Costs and benefits of logistics pooling for urban freight distribution: scenario simulation and assessment for strategic decision support

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Abstract

Collaborative transportation and logistics pooling are relatively new concepts in research, but are very popular in practice. In the last years, collaborative transportation seems a good city logistics alternative to classical urban consolidation centres, but it is still in a development stage. This paper proposes a framework for urban logistics pooling ex-ante evaluation. This framework is developed with two purposes. The first is to generate comparable contrasted or progressive scenarios representing realistic situations; the second to simulate and assess them to make a "before-after" comparative analysis. In this framework, a demand generation model is combined with a route optimization algorithm to simulate the resulting routes of the proposed individual or collaborative distribution schemes assumed by each scenario. Then, several indicators can be obtained, mainly travelled distances, working times, road occupancy rates and operational monetary costs. To illustrate that framework, several scenarios for the urban area of Lyon (France) are simulated and discussed to illustrate the proposed framework possible applications.

Keywords: urban logistics; resource sharing; freight transport pooling; policy-oriented modelling; simulation-based comparative analysis.

1. Introduction

Abstract

The freight transport sector is a major source of employment and often plays an important role in the economic development of regions and country. However, freight transport is also a disturbing activity, due to congestion and environmental nuisances, more particularly in urban areas (Crainic, 2008). In urban context, city logistics has been developed for more than fifteen years, giving solutions and methods to support public authorities and also other stakeholders in urban freight transport planning and management (Taniguchi et al., 2001). One of the most popular solutions related to city logistics is that of urban consolidation centres (UCC). Because they are located near the city centres, UCCs usually have significant costs related to real estate expenditures, and urban distribution systems based on consolidation also require extra support to ensure their economic continuity (Dablanc et al., 2010). For these reasons, UCC in Europe are currently resumed to a few operationally rentable cases, most of them in Southern Europe (France and Italy).

Another solution is that of logistics pooling, that can be defined analogously to car-pooling as the common usage of logistics resources: material (vehicles, platforms), human (drivers, land operators) and immaterial (software tools, information). We observe several projects dealing with urban logistics resource sharing in the last years, most of them being still at a development phase (Gonzalez-Feliu and Morana, 2011). Most of these projects aim to make a semi-closed group of collaborators who share vehicles and platforms to reduce their logistics costs and the environmental nuisances related to last mile distribution in urban dense zones. Although several urban logistics pooling projects have been started in Europe, they remain at the conceptual level, and no experimentation or evaluation has already been made. The evaluation of a logistics system is important since the performance of the system will be assessed “ex ante” (Filippi et al., 2010) and will motivate public authorities for the implementation of a pilot phase or a deployment of these systems. This is the case of the LUMD project (Presstalis, 2011) that will pursuit with an experimentation in Strasbourg (France), mid 2012.

This paper proposes to present a methodology for scenario assessment and simulation in the context of urban logistics pooling project, as well as to show the application of this methodology to scenario assessment. The proposed research shows the link between base research in various disciplines (applied mathematics and modelling, urban economics, computer science) and their application in a commercial tool for operational planning. First we present the main concepts of logistics sharing, focusing on urban freight consolidation. Then, an integrated simulation framework combining an optimization module, a scenario generator and an environmental module is presented. After describing the method, the retained scenarios are described and simulated. Finally, the main results and future developments are presented and commented.

2. Urban consolidation and logistics pooling

Traditionally, urban freight transportation planning has been made by the operating companies. In the last years, the public authorities have started to get involved into the development of solutions to deal with the major problems of freight transportation in city centres: congestion, air pollution, noise and other nuisances. Some of the most common measures taken by the authorities in different countries are restrictive policies, mainly regulation on parking, and street access. In several countries, surveys and data collection activities have been undertaken, and some studies give elements of freight transportation analysis and organisation for urban areas (Dablanc, 1998; Taniguchi et al., 2001; Crainic et al., 2004; Rosini, 2005; Crainic, 2008; BESTUFS, 2009). These efforts are aimed at better understanding and quantifying these phenomena and represent a first step in the development of a new discipline, called by several authors City Logistics (Taniguchi et al., 2001; Crainic, 2008) or Urban Logistics (Routhier, 2002; Anderson et al., 2005). The main goals of City Logistics measures and projects are related to congestion and air pollution rates, without a penalisation of the commercial activities in the city centres.

