribution of this study does not refer to the creation of new solutions or models; it rather refers to the application of a method belonging to product innovation and operation management to freight transport in urban areas, and in particular the involvement of stakeholders in decision-making to enjoy the method benefits.

The positive aspects of this contamination between different areas of study are many: the application of the House of Quality has allowed to better understand the impacts that urban freight solutions can have on stakeholders, and in particular on the most important to them. In addition, the completion of the House of Quality matrix allowed to discuss and analyse the solutions in all their aspects. Further, the application of the House of Quality to the case study of Bergamo has allowed to look at the decision-making process from a different point of view: it was possible to think about the solutions without missing stakeholders' requests and priorities.

In conclusion, by the results of the case study discussed in this chapter, it is possible to provide an answer to the RQ1: The HoQ applied to the city logistics context enables the stakeholders reasoning about the best city logistics solutions fitting with their necessities reaching a shared and compromising set of solutions.

The weak element of this method is the subjectivity in the compilation of the matrix of scores. In particular, it proved difficult to determine to what extent each solution impacts on the needs highlighted by the stakeholders. Further analysis is thus required in this respect, for example using simulations and/or pilot projects on small proof of concept solutions.

5. Data sharing platform

As discussed in paragraph 3.1, it is necessary to clearly understand all the existing data (geographical or in the regulations field) that could be useful in a transport operation in an urban context. That because it is not possible to retrieve only a type of data concerning the urbanistic aspects (e.g., road networks, parking, shop location, historical barriers) not considering the regulation aspects (e.g., time windows, limited traffic zones, access regulations): it would be a risk excluding some key information for designing an efficient city logistics solution. This chapter explains a framework that could be used to do that. In particular, in this chapter are illustrated the outcomes of the paper "Golini, R., Guerlain, C., Lagorio, A. & Pinto, R. (in press). An assessment framework to support collective decision-making on urban freight transport." submitted and accepted in the journal *Transport*. This chapter contributes to answer to the *(RQ2) Is it possible to define a database platform in which it is possible to collect, consult and update as many existing data as possible regarding urban freight transport?* (Figure 5-1).

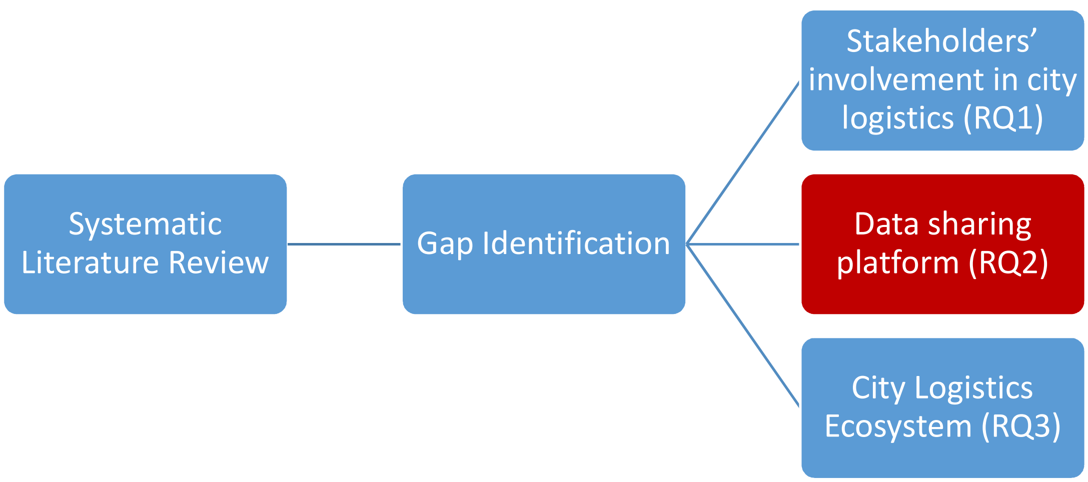

Figure 5-1 Research question 2 over the research structure

As showed in the chapter 2, the lack of data is one of the main obstacle in the urban freight context. To plan, project and implement efficient city logistics solutions lots of data are necessary (e.g., number of deliveries per week, location of shops, location and number of loading and unloading areas). The activities linked to the retrieving of these data are often expensive and time consuming. That because lots of this data, such as the number of deliveries, are obtainable only by doing questionnaires and interviews both to carriers and shop owners and we have already observed in the chapter 1 that the number of shops and their suppliers in a city could be very high. Moreover, these data have to be updated. But, there are also lot of data that are already collect ad digitalized by local authorities, available and quite stable over time such as the road network, the location of the shops, of the warehouses, the parking stalls or the traffic regulations. So, one of the solution to start to overcome the problem of the lack of data in an urban freight context could be to start to collect, aggregate and update all the already available information and data about freight transport in one place, with the possibility to integrate those data with others collected by questionnaires and interviews. Consequently, to solve this gap a data sharing platform is necessary. A data sharing platform should consist in a platform where is possible to see all the transportation resources in the city such as infrastructures (e.g. roads, parking areas, railways), services (e.g. lines and timetables), rules (e.g. road and parking regulations) and tariffs (e.g. collective transport, parking, road tolls) that determine travel opportunities (Cascetta, 2006). In this research, the data sharing platform also aims to give to the stakeholders an idea of the state of the transport resources as is, starting from real and current data.

5.1. The urban freight transport framework

Building a data sharing platform is a gradual process. First of all, it is necessary to understand which are the elements of the city that are directly involved in the urban freight transport activities or that could be impacted by them: it is necessary to build an urban freight transport framework in order to have all the elements listed and defined. The identification of the framework should be very careful, in order to not forget any relevant element of the urban freight transport. To do that a further analysis of the literature was done, focused on the characteristics of the city involved in the freight transport activities. After that, it is necessary to identify, for each element, an accessible and updated source of information and data about it. Doing this, all the government databases have been explored at a local, regional and national level. Also the database of the most important data sharing platform have been included in the possible sources of data such as Open Street Map.

As described, in order to devise the framework, the following building steps have been followed, as further described in the remainder:

1. Identification of the main features of the city, which are relevant to urban freight transport;
2. Definition of the layers and sources of information;

5.1.1. Step 1: Identification of the main features

There are several features of a city to be analysed for a better understanding of city logistics activities and impacts. On the basis of the literature, the most important features are the following:

1. **Morphology and historical heritage**: size of the area, presence of hills, rivers, canals, waterways that can create natural access barriers or make more difficult the distribution. Moreover, presence and extent of the historical centre that characteristics the higher touristic concentration and narrow streets (Muñuzuri et al., 2005; Pulawska & Starowicz, 2014).

2. **Population**: total population and density, as most dense areas have the highest demand for goods, especially parcels (Marcucci et al., 2015).

3. **Land use:** location of residential, commercial or office zones that affects the demand and typology of goods during the day (André Romano Alho & de Abreu e Silva, 2015).

4. **Infrastructures:** roads types, number of roads, roads dimensions, road tolls which affect accessibility to the city (Lian, 2008; Mohajeri, Gudmundsson, & French, 2015).

5. **Typology and distribution of commercial activities** (Joubert, Fourie, & Axhausen, 2010; Kittelson & Lawton, 1987) divided mainly into the following types of business: Commerce, non-food, bulky items, Commerce, non-food, small items, Food retail, grocery stores, gas stations, Health, High value, HoReCa.

6. **Transportation companies and logistics activities location** which represent relevant points of origin of commercial traffic towards the city (J. Allen, Browne, & Cherrett, 2012; Lüer-Villagra & Marianov, 2013).

7. **Access restriction measures** such as weight restrictions or delivery windows which affect accessibility of the city centres and concentrate private and commercial traffic in specific hours (Holguín-Veras, 2008; Quak & de Koster, 2009).

8. **Existing UFT** infrastructures such as freight terminals, urban consolidation centres (Browne & Gomez, 2011; Cherrett et al., 2012a).

To the best of the author's knowledge, these different features of the city have been rarely considered together. The reason is that they belong to different fields, such as urban planning, geography, logistics, and so forth. However, since transportation is a sub-system in the broader city system, the previous mentioned framework proposes to consider these dimensions jointly.

5.1.2.Step 2: Definition of the layers and sources of information

In this second step, for each feature described in Step 1, possible sources of information have been identified, giving priority to open data sources to extend the application of the framework to other cities. In particular, Open Street Map (OSM) was used: this decision has the advantage to ensure automatic updates, thanks to API routines provided by the OSM platform (www.openstreetmap.org). However, further sources have been considered in order to increase the reliability and quality level of the information (e.g., data from public authorities). In this respect, it is impossible to be in any sense exhaustive, since the availability of data and information depends upon the areas and cities considered. The application examples presented at the end of this chapter illustrate how the different sources of information can be retrieved and combined.

With a view on making the framework user friendly to stakeholders and harmonized with the sources of data, the features identified in Step 1 were reorganized in eight categories (Table 5-1). In this effort, INSPIRE (European Commission, 2014a), a European directive, was used. This European directive aims at facilitating the sharing of spatial data between public authorities and improving accessibility. For instance, infrastructures were split into two categories: road network and railway network with waterways, as the former is a capillary infrastructure while the latter are linear infrastructures (railways, rivers and canals).

Next, for each category a set of layers was defined. The layered subdivision was necessary to aggregate different kind of information related to the same category. For instance, the category "access restrictions" was broken-down in the following layers: delivery windows, limited traffic zones, access restrictions and road barriers.

The final framework comprises of 28 layers, classified in eight categories. The categories and layers are summarized in Table 5-1, which also reports potential sources of information. It is possible to underline the sparsity of the sources and the relevance of direct observation, thus supporting the need for a unified way to organize this information. Then, all the retrieved data in the urban freight framework are ready to be implement in the urban freight data sharing platform and be consulted by the stakeholders.

Category	**Description**	**Layers**	**Possible sources**
Morphology	Includes layers that serve as a background related to the morphology of the city, such as the presence of natural enablers or barriers to urban logistics (e.g., canals, rivers, hills).	Morphology	Google maps (Terrain) (https://www.google.co.uk/maps)
Administrative units	Related to the information representing municipality borders and historically relevant areas that may require careful consideration when UFT plans are devised.	Municipality/city borders	OSM (https://www.openstreetmap.org/)
		Historically relevant areas	Municipality development plan (https://territorio.comune.bergamo.it/)
		Neighbourhood / quarters	Municipality development plan (https://territorio.comune.bergamo.it/)
Society and commercial activities	Includes the information regarding the population density and land use (i.e., green, industrial, infrastructure, residential, residential/commercial,	Population density	Corinne Land Cover (http://land.copernicus.eu/pan-european/corine-land-cover)

Category	Description	Layers	Possible sources
	and tertiary). Also includes residential rent prices and information about the location and typology of commercial activities.	Land use	Municipality development plan (https://territorio.comune.bergamo.it/)
		Rent prices	Municipality, websites (https://territorio.comune.bergamo.it/)
		Shops (further divided as in Table 2)	OSM, Municipality survey
Road network	Motor vehicles network (including bus lanes and other dedicated road), cycle network and pedestrian network are mapped in this category.	Motor vehicles network	OSM (https://www.openstreetmap.org/)
		Cycle network	OSM (https://www.openstreetmap.org/)
		Pedestrian network	OSM (https://www.openstreetmap.org/)
		Bus Lanes	Municipality GIS (https://territorio.comune.bergamo.it/)
Access restrictions	Access restrictions (or controlled access) schemes.	Delivery windows	Municipality website, direct observation (https://territorio.comune.bergamo.it/)
		Limited traffic zones	Municipality website, direct observation (https://territorio.comune.bergamo.it/)
		Access restrictions (height/weight/width, fuel)	Municipality website, direct observation (https://territorio.comune.bergamo.it/)