Several city logistics actions are organised around the concept of urban consolidation centre (UCC), defined by Allen et al. (2007) as "*a logistics facility situated in relatively close proximity to the geographic area that it serves (be that a city centre, an entire town or a specific site such as a shopping centre), to which many logistics companies deliver goods destined for the area, from which consolidated deliveries are carried out within that area, in which a range of other value-added logistics and retail services can be provided*". The first UCCs were private or semi-private initiatives, following economic and optimization interests (Dablanc and Massé, 1996). Later, environmental and social issues made public administrations to develop such systems for urban goods distribution (Gonzalez-Feliu, 2008).

In order to make a European overview on UCC we have selected the main experiences show in literature (Dablanc and Massé, 1996; Patier, 2002; Browne et al., 2005; Rosini, 2005; Allen et al., 2007; Gonzalez-Feliu, 2008; Spinedi, 2008; BESTUFS, 2009, Dablanc, 2010; SUGAR project, 2010; Dablanc et al., 2010; Danielis et al., 2010; Gonzalez-Feliu and Morana, 2010; Trentini and Malhéné, 2010). We present in Table 1 a synthesis of the experiences taken into account.

Country	**Total number of UCCs**	**Operational UCC in 2010**
Italy	16	10
France - Monaco	15	7
United Kingdom	15	3
Germany	13	5
The Netherlands	6	2
Sweden	4	2
Spain-Portugal	3	1
Switzerland	2	0
Greece	1	0
TOTAL	75	30

Table 1: Synthesis of the main European experiences

We can observe that only few experiences are nowadays operating (about 40% of the total), and in many cases they need an important contribution of public authorities, both in terms of funding and organizational support.

Italy is the case with the most planned and operational UCCs. From the case of Siena's UCC (Browne et al., 2005) to the last developments of Cityporto's network of cities with UCC (Gonzalez-Feliu and Morana, 2010), more than 15 UCC have been planned. Most of them derive from public decisions and have an important contribution of public authorities, both related to regulation and funding. The main UCC in Italy are related to medium-sized cities, i.e. cities between 100 000 and 500 000 inhabitants, like Bologna, Genova, Ferrara, Padova, Parma, Siena, Venezia-Mestre and Vicenza, among others (Browne et al., 2005; Gonzalez-Feliu, 2008; Spinedi, 2008). In the last 5 years, other small cities (from 10 000 to 50 000 inhabitants), like Frosinone or Aosta have started to develop such systems (Trentini et al., 2011). The only application cases in big cities are those of Milan, where the public transport operator ATM used their bus depots and other facilities to propose an urban freight delivery system and that of Naples, which made a pilot of a urban-regional rail distribution system (Gonzalez-Feliu, 2008). The city of Rome have considered the idea of developing an UCC network (Crainic et al., 2004), although the project stopped after the preliminary study. What we can note from all these experiences is that most of them derive from regional, national or European funds (mainly related to research and development programs). Most Italian UCCs benefit from a strong support of public authorities, which can take the form of finantial support, even for operational management (Venezia-Mestre, Ferrara, Genova) or a regulation support to increase the UCC' attractiveness (Bologna, Modena, Parma, Vicenza). However, we find two particular cases where the contribution of public authorities was limited to a general regulation not directly benefiting the UCC distribution system but promoting green transport in city centres: that of Cityporto, a network of UCC which derive from the successful experience of Padua (this experience will be presented below) and the case of ATM in the city of Milan. Cityporto Padova is considered one of the Italian successes and will be presented in next section. Concerning the UCC system in Milan (ATM develop a network of three urban platforms in Milan with a dedicated fleet of environmental friendly vehicles), the system was operational between 2005 and 2008 (Trentini et al., 2011). It stopped because a major change in urban regulation that forbit ATM to use the bus corridors for freight distribution.