Category	Description	Layers	Possible sources
		Road barriers	Municipality website, direct observation (https://territorio.comune.bergamo.it/)
Transportation facilities	Includes information about all the facilities (except for roads and railways) supporting the execution of urban logistics processes. Includes the location of LPG (Liquid Petroleum Gas) and CNG (Compressed Natural Gas) stations, as well as electric vehicles charging points. Further, information about loading and unloading bays and parking slots. Finally, the presence of airports is considered in this category.	Airports	OSM (https://www.openstreetmap.org/)
		Alternative fuels stations	mylpg.eu, cngeurope.com
		Charging points	openchargemap.org
		Street parking	Municipality GIS (https://territorio.comune.bergamo.it/)
		Loading/Unloading bays	Municipality GIS, Direct observation (https://territorio.comune.bergamo.it/)
		Parking lots	OSM, Yellow pages, Google maps
Delivery points and transportation companies/facilities	Includes the location of the main transportation companies (express couriers and 3PLs) that regularly deliver the goods in the city. Further, contains specific logistics infrastructure such as urban distribution centres (UDC) and city terminals is considered in this category.	Parcel solutions	Various websites (couriers, operators, online retailers)
		Transportation companies/couriers	Yellow pages, various databases
		Logistic infrastructures (UCD, city terminals)	Municipality GIS, Direct observation (https://territorio.comune.bergamo.it/)
Railway network and waterways	Includes data about railway and waterway networks	Railway network	OSM (https://www.openstreetmap.org/)
		Tram network	OSM (https://www.openstreetmap.org/)

Category	Description	Layers	Possible sources
		Water network	OSM (https://www.openstreetmap.org/)

Table 5-1 Information used in the framework and sources (Open Street Map: OSM)

5.2. Application cases of the framework: Bergamo and Luxembourg

The case studies illustrated in this paragraph have been elaborated during a research project between the University of Bergamo and the Luxembourg Institute of Science and Technology (LIST). In order to make the collected information readily available, easily retrievable, and clearly represented, during the project an online interactive platform was relied (Figure 5-3). In particular, the Smart City Logistics (SCL) platform (http://smartcitylogistics.org/) was used, a Geographic Information System (GIS) developed by the Luxembourg Institute of Science and Technology (LIST) (Guerlain, Cortina, & Renault, 2016). In the platform, the same category/layer structure of Table 5-1 was replicated.

The advantages of using such a platform are its user friendliness, its online access (i.e., the involved decision makers and relevant stakeholders can check the information and use the platform remotely) and its inter-operability between different systems. Indeed, the user can combine different layers via web services without IT expertise.

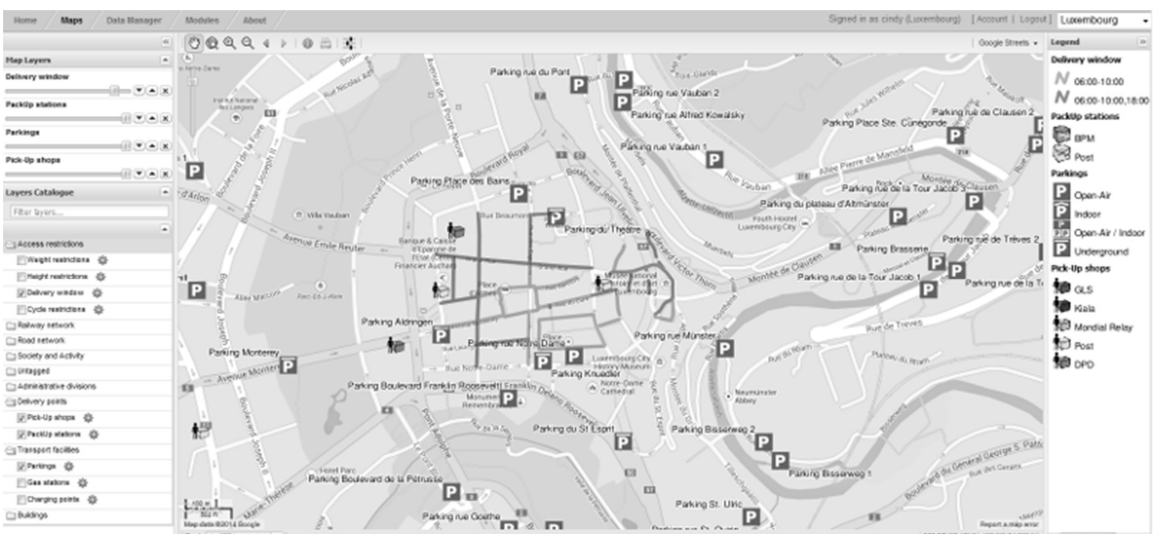

Figure 5-2 Screenshot from the Smart City Logistics platform (publicly accessible at: http://smartcitylogistics.org/)

In this case studies the data framework necessary to build the data platform was applied to the city of Bergamo and Luxembourg. The two cities, sharing similar geographical, demographic and infrastructural characteristics (Table 5-2), have shown increasing interest for urban freight transport issues, and have undergone a process of stakeholder involvement.

Characteristic	Bergamo	Luxembourg
Morphology/ Area	39.6 km2	51.73 km2
Morphology/ Hills	Hilly landscape (min elevation: 211 m; max elevation: 645 m)	Hilly landscape (min elevation: 232 m; max elevation: 408 m)
Morphology/Rivers, canals, waterways	No	Yes, but not navigable waters
Population/ Population	121,316	107,340
Population/ Population density	3,063/km2	2,100/km2
Historical heritage/ old city	Yes (10% of the city area)	Yes (4% of city area)

Table 5-2 Some characteristics of the two case studies (reference year: 2014)

Both cities are set up in a hilly landscape: "Città Alta" ("upper city") and part of the "Città Bassa" ("lower city") in Bergamo, and Ville-haute ("upper city") and Grund ("lower city") in Luxembourg city compose the historical part of the cities. Both cities are divided in neighbourhoods (7 for Bergamo and 24 for Luxembourg), with different characteristics. In particular, in both cities there are two quarters at the very centre of the city with the highest concentration of commercial activities and services. However, these neighbourhoods are also those with the highest historical relevance, thus more vulnerable to the negative impacts of UFT activities (e.g., noise, pollution, congestion). The author joined both teams to ensure the consistency in the data collection.

After having collected the data and set-up the platform, several round tables and workshops were organized with relevant stakeholders. In Bergamo, the key stakeholders involved were representatives of the municipal council of mobility and transportations, one representative of a large express courier, one representative of the local couriers, one technology provider, and one representative of the shop-owners. In Luxembourg, the key stakeholders involved were the Ministry of Sustainable Development and Infrastructure, representatives of the logistics service providers, one representative of the shop-owner association, own account transporters. The tool was used by the stakeholders to envision possible solutions for city logistics. The data collection process and the outcome of the use of the framework are reported in the next paragraphs.

5.2.1. Data collection

The framework provides directions about the potential sources of data and suggests how to classify the information. The collection phase (September 2014 – June 2015), however, remains an extremely time consuming activity aiming to reconstruct a comprehensive picture from sparse contributions. The entire list of sources for both Luxembourg and Bergamo is summarized in Table 5-3. Finally, the data gathered were uploaded on the SCL platform.

Category	Layers	Luxembourg Sources	Bergamo Sources
Morphology	Morphology	Google maps (Terrain)	Google maps (Terrain)
Administrative units	Municipality borders	OSM/Postal codes	OSM/Postal codes
	Historically relevant areas	Local documentation from the municipalities	Local documentation from the municipalities
	Neighbourhood/quarters	Municipality development plan	Municipality development plan
Society and commercial activities	Population density	Corinne Land Cover	Corinne Land Cover
	Land use	Municipality development plan	Municipality development plan
	Rent prices	Municipality	Platforms for renting and selling houses
	Shops	OSM	Municipality survey Regional database
Road network	Motor vehicles network	OSM	OSM
	Cycle network	OSM	OSM
	Pedestrian network	OSM	OSM
	Bus Lanes	Municipality	Municipality
Access restrictions	Delivery windows	Municipality	Municipality
	Limited traffic zones	Municipality	Municipality
	Access restrictions (height/weight/width, fuel)	Municipality	Municipality
	Road barriers	Municipality	Municipality
Transportation facilities	Airports	Municipality	Municipality
	Alternative fuels stations	Publicly available websites	Publicly available websites
	Charging points	Publicly available websites	Publicly available websites
	Street parking	Municipality	Municipality
	Loading/Unloading bays	Direct inspection	Municipality
	Parking lots	Municipality	Municipality

Category	Layers	Luxembourg Sources	Bergamo Sources
Delivery points and transportation companies/facilities	Parcel solutions	-	-
	Transportation companies/couriers	Direct inspection	Direct inspection
	Logistic infrastructures (UCD, city terminals)	-	-
Railway network and waterways	Railway network	OSM	OSM
	Tram network	OSM	OSM
	Water network	-	-

Table 5-3 List of sources for each offer layer for Luxembourg and Bergamo

Although the data collection activity can hardly be standardized, the appreciation of the effort devoted to such activities in a real-scale case underlines the importance of having a proper method to organize the different layers of information. In particular, the *commercial activities* were also divided in different categories according to the nature and/or volume of the goods and related transport. For Luxembourg, it was possible to use directly the OSM classification of activities. Thus, a furniture store was classified as dealing with bulky and non-food items, whereas a clothing shop was classified as dealing with small and non-food items. This classification allows the user to better identify potential customers of a logistics initiative. Supermarkets were excluded from the analysis, as they usually have their own distribution systems in place.

The information about *loading and unloading bays* in Bergamo was provided by the public administration while for Luxembourg city it was necessary to retrieve the information via direct inspection. Because of this, for both cities we focused only on a central area with a high density of commercial activities.

Data about gas stations and electric vehicle charging station was retrieved from publicly available websites (e.g., mylpg.eu, cngeurope.com, openchargemap.org, plugsurfing.com). Collecting information about the main *transportation companies* (express couriers and third party logistic companies) that regularly deliver the goods in the city, was very labour-intensive, as for Luxembourg the market turned out to be very fragmented, while for Bergamo some interviews were needed to understand which companies deliver in the city area.

Finally, neither city has specific *logistic infrastructures* in place, such as urban consolidation centres or city terminals, and the two cities have no waterways.

5.2.2. Results of the application of the framework and stakeholder engagement

The platform was well-received by the stakeholders that, after a quick demonstration, became able to directly interact with it. After a more general discussion about the characteristics and problems of the city, the researchers proposed to the stakeholders a set of UFT solutions to be analysed with the support of the platform.

For instance, Figure 5-4 shows an example of how the combination of the layers was used in the case of Bergamo in order to identify potential locations for an urban distribution centre (UDC). In the map in Figure 5-3 are visible the municipality/city borders, the historically relevant areas (Città Alta) and the quarters which are all potential areas served by a UDC.

The map also displays the shops that represent the delivery points and the motor vehicles network for the route calculation, location and accessibility of UDC and served area. Moreover, we can see the zones restricted to vehicles up to 3.5 tons.

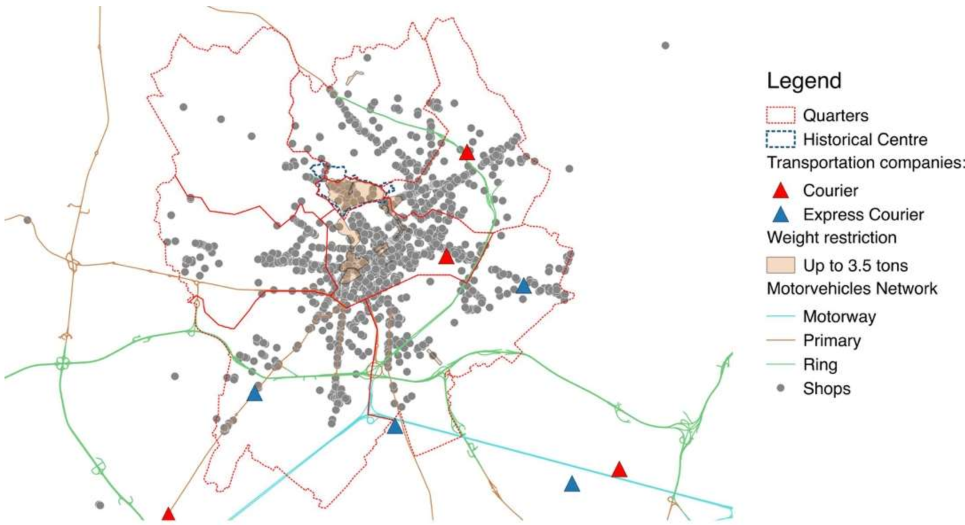

Figure 5-3 A selection of layers used to evaluate potential locations for a UDC (Bergamo)

From this map, it appeared that the historical centre (Città Alta) hosts a large number of shops, but has very low accessibility due to access restrictions and transport infrastructures. Consequently, the stakeholders focused on this area to evaluate the possibility to develop a micro UDC for Città Alta in combination with electric vehicles and cargo bikes. Moreover, in Bergamo, the complex layout of the areas subject to restriction measures became clear to everyone after displaying the information using the SCL platform, while during previous meetings the representatives of transportation companies struggled to explain why this was a major issue for them.

Thanks to the interaction with the stakeholders, we could identify the information layers that provide relevant information to the evaluation of different solutions (Table 5-4). It emerged that some layers are useful only for some solutions while others are more general. For instance, the localization of a freight terminal for modal shifts requires information on all types of infrastructure (water, air, ground transportation facilities) while the other solutions only need the road network.

It can be seen from Table 5-4 that the most used layers (at least for 4 out of 6 solutions) are:

- Basic terrain map for spatial orientation

- Maps in the administrative units' group: in order to identify the geographical limitations of the interventions (i.e., municipality/city borders or neighbourhood/quarters) or the critical areas to serve (i.e., historically relevant areas)
- Population density and land use: in order to estimate the level and typology of the demand (for instance, distinguish high/low density residential/office/industrial areas)
- Shops, for the same previous reason (estimate level and typology of demand)
- Motor vehicles network
- All the layers in the access restrictions group, to assess the current situation in terms of restricted areas
- Street parking and loading/unloading bays, since parking space near delivery points is necessary to implement almost every type of solution

With reference to Table 5-3, all the information for the above-mentioned layers can be easily gathered, except for loading/unloading bays and access restrictions that need to be retrieved from the municipality. However, from the combination of Table 5-3 and Table 5-4, future users of this framework can decide whether gather information for all the solutions or focus on one specific solution and gather only the information that is needed. From our experience, we suggest gathering as much information as possible since there are a lot of communalities and synergies in the data gathering process.

The existence of an historic centre and the hilly morphology emerged as two very relevant factors for both cities. In fact, to preserve historical centres, policy makers define areas with specific delivery windows and the hilly landscapes further limit the accessibility to delivery vehicles. While restrictions can be good in principle, in practice, they often bring to a fragmentation of the deliveries. This problem is particularly evident in Bergamo, where the areas subject to restrictions are many, discontinuous in space, and not homogeneous in time. However, also in Luxembourg there are different delivery windows in the streets in the same area, thus leading to potential problems for transportation companies. These considerations led the stakeholders in both cities to agree on a harmonization of such measures.

In terms of transportation infrastructures, the two cities appear quite similar, but significant differences emerge in terms of typologies of shops: Bergamo has a relevant share of shops in the "commerce small items" category and Luxembourg in the "HORECA" one. This observation led to the possibility to experiment electric vehicles distribution in Bergamo. Moreover, Luxembourg features a very fragmented market of the transportation companies, thus suggesting the need of a consolidation centre. On the contrary, in Bergamo, where there are already few companies operating, a micro urban consolidation centre could be designed for the parts of the city more difficult to reach, and with higher historical value (i.e., Città Alta).

Furthermore, in Bergamo there seems to be a mismatch between the location of loading and unloading bays and the shops, while in Luxembourg the issue concerns the narrow time window exclusively dedicated to deliveries operations. As a consequence, in both cities emerged the need to review the loading/unloading bays layout and policies.

Table 5-4 Combined use of layers to support solutions evaluation and design

Group	***Layer***	**Freight consolidation and delivery by truck (CC: Consolidation Centre)**	**Modal shift (only localization of the freight terminal)**	**Access restrictions, charging and environmental standards**	**Lane and space use**	**Alternative fuels/vehicles**	**B2C Solutions**
Morphology		Basic map for spatial orientation	Basic map for spatial orientation	Basic map for spatial orientation	Basic map for spatial orientation	Basic map for spatial orientation	Basic map for spatial orientation
Administrative units	*Municipality/ city borders*	Limit of the area served by the CC		Limit of the authority for restriction	Limit of the authority for regulation	Limit of the authority for incentives	
	Historically relevant areas	Potential area to serve from the CC		Potential area to restrict access	Localization of loading bays	Potential area to serve	Identification of served areas
	Neighbourhood/quarters						
Society and activity	*Population density*	Localization and potential area to serve from the CC	Localization of the freight terminal (avoid dense/residential areas)	Type of intervention (e.g. noise reduction in dense / residential areas)	Demand estimation	Potential area to serve	Demand estimation/categorization
	Land use						
	Rent prices	Localization of the CC (space cost)	Localization of the freight terminal (space cost)				

Group	***Layer***	**Freight consolidation and delivery by truck (CC: Consolidation Centre)**	**Modal shift (only localization of the freight terminal)**	**Access restrictions, charging and environmental standards**	**Lane and space use**	**Alternative fuels/vehicles**	**B2C Solutions**
	Shops	Demand estimation, delivery points		Balance restrictions with shop owners' needs	Demand estimation, localization of loading/unloading bays	Demand estimation, delivery points	Potential pick up shops
Road network	*Motor vehicles network*	Route calculation, location, accessibility of CC and served area	Localization of the freight terminal	Define restrictions at the street level		Route calculation, Network which can be used	Accessibility of delivery points
	Cycle network						
	Pedestrian network						
	Bus Lanes	Reserve lanes for CC vehicles			Lanes which can be used for delivery vehicles	Reserve lanes for electric vehicles	
	*Traffic flows**						

Group	*Layer*	Freight consolidation and delivery by truck (CC: Consolidation Centre)	Modal shift (only localization of the freight terminal)	Access restrictions, charging and environmental standards	Lane and space use	Alternative fuels/vehicles	B2C Solutions
	*Pollution levels**	Critical areas, location of the CC		Potential area to restrict access		Potential area to serve	
Access restrictions	*Access restrictions (height/weight/width)*	Identify constraints for the CC vehicles		Evaluate/harmonize existing measures	Identify constraints to reach loading/unloading bays, Current restrictions	Potential area to serve, Evaluate existing measures, Incentive for alternative/clean vehicles	Identify constraints to reach delivery points
	Road barriers			Evaluate/harmonize existing measures, Current restrictions	Identify constraints to reach loading/unloading bays		
	Limited traffic zones					Potential area to serve, Potential incentive for alternative/clean vehicles	
	Delivery windows						
Transportation facilities	*Airports*	Localization of the CC	Localization of the freight terminal				
	Water network						

Group	*Layer*	Freight consolidation and delivery by truck (CC: Consolidation Centre)	Modal shift (only localization of the freight terminal)	Access restrictions, charging and environmental standards	Lane and space use	Alternative fuels/vehicles	B2C Solutions
	Charging points					Route calculation, Service offered to logistics providers	
	Alternative fuels stations						
	Street parking	Identify parking points for CC vehicles		Parking areas affected by restrictions	Identify available spaces, evaluate current situation	Identify parking points for vehicles, Potential incentive for alternative/clean vehicles	Identify parking points to reach delivery points
	Loading/Unloading bays						
	Parking lots	Identify hub areas, facility which can be used		Accessibility	Use parking lots as hub areas		
Delivery points	*Parcel solutions*						Evaluate existing solutions, Service offered to consumers
	Transportation	Potential suppliers	Potential partner		Potential user		

Group	*Layer*	Freight consolidation and delivery by truck (CC: Consolidation Centre)	Modal shift (only localization of the freight terminal)	Access restrictions, charging and environmental standards	Lane and space use	Alternative fuels/vehicles	B2C Solutions
	companies/couriers						
	Logistic infrastructures (UCD, city terminals)	Evaluate existing solutions, facility which can be used	Evaluate existing solutions				Facility which can be used
Railway network	*Railway network*	Localization of the CC	Localization of the freight terminal				
	Tram network						

5.3. RQ2 Outcomes

In conclusion, it is possible to say that a better understanding of the city's context and available data is essential to propose adequate solutions in the field of urban freight transport. However, collecting and sharing information with decision makers is a complex and time consuming task.

The framework presented in this chapter allows the identification and evaluation of the most important dimensions affecting the urban freight transport system, designed with the specific objective to enable stakeholder engagement and solution identification. The framework is designed to exploit as much as possible open data, such as Open Street Map data for infrastructures and commercial activities. The organization of the data and information in layers supports the understanding, analysis and discussion between stakeholders. In this chapter, to illustrate one of the use of this offer framework, the framework was applied on two cities (Bergamo and Luxembourg). The cases helped to assess the quality and reliability of the information retrieved, and demonstrated the ability of the framework to identify and make comparable the different features of a city. Moreover, the cases proved that a visual tool derived from the framework can be of great help to engage stakeholders in the early phases of the design of urban freight solutions. Finally, the cases helped to understand which data from the framework can be more helpful in the analysis of specific urban freight transport solutions, hence providing a practical example for future users.

In conclusion, building up on previous literature and case studies, this chapter show a possible urban freight data framework that could be a standard framework for supporting the data collection to build an urban freight sharing data platform and a first stakeholder engagement. Thus, this framework could be a possible answer to the RQ2 and a possible basis for the creation of a data-sharing platform.

Moreover, this framework can be particularly useful for decision makers working in cities still at the beginning of their city logistic journey. However, even more advanced cities could benefit from these insights in order to enrich their data sources and benchmark against other cities.

Of course, this framework is subject to several limitations that is possible to partially overcome by including an analysis of the traffic flows, provide a set of quantitative indicators for the different features, enrich the list of features, and develop demand estimation models based on the collected information such as the number of delivery per week for each shop. Moreover, large retailers and supermarkets that have their own distribution systems in place were purposefully excluded, but of course, the analysis could be more complete if this freight traffic flows could be included in the data platform. Finally, even if the framework could be implemented in all the cities because includes all the urban freight characteristics and element the same thing cannot be for the data sharing platform. That because each city has its own digitalization system, each European state has a different method of data storage and not always all the data present in the framework are available in the same source or in the same format. Also the already sharing data platforms, such as Open Street Map, have not the same detailed data in every city: it depends by the number of people that had share the data on the platform.

However, they are an important part of the picture when considering the demand, traffic and interactions with the other solutions. For instance, some retailers can host parcel lockers in their stores or parking lots. Because of this, this framework could be seen as a platform, open to future technological advancements (e.g., new available data sources, new solutions) and new case studies so to have a growing library of shared experiences.

6. The city logistics ecosystem: the loading/unloading bays application

As seen in chapters 4 and 5, city logistics initiatives involve multiple stakeholders, often with conflicting goals, playing different roles performing diverse operations, and subject to different (and somehow restrictive) rules for accessing the city centres. These actors, and all the resources involved, constitute a transportation system, that is “a combination of elements and their interactions which produce the act of transport” (Cascetta, 2001). Such a system is in continuous interaction with other systems within a city. Indeed, urban freight transport could be considered as a sub-system included in the transportation system, that is a typical example of a “System of Systems” (SOS). A SOS is “*a distinct class of systems generally characterized as large, complex, geographically distributed, and composed of components that are significant systems in their own right*” (Shenahr, 1994). Moreover, “*these systems are composed of subsystems that are capable of operating independently of the integrated whole, and do operate in partial independence as part of normal operations*” (Maeir, 1998). Thus, transportation itself can be considered as a “System of systems” (De Laurentis et al., 2007) because, for example, in the urban context, transportation includes both people mobility and freight transport. The urban transportation system is also incorporated into the city system, which also includes other collection and distribution systems (i.e. water, energy, waste and communications systems) (Figure 6-1).
Also urban freight transport, as showed in the chapter 5, could be separated in sub-systems: ideally very category listed in table 5-1 could constitute an urban freight transport sub-system.