On similar patterns, the French UCC have been developed (we include the UCC of Monaco in this category for reasons to culture and geographical proximity to France). Note that in this country, a National Comitee for Urban Goods Transport have been created in 1995 and is still operating[1], which facilitates the exchanges and promotion of good practices. Thres main development periods related to UCC can be defined:

- before 1995, some private experiences, like those of Pari or Aix-en–Provence (near Marseilles) were carried out but stopped for reasons of rentability or strategy changes by the promotion companies;

- from 1995 to 2003, experiences were promoted by public authorities, mainly with similar funds as the Italian experiences and with a viewpoint of a "freight public service";

- after 2003, private or semi-private companies have proposed last mile distribution services to transport operators based on UCC or similar platforms, like La Petite Reine or Natoora, or big companies, like Chronopost or Monoprix, have developed distribution schemes using private UCCs.

In France, we observe two types of UCC: city-based UCC, which are related to an entire city or its historical center (La Rochelle and Monaco are the two that remain still operational); area-based UCC, more related to a neighborhood and used by several companies without an aim of

[1] For more information, see http://www.transports-marchandises-en-ville.org/

public service (Bordeaux, Paris, Rouen) and private UCCs, like those of Chronopost and Samada-Monoprix (Paris), Colizen and La Petite Reine (several cities in France).

Germany has also developed several UCCs, but the operational experiences represent less than 40% of the total number of projected UCCs. This can be explained by the fact that German UCCs have in general been developed by consortiums of private companies without public funding support for their construction and operational cost balancing, although research and development funds and regulation support have been provided by the authorities in some cases. Indeed, German UCCs are an example of non-direct intervention of public authorities. This makes the number of successful UCC lower than those in France or Italy and has a stronger connection to the market and the business development of the concerned transport operators in UCCs.

The German UCC success rate, lower than the French and Italian ones, remains still higher than countries like the United Kingdom or The Netherlands, which the public authority support did not result on operational logistics schemes, resulting on a very small number of still opened UCCs (about 20-30% of the total number of projects). Other countries have also projected UCCs in a minor intensity, but the results are not encouraging (if we add all the remaining experiences, we obtain a success rate of 30%). Note than in both cases the UCC systems were supported by the public authorities, mainly in the form of strong regulation policies, but the financial support was lower than in France and Italy.

Other interesting cases have been observed in Sweeden and Switzerland, with similar schemes than UK and Dutch UCCs. The successes are still few, but several learnings can be extracted from them. Finally, the remaining south-west Europe countries (Greece, Portugal and Spain) are only starting to think to the question, and follow the French and Italian patters. However, the problem of financial support to ensure the UCC continuity is still an important obstacle to their development and assessment.

As most of these experiences show, a UCC needs an important initial investment in terms of infrastructures, facilities and human and technical resources, including delivery vehicles, which are often compensated by public financial support. This support is not always enough, as operational costs are not always covered by the UCC overall income. Moreover, transport operators remain still reticent to use UCC under some conditions because the schemes related to these logistics platforms suppose at least an additional rupture of charge. The main limits to the usage of UCC can be grouped on the following categories (Gonzalez-Feliu, 2012):

- *Legislation*. Although it can be seen as a favourizing factor to UCC development in any cases (restrictions on access to some areas of the city for non-UCC vehicles can help the development of UCC), legislation can also be a limitation when it is related to freight compatibility, i.e. the norms and laws that forbid the loading of a vehicle with products of different sorts (for example dangerous goods, fresh food, waste, raw materials, etc.) or when dealing with competition laws that can limit the development of sharing approaches.

- *Organisation*. The physical and organizational conditions for freight compatibility, can limit the development of UCC. For example, dimensions, the type of packaging, the stock unit and the need of specific material for loading and unloading operations will be a limitation for two shipments to cohabit the same vehicle or consolidation platform. Another organizational factor related to the acceptability of transport carriers arises on the changes they will make on their distribution schemes.

- *Cost*. If a rupture of charge implies organizational changes, it also supposes cost increases. Although some UCCs have found optimization schemes to reduce these costs and facture similar costs to the transport operators, the question is still a current discussion subject when planning and developing these platforms.