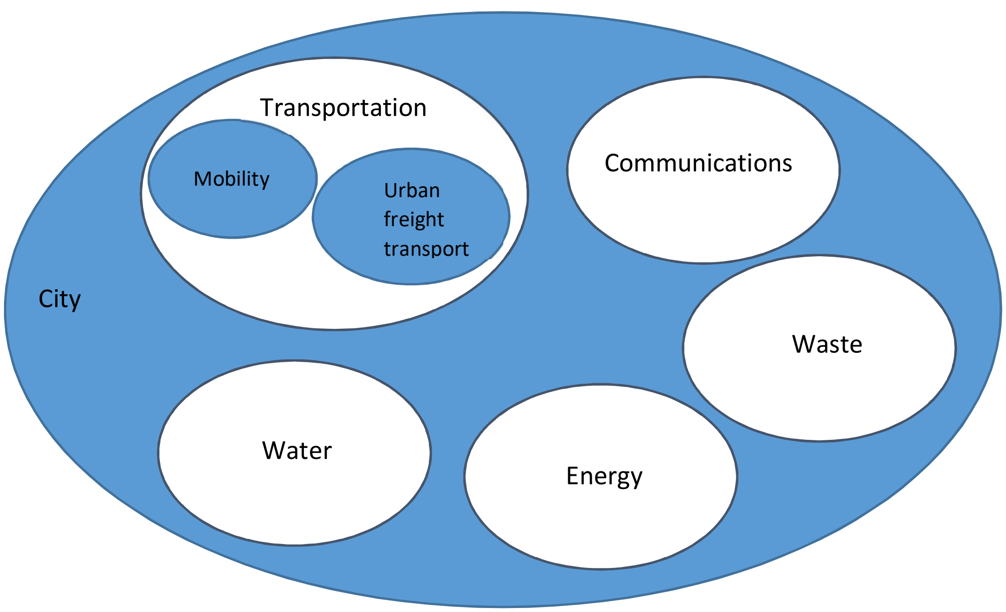

Figure 6-1 The city system of systems (author’s elaboration)

As a consequence, it is necessary to enable stakeholders to perceive in a visual, clear and understandable way, all the elements that constitute the transport system of goods in urban areas, as well as the relationships with the whole transport system and the whole city system (Lagorio et al., 2017). In this way, the stakeholders involved in the decision-making process can have a global view on city logistics issues, taking into consideration not only aspects directly affecting their daily operations, but all the elements forming the system and the different relationships among them (Thomas & Cook, 2005). Thus, it is possible to consider the city as a SOS, and urban freight transport as a system-city subsystem.

6.1 The city logistics ecosystem

Adapted from the biological/ecological sciences, the ecosystem perspective is based on the premise that industries consist of a heterogeneous and continuously evolving set of constituents that are interconnected through a complex, global network of relationships, co-create value, and are co-dependent for survival (Basole, Huhtamäki, Still, & Russell, 2016). More precisely, a definition of a biological ecosystem has been provided by Barnett et al. (1999): "An ecosystem is a community of interacting organisms and the physical environment in which they live. Ecosystems are not just assemblages of species; they are systems combined of organic and inorganic matter and natural forces that interact and change". Although this definition is strictly related to the ecological area, the highlight on the interconnections between the participants to the ecosystem resembles the features of the business ecosystem as defined by Moore (1998). Moore describes business ecosystems as "communities of customers, suppliers, lead producers, and other stakeholders interacting with one another to produce goods and services and coevolving capabilities". Starting from the previous definitions of 'ecosystem' both in terms of biology and business, it is possible to transfer the knowledge coming from those specific fields to the city logistics and freight transportation ones. Many commonalities with the framework for integrated assessment and valuation of ecosystem functions, goods and services provided by De Groot (2006) can be found in the city logistics architecture. In particular, the framework proposed by De Groot (2006) enables to envision a comprehensive understanding of the ecosystem elements and their connections in an urban planning context. This ecosystem framework is the only existing one that considers all the urban planning aspects that are also present in the urban transport system (and consequently in the urban freight transport system), and so it could be considered a good starting point to elaborate an urban logistics ecosystem framework. De Groot et al. (2006) define ecosystem functions as "the capacity of natural processes and components to provide goods and services that satisfy human needs, directly or indirectly". More in details, natural processes are defined as the result of complex interactions between biotic (living organisms) and abiotic (chemical and physical) components of ecosystems through the universal driving forces of matter and energy. Furthermore, the ecosystem functions concept provides the basis on which ecosystem value to human can be assessed. De Groot assess that the observed ecosystem functions are re-conceptualized as 'ecosystem goods and services' when human values are implied. The 'ecosystem goods and services' is an anthropocentric concept since human beings are valuing agents translating the ecological process into values. Likewise, within an urban context the ecosystem functions would be the different conditions, namely the specific features of the city in terms of regulations, layout, means of transportations, data collection and information sharing, which allow the realization and the success of a city logistics solution.

6.1.1 The ecosystem functions

The different types of functions, their analogies in terms of city logistics and examples of Key Performance Indicators (KPIs) for each function are here presented.

- **Regulation functions**

It relates to the capacity of natural and semi-natural ecosystems to regulate essential ecological processes and life support systems. In terms of city logistics, the regulation functions can be represented by the legislation and public regulations imposed by local authorities and municipalities. Therefore, examples of crucial parameters to be considered as KPIs are the availability and breadth of delivery time windows (Patier & Browne, 2010), the range of alternative services offered to carriers (Harrington, Singh Srai, Kumar, & Wohlrab, 2016).

- **Habitat functions**

It is the natural ecosystem that provides refuge and reproduction habitat to wild plants and animals.
In the city logistics context, the habitat functions can be the specific features of the territory in which the city is placed. Namely, the layout of the city and the infrastructures. As showed in the chapter 6, freight journeys are influenced by factors such as size, density and layout of the city since few modal options exist (e.g., roads, railroads), moreover several geographical, spatial and land use factors have important influences on freight activity in urban areas by impacting the type and quantity of goods demand, the distances travelled by freight transporters and warehouse location choices (Allen et al., 2012). From these considerations, it is possible to notice that the habitat function is the most binding when implementing a city logistics solution, since it cannot be easily modified and consequently it strongly influences all the other functions. The crucial indicators to be considered (i.e. KPIs) could be point density, commercial homogeneity (Alho & de Abreu e Silva, 2014) and the eventual presence of narrow streets and other urban obstacles (Muñuzuri et al., 2005).

- **Production functions**

In the context of city logistics, the production function relates to the transportation activities and processes required to move goods which are then received by the consignees in the city. These actions and processes are crucial to inhabitants' consumption since they made goods available in central locations.
Consequently, the parameters to be considered are the delivery frequency, on-time delivery rate (Cherrett et al., 2012b), process time and total lead time, load factors (Anand, Yang, et al., 2012), average route length (Harrington et al., 2016).

- **Information function**.

City logistics initiatives use huge amount of information to maintain all the stakeholders involved in the process. The information functions are necessary to allow the communication among the parties involved and to better manage and organize all the activities performed in the process. The crucial indicators related to information function could be described by delivery data availability and completeness, vehicle and parcel traceability (Benjelloun et al., 2010) and traffic data sharing possibility (Harrington et al., 2016).

- **Carrier functions**

Most human activities (e.g. cultivation, habitation, transportation) require space and a suitable substrate (soil) or medium (water, air) to support the associated infrastructure. The use of carrier functions usually involves manipulation of the natural ecosystem and thus, the capacity of natural systems to provide carrier functions on a sustainable basis is usually limited (De Groot, 2006).

In the urban freight context, the concept of carrier functions can be interpreted as the manipulation introduced in the ecosystem due to urban freight transportation activities: commercial traffic generates significant externalities in urban areas, including congestion, air pollution (small particulates, NOx, greenhouse gas emissions), noise, and traffic incidents (Dablanc, Giuliano, Holliday, & O'Brien, 2013). The carrier functions are those types of vehicles used while performing a freight distribution activity that impact differently, depending on their features (engine, size, etc.), the ecosystem of which they are part of.

Therefore, examples of KPIs related to this function are proportion of typologies of vehicles according to their age (Euro classification based on emission standards) (Patier & Browne, 2010), induced noise pollution (Morana, Gonzalez-Feliu, Morana, & Gonzalez-Feliu, 2009) and induced traffic congestion (Fernandez-Barcelo & Campos-Cacheda, 2012).

6.1.2 Ecosystem values

The relevance (or "value") of biological ecosystems is divided into three different categories: ecological, socio-cultural and economic value, according to the sphere of impact of the functions and services. The following paragraphs provide a description of the three mentioned dimensions.

- **Ecological values**

The use of goods and services associated to the ecosystem functions should be limited to sustainable use levels to ensure the continued availability of the latter. The capacity of ecosystems to provide goods and services depends on the related ecosystem processes and components providing them and the limits of sustainable use are determined by ecological criteria such as integrity, resilience, and resistance (De Groot et al., 2006).

As mentioned by Goldman and Gorham (2006), the transportation sector consumes resources such as energy, human and ecological habitats, atmospheric carbon loading capacity, and individuals' available time. Therefore, it is crucial that urban transportation ecosystems are built and aim to reach sustainable level of environmental capacity usage. The capacity usage is strictly connected to three main phenomena underlined by (Morana, & Gonzalez-Feliu, 2009): to greenhouse gas emissions, local pollution and noise emissions. Greenhouse gas emissions are the main contribution to global warming and are directly related to fuel consumption. Therefore, it is crucial that a CLP can address these routing issues and ease the driving to decrease the amount of greenhouse gas emissions and improve the environmental value. Consequently, the main parameters to be considered for valuing the environmental impacts on the urban ecosystem are the resultant air pollution (Russo & Comi, 2017), climate and habitat changes, noise pollution caused by freight vehicles.

- **Socio-cultural values**

Social values and perceptions play a remarkable role in determining the importance of natural ecosystems and their functions, to human society. This meaning that natural systems are crucial sources of non-material well-being and are indispensable for a sustainable society.

Within city logistics initiatives context, social and human perceptions are parameters to be considered when dealing with sustainability policies. Inhabitants are the receivers of the local authorities' actions and thus they attribute value to the results of such regulations. The same happens for the other participants to the network: they are affected by each single policy or city logistics solution and thus, a value is attributed to the functioning of such a modified environment accordingly to stakeholders' perceptions. A useful factor to consider is related to restriction and comfort levels for different categories of people. For instance, trucks blocking a street, problems to park because of freight transportation, and other situations will be considered negative by the usual drivers of city center (i.e. one of the valuing agents). On the other hand, a system which reduces congestion and produces more parking areas, or at least the perception of no big commercial vehicles in the city center will be considered good solutions. Regarding the traffic noise, it can be related both to environmental and social-cultural values. As matter of facts, it affects respectively the city comfort and the human wellbeing.

Consequently, the main parameters to be considered for valuing the socio-cultural impacts on the urban ecosystem are the number of accidents due to operating vehicles (Dablanc et al., 2013), the interference of freight transportation with citizens' daily activities and the resultant urban liveability (Morana & Gonzalez-Feliu, 2015).

- **Economical value**

De Groot et al. (2006) describe economical valuation as methods based on efficiency and cost-effectiveness. Some provided examples are direct market valuation based on goods and services exchange value, indirect market valuation based on not explicit assessment means (e.g. willingness to pay, avoided cost, replacement cost, etc.), contingent valuation relying on service demand elicited by posing hypothetical scenarios involving the description of alternatives in a social survey questionnaire, and group valuation based on the assumption that public decision making should results from an open public debate.

Applying this concept to the field of urban freight transport, there is a strong connection to the economics of goods transportations. The regulation and habitat functions directly impact the efficiency and efficacy of an urban transportation solution and thus its cost to both the carrier and the receiver. Regarding the economic performance of a city logistics initiative, public subsidies, and low-cost recycling of existing facilities are the most common forms of assistance when launching an urban logistics project (Dablanc et al., 2013), but unfortunately, as stated by Lindholm and Behrends (2012), few city logistics initiatives managed to fulfil a complete implementation after the external funding scheme ended successfully. Gonzalez-Feliu & Morana

(2009) underline that one of the main factors in city logistics solutions is their economic continuity: most solutions have shown interesting results in the pilot and test phases, but could not survive after the substantial public funding support was stopped. Consequently, the main parameters to be considered for valuing the economic impacts on the urban ecosystems are the costs of traffic congestion (Russo & Comi, 2017), trip length (Cherrett et al., 2012), delivery time (Morana & Gonzalez-Feliu, 2015), and infrastructure costs (Morana et al., 2009) and the autonomous financial sustainability (Lindholm & Behrends, 2012).

A summary of the main KPIs for each function and value and the relative sources of provenance from the scientific literature can be found in Table 6-x.

Functions	KPIs	Sources
Regulation	Availablty and breadth of delivery time windows	Patier and Browne, 2010
	Range of alternative services offered to carriers	Harrington, Singh Srai, Kumar, & Wohlrab, 2016
Habitat	Density	Allen, Browne & Cherrett, 2012
	Commercial homogenity	Alho & de Abreu e Silva, 2014
	Presence of obstacles (i.e., narrow streets, historical walls)	Muñuzuri et al., 2005
Production	Delivery frequency	Cherrett et al., 2012
	Process time and total lead time	Anand et al,, 2012
	On-time delivery rate	Cherrett et al., 2012
	Load factors	Anand et al., 2012
	Average route length	Harrington, Singh Srai, Kumar, & Wohlrab, 2016
Information	Delivery data vailability	Benjelloun et al., 2010
	Vehicle and parcel traceability	Benjelloun et al., 2010
	Traffic data sharing possibility	Harrington, Singh Srai, Kumar, & Wohlrab, 2016
Carrier	Typologies of vehicles according to their age	Patier and Browne, 2010;
	Induced noise pollution	Morana, & Gonzalez-Feliu, 2009
	Induced traffic congestion	Fernandez-Barcelo & Campos-Cacheda, 2012
Values	**KPIs**	**Sources**
Ecological	Resultant air pollution	Russo & Comi, 2017
	Climate and habitat changes	Goldman & Gorham (2006)
	Noise pollution	Morana, & Gonzalez-Feliu, 2009

Socio-cultural	Number of accidents due to operating vehicles	Dablanc, Giuliano, Holliday, & O'Brien, 2013
	Interference of freight transportation with citizens' daily activities	Morana & Gonzalez-Feliu, 2015
	Urban liveability	Morana & Gonzalez-Feliu, 2015
Economical value	Costs of traffic congestion	Russo & Comi, 2017
	Trip length	Cherrett et al., 2012
	Delivery time	Morana & Gonzalez-Feliu, 2015
	Infrastructure costs	Morana, & Gonzalez-Feliu, 2009
	Autonomous financial sustainability	Lindholm and Behrends, 2012

Table 6-1 Main KPIs for Functions and Values

A comprehensive adaptation of the mentioned ecosystem functions and ecosystem values is provided in Figure 6-2. Such an adapted framework for urban freight transportation ecosystems provides an overview of the numerous parameters affecting city logistics networks and therefore of the complexity of decision making process. More details about the empirical application of this method could be find in (Lagorio, Pinto, & Golini, 2017).

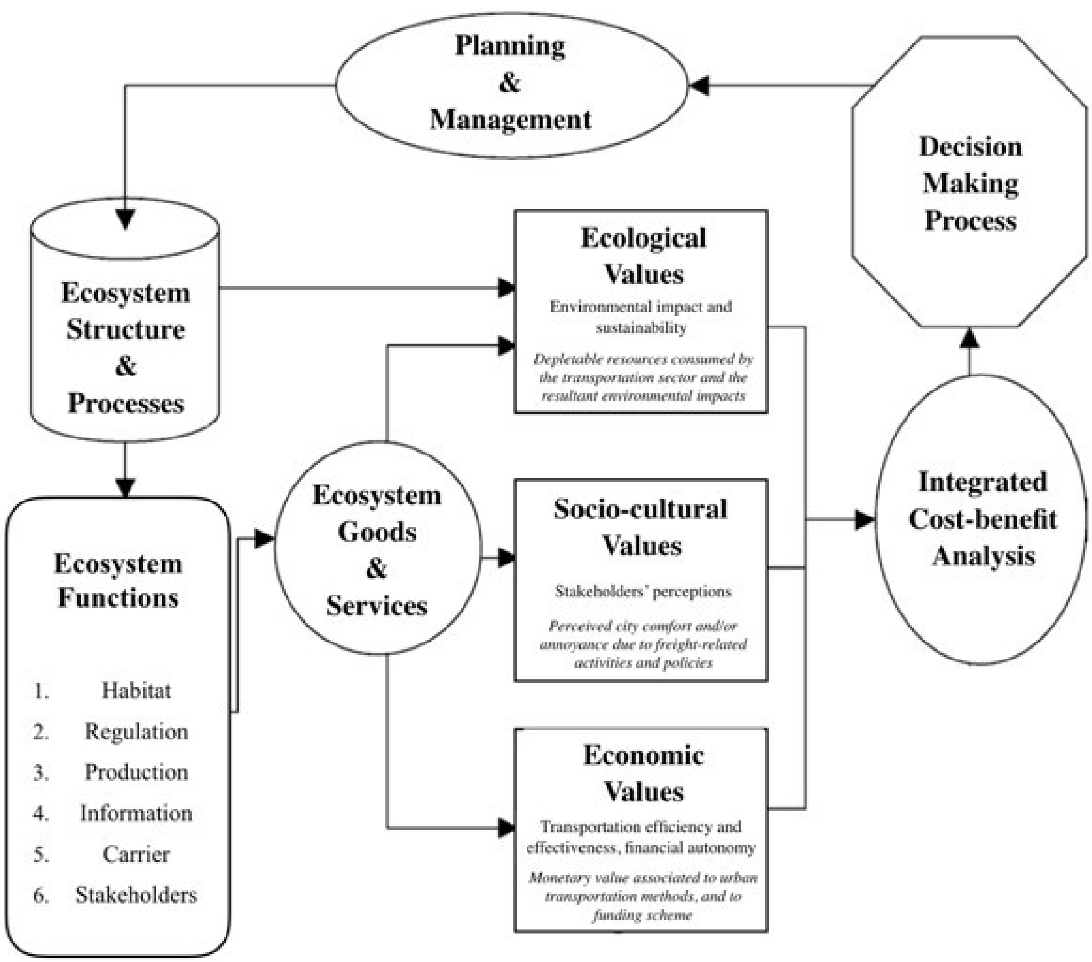

Figure 6-2 City Logistics ecosystem Source: Lagorio et al. (2017)

6.2 The loading/unloading bays context

These aspects led to the *(RQ3) How is it possible to optimize city logistics infrastructures in a harmonious and coherent way respect to the entire city logistics ecosystem?* that is the third and last gaps addressed in this thesis (Figure 6-3).

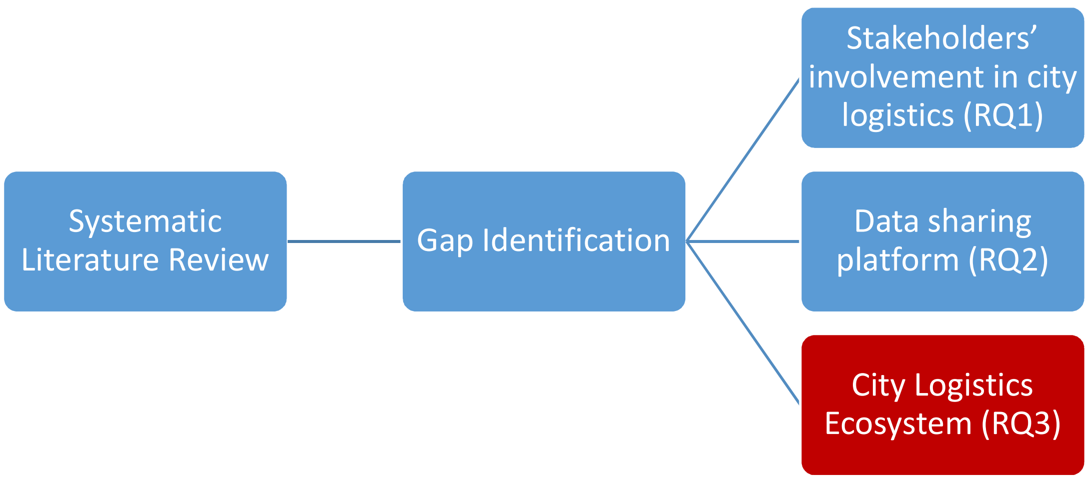

Figure 6-3 Research question 3 over the research structure

To address this gap, an application regarding loading and unloading bays has taken in consideration. This application could explain how is possible take in consideration all the aspects in the city logistics ecosystem planning a city logistics solution. In the loading and unloading bays case it is possible to take in consideration regulations aspects (i.e., access restrictions and time windows), habitat aspects (i.e., the road and the parking areas), production aspects (i.e., waiting time, time windows exceeds), carrier aspects (i.e., loading and unloading operation duration, maximum length travelled by carrying freight for the operators) and information (i.e., the possibility to reserve the loading and unloading bay on-line). Also the city logistics ecosystem's values could be identified: an improved location and management of loading-unloading bays means less freight vehicles on the roads searching for a parking stall (ecological values), less vehicles double parked potentially dangerous (socio-cultural values), faster and more efficient operations of freight loading and unloading (economic values). In particular, this chapter report the outputs of the paper "Pinto, R., Golini, R. and Lagorio, A. (2016) 'Loading/unloading lay-by areas location and sizing: a mixed Analytic-Monte Carlo simulation approach', IFAC-PapersOnLine, 49(12)".

Apparently, the loading/unloading area may seem a problem of lesser importance than the topics that are raising greater interest in scientific literature, such as vehicles routing problems or urban distribution centres (see Chapter 2.3). However, observing the results of both the analysis illustrated in the chapters 4 and 5, this problem raises a great interest for the carriers, the retailers, and also for the public authorities. During the Bergamo 2.035 project (the Bergamo Logistica project cited in the paragraph 4.4.1), seven people were interviewed including representatives of associations (carriers, couriers and retailers), members of local administration, and representatives of important business players located in the Bergamo territory (i.e. companies and airport manager) in order to understand the most important and critical elements for those involved in freight transport in urban areas.

Interviews were conducted personally by the author between November 2013 and May 2014. The interviews were semi-structured, so that they could be partially comparable. Due to this, it was possible to benefit from the open answers, which focused the attention to some elements that were not considered before. From these interviews, some criticisms and the main interests of the respondents emerged. Therefore, it was decided to make a focus group with the people interviewed so that there could be an interaction between the stakeholders and a comparison between the different points of view and the needs of the different actors. The results of these two initial phases of surveys were included in the chapter 6 (Lagorio, A., Pinto, R. Golini, 2014). of the book "Bergamo 2.035 - A new urban concept". From the focus group, it emerged that the priority for traders and carriers was to start regulating freight transport from the critical elements present every day during the transport operations: the time windows and the parking places reserved for the goods loading and unloading operation, with the possibility of booking the parking stalls through an app or a website. From these interviews emerged also that the problem has not yet been resolved: most carriers are forced to park their vehicles outside the spaces allowed to carry out the operations of delivery. Moreover, analysing the data regarding accidents in urban area (Bauer et al., 2016), it is possible to observe that a large part of the accidents in urban centres that involve heavy vehicles are due to improper behaviour of drivers forced to park in double row and to try to end the deliveries as quickly as possible (Russo & Comi, 2017). Even for on field operators (drivers and shop owners) the problem of the loading and unloading operations during the deliveries is crucial: having access to a parking space near to the destination means greatly reducing the length of loading / unloading operations without delay (parking search, vehicle displacement, walkways with loads) or other interruptions in the operations (trader who must leave the store unattended to help the carrier). Finally, it is possible to see how the dedicated loading/unloading areas for the freight delivery are a solution already present in many cities, so it is possible to start from the situation as is and then optimize its location and number without having to overturn the current rules and without having to invest large investments: each municipal administration can optimize the daily operations of those who work in this sector with limited use of time and resources.