- *Responsibility*. The factors related to the transportation operation's responsibility are strictly derived from the contract between the different actors of these operations. If the collaborations among partners and customers of UCC distribution systems follow a contract or a chart where the questions of responsibility are well defined, these questions will not constitute an obstacle to sharing. On the other hand, if these questions are not clearly specified in a contractual document disputes related to responsibility can derive on legal conflicts

The main issue in UCC is to reach a rentability threshold that ensures the economic balance of the logistics facility. Imposing a unique UCC operator does not seem to be the most efficient solution, as shown by Dablanc et al. (2010), and other strategies have to be found. Collaboration is one of the most promising areas of study in supply chain management and has started to be applied to freight transport management. This collaboration can take place at different stages as shown below (Gonzalez-Feliu and Morana, 2011):

- *Transactional collaboration*: the first stage of collaboration consists of the common coordination and standardization of administrative practices and exchange techniques, requiring information and communication systems.
- *Informational collaboration*: the second stage concerns mutual exchange of information such as sales forecasts, stock levels and delivery dates. At this level, confidentiality competition have to be taken into account while sharing information.
- *Decisional collaboration*: This category concerns different planning and management decisions (Crainic et al., 1997), and is divided on three stages:
    - *Operational planning*, is related to daily operations.
    - *Tactical planning*, or middle-term horizon, which involves decisions like sales forecasts, route configurations, inventory management and quality control.
    - *Strategic planning*, related to long term planning decisions such as network design, logistics platform location, finance and commercial strategies.

Logistics sharing and logistics pooling are specific forms of resource sharing (Gonzalez-Feliu et al., 2010). Although in a narrow sense the word “sharing” refers to the joint or alternate use of inherently finite resources, both material and immaterial, it can also refer to the process of dividing and distributing (Gonzalez-Feliu and Morana, 2011). According to Gonzalez-Feliu and Morana (2011), operational decisions are in general individually made. Tactical and strategic decisions can be made by different actors or groups, with different modalities:

- In *non-collaborative sharing*, the shared resources are managed by their users independently, without a direct interaction between these users. The involved actors share infrastructures or vehicles but each of them uses them for their own purposes, without simultaneously sharing them.
- *Collaborative sharing with hierarchical decision making* is a further step on collaboration, where shared resources are commonly managed by their users. In order to manage and guide the collaboration, a hierarchy is established, and the main decisions are taken by a manager or a small group of stakeholders, the rest having their opinion but are not taking part on planning and management issues.

- *Collaborative sharing with non-hierarchical decision making* is a more co-operative approach where all users take part into the decision processes. Indeed, management can be sub-contracted or given to a third person, but all stakeholders are directly involved on strategic (and tactical decisions) at equal levels.

In the first and the second types of sharing, strategic decisions are taken by a single decision maker. In the third type, these decisions are made by the members of a collaborative group of actors under a partnership contract or other type of agreement.

Sharing resources in freight transport is related to three main issues: vehicle sharing, infrastructure sharing and route sharing. Concerning vehicle sharing, the logistics organisation is similar to that of car sharing or bike sharing systems for people transportation (Katzev, 2003, SUGAR project, 2010). Indeed, a freight vehicle sharing system proposes a fleet of shared vehicles, and each user of the system can book and use a vehicle for his or her own purposes. In these systems, each user continues to follow an individual organisation (vehicles are shared but each user continues doing its own transport schemes without merging them with those of other users). The second approach is that of platform sharing (Rakotonarivo et al., 2010), without necessarily a collaboration between users. These two issues have been recently studied in the literature (Simonot and Roure, 2007; Paché, 2008; Blanchard and Carbone, 2010; Gonzalez-Feliu and Morana, 2011). The third, less studied, is that of logistics pooling.