For these reasons, added to the reasons explains at the beginning of this chapter, the theme of loading / unloading bays for freight delivery in urban context is explored more in details in this thesis work, in order to constitute a case study for a city logistics ecosystem application.

6.3 The loading/unloading lay-bys location and sizing

The location and sizing of loading/unloading lay-bys (also referred to as commercial vehicle parking areas or commercial loading/unloading zones) in urban centres deals with one of the aim of the city logistics projects: in particular, it helps to reduce the traffic congestion, as well as the interferences of the urban freight traffic with the people mobility. This infrastructure (especially, the lack or incorrect design thereof) can have a substantial influence on the traffic flows and on the efficiency of the urban freight and transport service system. Therefore, in this chapter a mixed Analytic-Monte Carlo simulation approach is presented in order to find an optimal distribution of the lay-by areas according to the demand and location of the business activities. The model here presented has been tested on a pilot area in the city of Bergamo, in the north of Italy.

As stated in the first two chapters of this thesis, many European cities have a historical urban heritage and urban constraints that make them a logistics nightmare; unlike the so-called pop-up towns born from greenfield, for example in China, European cities are characterized by their historical configurations, and are often ill-suited to accommodate an increase of traffic flows in urban centres. Freight transport in urban areas is difficult to optimize being interwoven with the context in which it operates (Lagorio, Pinto, & Golini, 2014).

Moreover, a recent survey in the city of Bologna (Italy) reported that more than 85% of the stops by commercial vehicles for loading/unloading operations are in non-dedicated areas or even in double-parking (Dezi, Dondi, & Sangiorgi, 2010b). Resorting to double-parking affects the traffic flow in the area, generating congestion and access problems, particularly acute in the central districts of the city. Hence, the need to establish a location and management model for the lay-bys in the city, reconciling two conflicting goals: on one hand, the need for ensuring an efficient distribution of goods (even considering the requests for frequent and small delivery from retailers that operate a just in time policy). On the other hand, the necessity to regulate freight traffic to minimise the environmental impact and the hindrance to traffic flows (Maggi, 2011). Thus, the location and management of commercial lay-bys within the city aim at achieving two different goals: i) economic efficiency in the delivery of goods, and ii) enhanced social welfare achieved by reducing the hindrance to the traffic flow caused by irregular parking practices.

6.4 Background and case outline

The location and management of the commercial lay-bys involves several aspects. In summary, it possible to define the following main tasks:

- Identification of the number and location of the lay-bys in the city. Regarding this aspect, it is important to consider the distance of the points of delivery (i.e., shops, retail points mainly, but also private demand points for the delivery of e-commerce purchases) from the lay-bys. A good location plan of the lay-bys should ensure the proximity of at least one lay-by to each delivery point.
- Identification of the number of parking stalls in each lay-by. A parking stall represents the physical space that a commercial vehicle can occupy in the lay-by area. In general, common stall size was considered (i.e., about 6 m × 2,5 m) as defined by the National Road and Highway Code, able to host

light commercial vehicles and small trucks used for the delivery in the city. The number of stalls determines the number of commercial vehicles that can simultaneously park in a lay-by area.

- Definition of the management policy for each lay-by. This aspect encompasses some further elements: first, the definition of the time window during which the lay-by is reserved for commercial vehicles. In some cases, in fact, a lay-by can be reserved for commercial vehicles for a portion of the day (i.e., from 7:00am to 10:00am) whereas if free for other vehicles outside that time window. Secondly, the possibility to effectively reserve a stall for a given period, for example using a mobile app such as in the Area DUM project in Barcelona (Ajuntament de Barcelona, 2015). This aspect opens up the problem of enforcing the reservations against the risk of unauthorized occupation.

The interaction of all the above-mentioned elements makes the overall problem complex and difficult to address with a single, all-encompassing method.

To provide further evidence to the discussion, this chapter refers from now on to the specific piloting area subject of the study. The problem of the location of parking lay-bys has been addressed with reference to a central district of the city of Bergamo, with a strong commercial presence, characterized by significant problems of traffic congestion (Figure 6-4). The considered area covers about 0.22 km2 and encompasses 162 commercial activities (i.e., an average of 736 commercial activities per km2). As illustrated in the chapter 5, first of all, elements of the pilot area that could interact with the proposed solution were upload into GIS software. In the case of loading / unloading sites, the road network, the location of the shops, the parking stalls already used for loading and unloading freight operations and stalls for parking cars (which can potentially become loading and unloading areas).

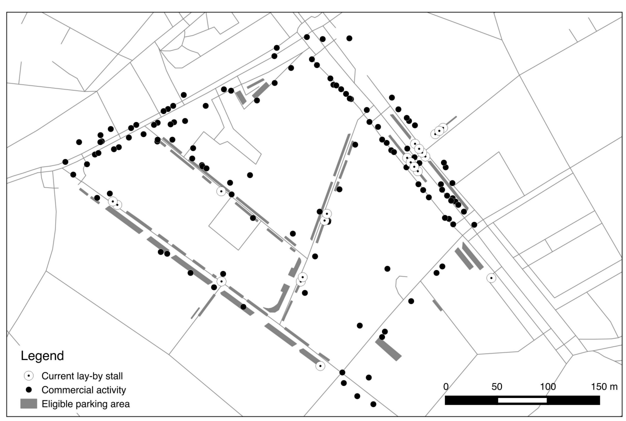

Figure 6-4 Offer elements in the area of the pilot study.

6.5 Data collection

Modelling the complexity of urban freight transport requires large amounts of data related to supply chain management, delivery practices, tour configuration, time windows, and so forth (Muñuzuri, Cortés, Onieva, & Guadix, 2010). Transport companies, operating in a very competitive environment, are normally reluctant to provide data on shipments, tours or timetables, which are viewed as commercially confidential (Morris, Kornhauser, & Kay, 1998). Thus, the collection of data to represent and model urban freight deliveries is an expensive and difficult task.

Due to the goals of the research, two categories of information are required:

- Spatial information: information about the position of each business activities in the pilot area, and information about the position of zones able to host lay-bys parking areas.
- Business information: information about the requirements of the business activities in the pilot area regarding their needs in terms of number and frequency of deliveries, and time required for loading/unloading activities.

While for the spatial information it was possible to resort to Geographic Information Systems (GIS) and commonly available maps as showed in the chapter 5, the category of business information required more effort. For a sample of the business activity present in the pilot area, and requiring delivery by means of commercial vehicles needing to park on a public space (i.e., on the road or in public parking stalls), interviews to the store managers were carried out to better understand their business requirements.

Finally, an on-field inspection of the area under study allowed us to validate the information retrieved from the GIS and the maps. In particular, the on-field inspection allowed filling the gaps and errors, especially for the identification of the parking zones that may be destined to host a lay-by (Figure 2). In doing this, also urban planning and physical constraints that were not detected from the maps was considered.

6.6 Proposed approach

As already mentioned in the previous section, the interaction of all elements involved in the analysis makes the overall problem complex and difficult to address with a single, all-encompassing method. Therefore, the problem was decomposed in two stages, each addressed using a specific method.

Indeed, the study of the locations of the lay-bys may be addressed as a facility location problem on a long horizon (i.e., once the lay-by areas have been positioned, they are unlikely to be subject to repositioning in the short term), whereas the occupation of the parking stalls implies the analysis of the dynamics of the commercial vehicles parking requirements over time.

In summary, the analysis is structured in two stages:

- The first stage addresses the design of an analytical model allowing the identification of the location of the lay-by areas. In this case, an analytical model is suitable since the location of the lay-by areas is based mainly on spatial information, which is deterministic in nature (i.e., not subject to variability).
- The second stage addresses the analysis of each lay-by area activated selected by the analytical model at the first stage to assess the most suitable size (i.e., number of parking stalls) ensuring acceptable performance in terms of space occupation and parking availability. In this stage, the main information used is the demand of the commercial activities; this information can be subject to variability in terms

of magnitude (i.e., number of deliveries per day) and over time (i.e., from one day to another, or from one season to another). Therefore, this phase opted for a simulation model in order to assess the performance of this design decision.

This research did not address the routing decisions or the interaction with other urban flows. In fact, the focus is on the location of the lay-by areas and the number of stalls for each area considering the current requirements from the business activities. In the next section, the models supporting the above-mentioned two-stage analysis are defined and discussed.

6.7 Models formulation

6.7.1 The location model

To define the best locations for the lay-by areas, a discrete covering model was adopted. The model aims at finding the minimum number of lay-by areas that can "cover" all the delivery destination points (i.e., shops and retail points), where a point is considered covered if there exists a lay-by area not farther than a distance *R*, called radius. In general, the radius represents the longest distance that a delivery operator is willing to walk (on a straight line) from the lay-by area to deliver the goods.

Such an approach requires the following steps:

- From the spatial information and the field inspection, the areas potentially eligible to host a lay-by area (in general at the borders of the streets) were identified. In general, the parking areas are considered with their coordinates in the continuous space (Easa and Dezi, 2011). Then a discrete model was chosen, which allows for a simpler formulation, with low impact on the accuracy of the location. To this end, each eligible area was discretized in a finite number of homogeneous lay-by areas, each identified by the location coordinates of its geometrical centre (Figure 6-5).

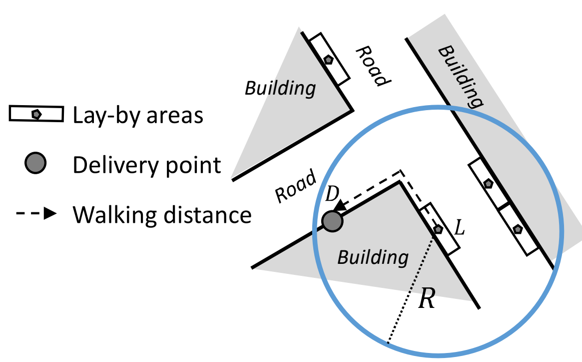

Figure 6-5 Covered area vs real walking distance.

- The notion of coverage should be adapted to the constraints of the field. In fact, with reference to the example reported in Figure 6-5, it is not corrected to consider covered a destination point within the circle of radius *R* and centred in the lay-by area; a point has to be considered covered if it is within a walking distance of R meters (i.e., real walking distance) from the centre of the parking lay-by. In Figure 3, the delivery point D is, thus, not covered from the lay-by L.

Given these assumptions, the covering model can be described as follows: given a set N of delivery points and a set M of feasible lay-by area locations, we want to define the minimum number of locations in M where a lay-by should be placed. A location selected for placing a lay-by is called active. The final objective is to cover all the delivery points in N. Formally, a delivery point $i \in N$ is covered if there exists at least one active location j such that the walking distance $d(i,j)$ between i and j is shorter that a pre-specified distance R (still called radius). The covering possibilities could be represented using a binary matrix $C=N\times M$ whose entries are defined as follows:

$$c_{ij} = \begin{cases} 1 & \text{if } d(i,j) \le R \\ 0 & \text{otherwise} \end{cases} \tag{1}$$

The formulation of the model requires the definition of the binary variables $y_j \in \{0,1\}$, which assumes the value 1 if a lay-by is placed in the location $j \in M$, and 0 otherwise. The objective function is, therefore:

$$\min \sum_{j \in M} y_j \tag{2}$$

and the covering location model is obtained adding the following constraints:

$$\sum_{j \in M} c_{ij} \cdot y_j \ge 1 \qquad \forall i \in N \tag{3}$$

In fact, all the delivery points $i \in N$ must be covered; this means that, among all the lay-by possible locations $j \in M$ within a distance R, at least one should be activated (i.e., $y_j = 1$). Clearly, it may result that some delivery points are covered by more than one parking lay-bys, whereas uncovered delivery points are not allowed. This may result in cases where isolated delivery points require their dedicated lay-by area. These corner cases can be subject of further cost-benefit analysis to exclude them or confirm the solution.