Logistics pooling can be defined by analogy to car pooling (De La Morsanglière et al., 1982; Gärlinga et al., 2000). We can introduce freight transport pooling as the mutual and contemporary use of a vehicle by two or more actors, all of them being conscious and having a direct action on decisions concerning this transport organisational aspects. Note than the usage of a freight forwarder or integrated logistics providers (4PL, LLP) are usual concepts in freight transport (Ville, 2010), but the responsibility and the decision making is relayed to a third party, who assumes its consequences. This is not a collaborative decision making case, as defined by Yearwood and Stranieri (2011). Indeed, in those transport and logistics schemes, the sender (or the receiver) contracts a company that organises all the transport and distribution related operations, involving other actors like transport operators and logistics providers. This company takes decisions and organises all the distribution processes, the sender (or the receiver) being only customers paying for a standard or personalised service. In logistics pooling approaches, the decisions are not taken by only one stakeholder but by the group participating on the pooling operations. As happens on car pooling (De La Morsanglière et al., 1982), a freight transport pooling involves deliveries having a common trip chain in their overall path, and follows the same principles of multi-echelon transport with cross-docking (Gonzalez-Feliu, 2011).

As logistics pooling follows similar schemes as integrated supply chains, we can envisage to adapt methods from supply chain evaluation to estimate the effects of this form of collaboration in a sustainable development viewpoint. However, as several stakeholders are involved, current works do not represent the specificities of pooling strategies on logistics planning and optimization. In next section we will propose a methodology from current work on supply chain sustainable performance evaluation current literature, reviewing simultaneously the recent literature on the subject. Then, we will illustrate it on a realistic applicative test case for small grocery retailer distribution.

3. Costs and benefits of freight transport pooling in a sustainable development perspective

Urban goods transport has specific characteristics concerning urban logistics: a lot of operators, a specific management of the logistic chains: various delivery vehicles, different organisations (rounds, direct trips), a large part of own account transport, a large part of subcontracting, leading to an expansive last mile movement worsened by congestion, more and more constraints in road sharing, new orientations in regulation and planning by local authorities. We can precise what is taken into account in the urban goods movement:

- Pickup-delivery vehicles used for inter-establishments trade (commercial, industrial, services) and goods vehicles for business trips (craftsmen carrying goods from depot to site, …): about 40% of the total amount goods traffic (in terms of road occupancy rates);

- Home deliveries and private cars carrying goods (household purchasing): about 50%;

- Vehicles involved in the urban management (waste collection, postal service, removal, hospital, public works, building works): about 10%.

Overall goods traffic segments listed above amounts to 20% (in car unit) of the total urban motorised traffic, what accounts for 25% of CO2 emissions. Later we take into consideration the two first segments seen above representing above 90% of the total urban motorised traffic, on which simulations will be implemented.

From an environmental point of view, there are several stakes and challenges about urban goods movement for public authorities as well as for private stakeholders (references).

Regarding public authorities, the main stakes are as follows (Pateir et al., 2007):

- To revitalize the economic activity of the urban areas, particularly the town centres (with retail shops and various services).
- To master urban sprawl, controlling strategic town planning.
- To diminish congestion issues in the more dense (central) urban areas.
- To diminish the impacts of nuisance due to greenhouse gas and other atmospheric pollutants emissions, and to reduce noise levels.
- To implement convenient goods distribution services (home deliveries …).

Regarding private stakeholders (Morana and Gonzalez-Feliu, 2011):

- To provide quality services (commercial and tertiary activities) to the customers.
- To reduce the economic costs related to the last mile management.
- To make sure that sustainable policies of the firms may coincide with urban transport practices.

Taking into account the stakes above, and considering the current economic, environmental and social context, we state that it is a priority that an to think “sustainably” when developing and evaluating a city logistics project. Several works deal with sustainability in logistics (Gunasekaran et al., 2007; Belin-Munier, 2010; Morana, 2010) and more precisely on city logistics (Behrends et al., 2008; Henriot et al., 2008; Routhier et al., 2009; Gonzalez-Feliu and Morana, 2010; Patier and Browne, 2010; Russo and Comi, 2011).

Although sustainable development is usually related to three separate spheres (economic, environmental and social), some authors think that it is important to take into account their inter-relations, not only in the analysis but also in the definition of sustainability and its main categories (Lindholm, 2010; Patier and Browne, 2010). The main three spheres of sustainable development can be interpreted as shown in figure 1:

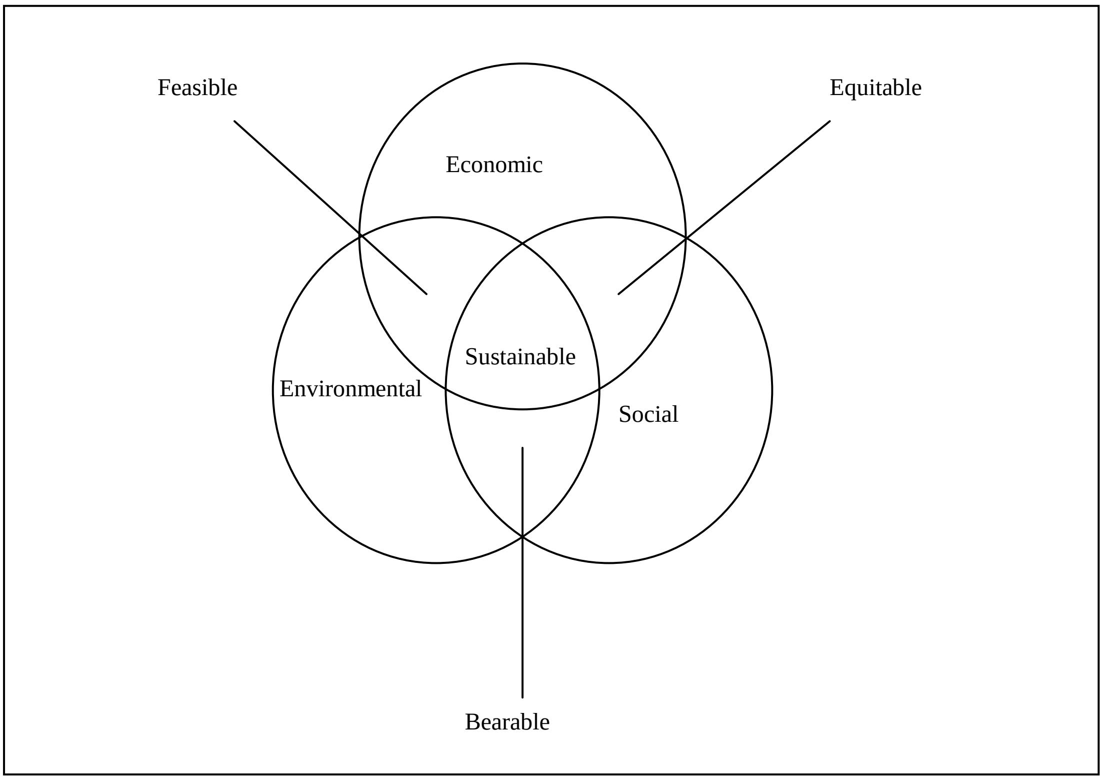

Figure 1: Components of sustainable urban logistics
(adapted from Lindholm, 2010; Patier and Browne, 2010)

3.1. Economic aspects

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 once the strong public funding support was stopped (Gonzalez-Feliu, 2008; Spinedi, 2008). Moreover, we can state that economic performance is seen crucial for a city logistics solution to ensure its continuity in time (Morana and Gonzalez-Feliu, 2011), although it is seldom clearly exposed in the valorisation of the solutions taken into account in this study.

The main economic costs in city logistics solutions belong to two different categories: the project development costs, related to strategic planning and new investments and developments, and the tactical and operational costs, related to the system monthly and daily operations. The first category includes the costs of the strategic planning elements (see section 2). These costs are generally not refunded, and it can be important to consider them in some cases. The second the transportation and logistics costs of the platform and the urban distribution network, mainly related to routing and scheduling, to platform management and to cross-docking and warehousing operations. Other costs that could also be considered are the execution costs and the maintenance costs, which have to be assumed by the transportation system in long term optics to assure the system is auto-sufficient and can be operative without the aid of public funds. Cost-benefit analysis are not easy to find in this field (only 4% of the solutions show them in a clear way), and most solutions that have stopped depended on public funding support that has decreased or disappeared, making them economically unsustainable. However, several economic indicators related to the logistics performance of urban distribution systems can be defined (Patier and Routhier, 2009). We propose to distinguish these indicators into two groups, to define the most signifiant ones respect to the city logistics solutions in practice and to discuss its measurability issues.