The result on the pilot area suggests activating nine lay-by areas, considering a walking distance R = 75 m, slightly shorter than R = 100 m stated in the literature (McLeod & Cherrett, 2011) because of the relative small size of the considered area.

The formulated covering model does not distinguish between the size of the delivery required by each delivery point (i.e., all delivery points must be covered, regardless the amount of goods they should receive). This assumption is coherent with the initial requirement to cover all the destination points defining both the minimum number and location of parking lay-by areas. In case the number of parking lay-by areas to be placed is limited, the model can be easily adjusted introducing a different objective function requiring to cover the maximum amount of "demand" (maximal covering problem).

6.7.2 Definition of the number of parking stalls per lay-by area

Solving the covering model allows defining the locations of the lay-by areas required to cover all the delivery points. As a further result, it is possible to associate each delivery point with a unique lay-by area. However, the described model is not suitable to define the number of stalls to be placed in each active location.

The definition of the correct number of parking stalls to be placed in each location is influenced by several parameters, such as i) the number of delivery points served from each lay-by area; ii) the number of expected delivery trucks per delivery point per day; iii) the time-window available for the loading/unloading operations (i.e., from 7:00 am to 10:00 am, or the whole day); iv) the average duration of the loading/unloading operations; v) the possibility to reserve the stalls in advance, thereby scheduling the arrival of the trucks.

The covering model allows to define only the first parameter (i.e., the number of delivery points served from each lay-by area), whereas all the others may be subject to some degree of uncertainty, or even not known at all.

If the parameters are known (at least, their average values) it is possible to define an average number of stalls per each lay-by area. For example, let us consider one lay-by area $k \in U \subset M$ (that is, U is the subset of active locations in M). Let us define the delivery window T_k, the average duration of the loading/unloading activities t_k, the number of delivery points n_k served from the lay-by area k, and the average number of trucks v_k required by each delivery point served from lay-by area k. Let us assume that it is possible to schedule the arrival of each truck, so it is possible to avoid conflicts in the occupation of the parking stalls within the lay-by. In this ideal situation, the number S_k of stalls to place in the area k is given by:

$$S_k = \left\lceil \frac{t_k \cdot n_k \cdot v_k}{T_k} \right\rceil \tag{4}$$

where the operator $\lceil x \rceil$ indicates the rounding up to the nearest integer of the number x.

However, in many cases, some of the parameters defined above are uncertain, or there may not be the possibility to schedule the arrival of the trucks, thus making necessary to deal with stochastic arrivals and performance. To deal with this aspect, it is necessary to assess the performance of the design decision about the number of stalls under different conditions. To this end, a simulation model was formulated, as described in the next subsection.

6.8 Assessing the solution performance: the simulation model

Simulation is a well-known approach suitable to deal with uncertain parameters. There are different simulation paradigms that may be used in this context. For example, Boussier et al. (2011) used an agent-based simulation approach to assess the performance of a strategy based on the sharing of parking places between light cars and vans for goods delivery. The authors have also shown that the implementation of behavioural models and learning process of cognitive agents based on stated preferences collected beside the network users are designed for capturing multi-agent interactions. Cortés, Muñuzuri, Nicolás Ibáñez, & Guadix (2007) used discrete-event simulation to analyse the freight traffic in the Seville inland port, focusing on the transport process through the estuary and its arrival to the port dependencies including the loading/unloading processes by the logistics' operators. Similarly, van Duin, Kortmann, & van den Boogaard (2014) adopted discrete event simulation to analyse the logistics performances and traffic influences for different fleet size configurations of different vessels types (touring boats, pleasure crafts and freight vessels).

According to the specific goals, modelling the complexity of urban freight transport usually requires large amounts of data. In our case, however, the interest is in the assessment of the performance resulting from a design decision about the number of parking stalls to place in each lay-by area. Thus, this work does not address higher-level decisions, such as for example the routes of each commercial vehicle, or the interaction at the traffic level with other transport services (i.e., public transport). Further, in the analysed case, it is possible to simulate each lay-by area separately from the others. The reason underpinning this opportunity is that once the parking lay-by areas have been optimally placed, each driver will naturally drive to the closest location (unique in general, although a delivery point may be covered by more than one lay-by area), thus reducing or even eliminating the interactions with the other locations.

On the basis of these considerations, a process-based Monte Carlo simulation paradigm was chosen, which requires less information and computational effort. The Monte Carlo simulation consists in producing thousands of scenarios (also called iterations or trials) sampling from the probability distributions of the events that can occur (Vose, 2008). In our case, an event can represent the arrival of a truck requiring a parking stall, or the duration of the loading/unloading operations, or even the number of trucks expected to visit a given lay-by. Monte Carlo simulation is most useful when it is difficult or impossible to use other mathematical methods; in the considered case, in fact, the analysis via analytical methods is very complex. The decision process of the drivers is simulated as summarized in Figure 6-6. When a driver arrives at the lay-by area, there are two basic alternatives: either one stall is available (so the driver can park and perform the delivery), or are all occupied. In the latter case, the driver can decide to i) wait for a stall becoming vacant, ii) occupy another parking place not reserved for the delivery operations (i.e., parking in a lot destined to cars, or even double-parking; in any case, this choice produces a negative effect on the traffic), or iii) evaluate other possible alternatives (such as deferring the delivery to another day). This study not assume the availability of a support system allowing the driver to remotely know the actual utilization of a lay-by area. For the sake of exemplification, Figure 6-7 reports the results of the simulation of the arrival of four trucks at a lay-by with a single parking stall, reserved for commercial operations for 2 hours: when the stall is occupied, the other arriving trucks must wait. Beyond the reserved time window of two hours (120 minutes), the stall is occupied even though it may be available for other vehicle categories (e.g., cars).

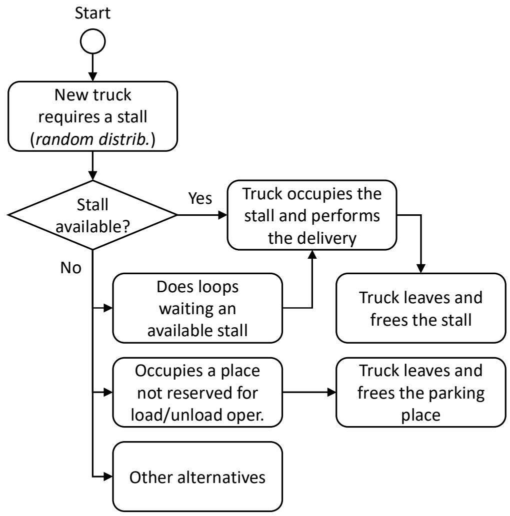

Figure 6-6 Example of a general stall occupation process.

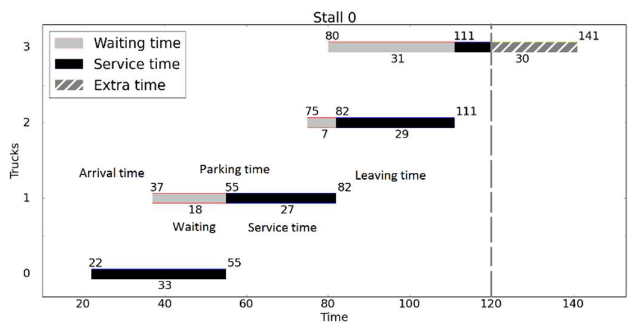

Figure 6-7 Example of the occupation of a single stall from the simulation.

6.9 Computational results: an example

As an example of a practical application of the model, the results related to the first option available when the best parking area is not available are reported, that is to wait for an available stall in the best lay-by area. Let us consider one parking area k=1 that serves $n_1 = 21$ delivery points. A service window T_1 =180 minutes is assumed, and an average loading/unloading time $t_1 = 30$ minutes as resulted from a local survey performed in the addressed area. As hypothesis, each delivery point receives on average $v_1 = 1$ truck per day. From (4), the minimum number of stalls to be placed in the lay-by area 1 is

$$S_1 = \left\lceil \frac{30 \cdot 21 \cdot 1}{180} \right\rceil = \lceil 3.5 \rceil = 4$$

Assuming that the 21 trucks (i.e., an average of one per delivery point) arrive independently from each other; since the service time is 30 minutes on average, as hypothesis the last truck arrives no later than 150 minutes (i.e., the max allowed time window for the deliveries) from the beginning of the time window T_1. Six different scenarios have been defined considering the following aspects:

- The number of stalls (a decision variable) varies between four and five.

- The number of delivery vehicles arriving during a day varies stochastically around the average of 21, between 19 and 23. The vehicles arrive independently from each other, uniformly distributed during the time window T_1; however, since the minimum service time is 30 minutes on average, it is assumed that the last delivery vehicle arrives no later than 120 minutes from the beginning of the time window T_1. In fact, after 150 minutes the area will be accessible again to private vehicles.

- The duration of the delivery time t_1 varies stochastically between 15 and 35 minutes according with the values expressed by the carriers during the *"Bergamo Logistica"* project interviews.

- The probability that the driver would wait for a commercial parking stall in case he/she arrives at a parking area at a time when no stall is available varies between 0.5 and 1. In this context, "waiting" means that the driver stays on the road looping, waiting for a free stall at a later time.

In conclusion, the cases reported in Table 6-2 have been simulated; each case has been simulated 1,000 times, the uniform distribution was used for the sake of the example; however, any other distribution may be used, according to the available data. and an excerpt of the results is reported in Table 6-3**Errore. L'origine riferimento non è stata trovata.**. The same procedure should be performed for each lay-by areas defined by the covering model, adjusting the values in Table 6-2 accordingly.

	Stalls	**Number of trucks**	**Service Time (min.)**	**Arrival Interval (min.)**
1	4	21	30	Uniform in [0, 150]
2	5	21	30	Uniform in [0, 150]
3	4	21	Uniform in [15, 35]	Uniform in [0, 150]

4	5	21	Uniform in [15, 35]	Uniform in [0, 150]
5	4	Int. random in [19, 23]	Uniform in [15, 35]	Uniform in [0, 150]
6	5	Int. random in [19, 23]	Uniform in [15, 35]	Uniform in [0, 150]

Table 6-2 Simulation cases

	Mean waiting	**Median waiting**	**Max waiting**	**Std. dev. waiting**	**Time windows exceeded**	**Average exceeded time**	**Average stalls saturation**
1	10.3	8.2	69	11.2	2165	26.585	83.8 %
2	3.2	2.4	47	5.8	598	4.883	69.4 %
3	4.9	3.1	53	7.4	583	4.851	72.3 %
4	1.5	0.7	32	3.7	258	1.250	58.1 %
5	5.2	4.7	62	7.7	728	6.573	72.3 %
6	1.6	0.9	38	3.9	230	1.116	58,0 %

Table 6-3 Results summary

The mixed Analytical-Monte Carlo simulation approach illustrated in this paper enables a thorough performance analysis of a design decision. In particular, the combination of an optimization model (using deterministic data) with a simulation model (dealing with random data) allows for a better understanding of the available alternatives. In general, regarding the waiting time, the value of median is bigger than the value of the mean, consequently, it is possible to say that the data distribution is asymmetrical and the most part of the data are smaller than the mean value, so taking in consideration the value of the mean waiting time is a precautionary choice. Analysing the data – summarized in Table 6-2 – it is possible to understand the potential impact of different options. For example, the design decision obtained using eq. (4) (i.e., four stalls) leads to fairly good performance even when the arrival times and the service times are stochastic. However, the performance degrades, especially in terms of waiting time and extra time when also the number of trucks is uncertain. Having these numbers about the different cases' performance, it is possible to evaluate the advantage and drawback of allocating one more stall in a given lay-by. As further development, it is possible to considerate: i) the possibility to extend the considered area and to compare the actual performance of the as-is setting against the performance resulting from the model; ii) the possibility to include more information in the driver's stall occupation process, for example assuming the presence of an ICT support monitoring (as in the Area DUM project) and communicating the current occupation of each stall.

6.10 RQ3 outcomes

This chapter answers the RQ3 using an example of a city logistics solution optimization. Through the loading/unloading bays model it is possible to support the municipality in analysing alternative solutions according to the carrier's needs (e.g. reduce the walking distance to no more than 100 meters carrying freight, perform the loading/unloading operations as fast as possible in order to respect all the deliveries timetable, avoid parking in a forbidden zones risking to incur in a fine), the retailers' needs (e.g. reduce the support to the carrier outside the shop, have the deliveries on time), and the budget limitation (e.g. transforming paid parking spaces into loading and unloading bays some revenues are lost). Moreover, making a sensitivity analysis on some parameters, such as the stall saturation, it is possible to evaluate the percentage of trucks not served by the loading/unloading bays. This percentage could contribute to the congestion in the investigated area or could constitute a potential risk if the driver chooses to parking in a forbidden area.

This is only one example of how it could be possible to implement a new city logistics solution (or improve an existing one) taking in consideration all the stakeholders' need and all the elements of the transport system that could be affected by the applied solution such as, in this case, the level of congestion in the streets in the areas if the number of truck parking is not adequate.

Moreover, in the loading/unloading bays model example, it is possible to find each element of the city logistics ecosystem: habitat (i.e., the parking stalls on the side of the streets), regulation (i.e., time windows), production (i.e., the loading/unloading operations), information (i.e., delivery data), carrier (i.e., typology and dimension of vehicles), stakeholders (i.e., carriers and retailers). Further researches should consider the application of the city logistics ecosystem framework to all the other city logistics solutions in order to define the elements that these solutions share with the other ecosystem existing in the city, especially with the people mobility. In this way should be easier to understand the impacts that the application of a particular city logistics solution should generate on the mobility ecosystem and more in general within the city.

7. General Conclusions

This dissertation work has started from the framing of the general context of urban freight transport by highlighting the main criticalities that led to the birth of city logistics initiatives and related solutions. The initial exploration of the existing scientific literature on the subject, as well as of the European projects related to the implementation of city logistics solutions, found that despite the great interest raised by the subject in both the operational and research sphere, researchers and practitioners are far from have lots of city logistics projects that can be self-sustaining from an economic point of view and that lasting over time. In particular, analysing some European city logistics initiatives and performing a systematic literature review regarding articles about urban freight transport several gaps hindering the performance of both the city logistics initiatives and the research have been found.

These gaps correspond to the involvement of stakeholders in city logistics projects, the lack of shared data, and the need to develop solutions that take into account the entire urban transport ecosystem. These gaps, emerged from the literature, were also confirmed by the analysis of European projects related to city logistics initiatives. In fact, many projects related to the urban distribution centers failed because of the lack of stakeholder involvement, or mismanagement or erroneous design of the center, caused in turn by incorrect sizing of freight transport flows in urban environment (Lagorio et al., 2016).

Involvement of stakeholders

With regard to RQ1, it is possible to say that proper stakeholders' engagement guarantees the effectiveness of the solutions implementation. Certainly, getting stakeholder participation and their active involvement in a city logistics project is not easy: there are many examples in the literature of models to facilitate stakeholder participation or simulate their behaviours and their choices. However, these models need lots of information as input, a great effort by researchers and they are not immediately understood by the stakeholders themselves.

The model proposed in this thesis is that of the House of Quality, a method that derives from product design, that allows to compare immediately and graphically the stakeholders' needs that must be met by possible city logistics solutions (i.e., Stakeholder Requirements), the weights that reflect the importance that these needs have for the stakeholders (i.e. Importance Weights) and the possible solutions to be applied to the urban freight transport (i.e., City Logistics Solutions) (Figure 7-1).

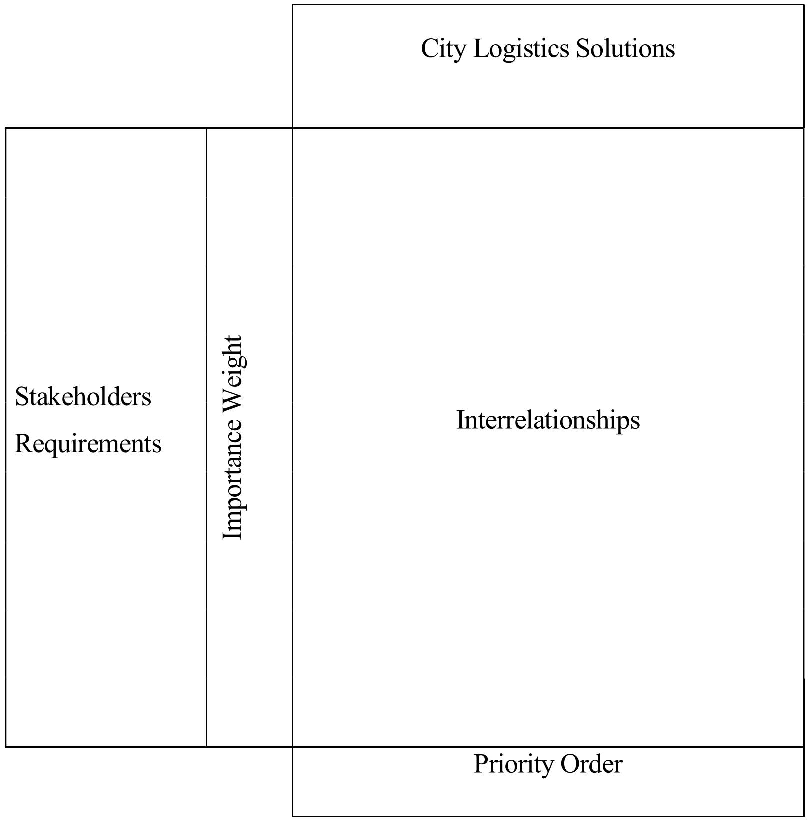

Figure 7-1 House of Quality matrix for urban freight transport

Since the proposed solutions are able to meet the stakeholders' needs with different level of effectiveness (i.e., Interrelationship) the matrix result is a priority order of solutions implementation (or at least order) to understand what are the solutions able to meet the highest number of stakeholder requests.

The advantage of this type of decision support tool is the visual immediacy and the limited construction cost of the matrix: it is sufficient to perform a focus group with the major players in the sector to define the needs they have in their daily operations and the degree of priority that these needs have for them. The rest can be done at a later point by the researchers. In this last element lies also the main limitation of the application of this method: who builds the matrix must decide how a city logistics solution can solve the needs of the stakeholders. Therefore, as far as the researchers try to be objective in assigning these weights and regardless of their field experience there will always be a margin of discretion by those researchers who fill the matrix.

However, the House of Quality remains one of the simplest methods for knowing stakeholder advocacy on some crucial aspects of urban freight transport.

Data sharing platform

Anyone who has to deal with urban freight transport is faced with the problem of lack of data. As already explained from the introduction of this thesis, the necessary data are many, very difficult to collect, and they need to be constantly updated.

However, it is not possible to dimension transport-related infrastructures without having previously made a major estimate of the demand for goods and without having an idea of the presence of existing stores and infrastructures.

For this reason, it is necessary to create data sharing platforms that allow putting together all the data related to the urban transport of goods that are available, and to share them with all the operators. The framework proposed in the thesis for the creation of a data sharing platform allows to gather all available data and to identify what data layers are needed to design each one of the most known and applied city logistic solutions.

To devise the proposed framework, therefore, all the characteristics of the city that are involved in urban freight transport, based on existing literature, have been identified. Next, for each feature, several layers of information were defined and a data source was identified for each layer. In this way, through the support of a GIS software, each source has been used, collected in a layer, and joined to the others. In this way, it is possible to select and display from the GIS map only the layers concerned from the city logistic solutions investigated, understanding what are the solutions that affect multiple layers, which are the easiest to implement and which additional data may have occurred for the implementation.

In this way, it is also easier to evaluate the elements on which the solutions are more closely related to the needs of the stakeholders, making it easier for researchers to build the House of Quality matrix, and partially dismantling the limitation due to the subjectivity of the researcher in evaluating city logistics solutions.

City logistics ecosystems

The third and final gap that has been addressed during this thesis work is the need for stakeholders to evaluate their decisions within an ecosystem. Urban freight transport uses infrastructures and is governed by rules shared by people's mobility. Even stakeholders are not just actors in the urban freight transport system: for example, traders are also interested in the city's tourism and cultural activities, so that they can increase the number of their customers, as well as municipalities are also concerned to other aspects of their citizens' lives such as the healthcare system or the security system. Consequently, when designing a city logistics solution, is fundamental consider what elements of the ecosystem are involved (infrastructures, rules, actors) and how they can be impacted by the solution taken into account.

For example, in the decision-making model presented in Chapter 6 on the optimization of loading / unloading lay-bys in the city, all the city logistics ecosystem aspects are taken in consideration: the regulation, the roads and parking stalls, the characteristics of the loading and unloading operations, the carriers' behaviours. However, the final decision lies with the public decision-maker, the municipality. The model shows how improve the loading and unloading bays operations: how the carriers waiting times could decrease and how the loading and unloading operations can be accelerated increasing the number of available stalls for the loading and unloading operations, but for each dedicated stall added there will be, for example, less car parking stalls for citizens (and less earnings if those parking lots are communal and paid). To go into detail in these observations is beyond the objectives of the thesis, but it is not possible to think of implementing city logistics solutions without taking account of them. Dealing with these aspects, as it emerged in the course of the work, can mean failing to realize a city logistics initiative losing money and trust.

Limitations

This thesis not propose definitive solutions to overcome main city logistics initiatives gaps and barriers, but just propose possible solutions easy to be understood and applied by both researcher and practitioners. There are also some limitations. The solutions presented in this thesis such as the House of Quality, the data sharing platform and the loading/unloading bays improvement model needed to be tested in more cities to guarantee their replicability. Moreover, there are some important aspects that have been neglected by this thesis and have been considered out of scope such as the freight demand estimation, the economic aspects related to the implementation of each city logistics solutions and finally the environmental earnings that could derive from the application of the city logistics initiatives in terms of CO_2 and PM_{10} emissions. This choice has been made because each one of this limitation is so complex that could be a theme for future researches in the field of urban freight transport.

Further Developments

As written in the paragraph before, the HoQ model and the loading/unloading bays model need to be tested also in other city apart from Bergamo to test their replicability. Also the City Logistics Ecosystem need to be used in new context and not also in the already existent projects to test its robustness and to eventually add some aspects that in the current projects are missing. Another possible extension of the City Logistics Ecosystem could be the investigation of the links between it and the people mobility.

Also the research about city logistics stakeholders could be extend with more in-depth investigations on individual stakeholders to better understand their way to evaluate city logistics solutions according to their interests.

Finally, a further interesting development of the research could be to understand how technological innovations (much debated in the context of the 4.0 industry) are integrated with the urban transport of goods and how they can constitute an instrument to overcome the gaps highlighted by the present PhD thesis work.

However, this thesis shows and proposes solutions, all discussed not only with other academicals researchers but also with the operators in the sector, trying to face in an easy and replicable way all the actual issues in the urban freight transport context.

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APPENDIX A: Complete and numbered list of papers constitute the corpus of papers of the Systematic Literature Review described in the chapter 2

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