The first group (enterprise vision) contains financial, logistics and quality indicators. The financial indicators show how sustainable is a solution globally, and is related to the need or not of public financial support. Because cost-benefit analysis are not always easy to be found (they are usually confidential), we propose to define other indicators, related to public funding of the city logistics solutions. Most public authorities show explicitly the amounts of subventions for urban and regional projects, including city logistics development (SUGAR project, 2010). It is then interesting to define the percentage of the total costs covered by public funds, for both city logistics solution development costs and tactical and operational costs. The city logistics solution development costs are in general funded by the public authorities at more than 70%. Instead, the reduction of public funding for tactical and operational costs can become a target to meet in order to ensure the economic continuity. For this reason, the percentage of the costs covered by public funds for the tactical and operational functioning of the city logistics system are calculated at the first year of the project and at each other year, in order to define the current percentage and its trend. The logistics indicators allow to estimate the logistics performance of the city logistics system. Several indicators have been defined in the various solutions of this study. The most significant are the loading rates (both the average and the minimum), the number of km travelled by the routes, the average number of customers delivered by each route and the average number of parcels treated by the system each month.

The second group (system vision) is less relevant for the economic sphere. However, the changes on the number of jobs related to logistics and transportation in the overall urban area can be a good indicator of this group. Another indicator that can be defined is the congestion; However, measuring or estimating the congestion rates is an issue that needs a more detailed analysis. The congestion can be measured by the occupancy of the vehicles in movement or by those stopped in non-permitted places, mostly in double line. Since this second phenomenon is difficult to measure (as is also the dynamic behaviour of congestion), the total number of vehicles related to urban goods movement can be estimated using simulation tools, like Freturb (used by several French public administrations), City Goods (developed by the Emilia Romagna region for its main cities) and the commercial software Viseba, which includes a urban good movement simulation module. For a more detailed survey on this type of simulation methods, see Ambrosini et al. (2008). These methods can estimate the total number of km corresponding to different categories of economic activities in a city. Moreover, several categories of logistics organizations can be derived from them. From the spatial distribution of these flows and the characteristics of the routes (Routhier, 2002; Rosini, 2005), the total number of km, the number of stops and the average speed can be estimated for the routes of each type of logistics organization. Once the traffic flows are simulated, the total number of travelled km can be pondered transforming them in km.PCU (Private Car Unit).

3.2. Environmental aspects

The environmental issues of city logistics are related to three main phenomena: greenhouse gas emissions, local pollution and noise emissions. Analogously to the economic sphere, two groups of indicators can be defined. The first defines the environmental performance of the city logistics solution in a Green Supply Chain Management approach. This performance can be evaluated by reverse logistics and waste management indicators, commonly used in global logistics approaches but no always easily appliable to the context of city logistics. The second group gives an idea of the impacts of the city logistics solution respect to the overall urban area's goods movement environmental effects. These indicators are usually the reduction of the different polluting emissions, and are estimated for the three main component of the environmental impacts:

3.2.1. Greenhouse gas emissions

One of the main objectives of city logistics solutions is to decrease the greenhouse gas emissions that are the main contribution to global warming, in order to meet the targets of the Kyoto Protocol[2]. Most experiences that show the environmental gains make a direct relation between CO2 emissions and contribution to global warming. Although this gas, directly related to fuel consumption, is the main greenhouse gas of freight transportation, the other emissions are not negligible to do not include them in the greenhouse gas emission simulation and estimation approaches. These substances are CO and some of the local pollution gases like NOx and SOx. In order to estimate the real contribution of freight transportation in urban areas to global warming, a measure unit can be defined, the CO2 equivalent. To calculate the total emissions, in CO2 equivalent, each substance emissions can be estimated from the total distance travelled by a vehicle, its number of stops and its average speed, using conversion tables (ADEME, 2003; LET et al., 2006).

3.2.2. Local pollution

Local pollution is related to two types of substances: polluting gases (mainly for air pollution) and solid particles (polluting both air and soil). The emission rates of these substances depend on both fuel consumption and travel behaviour. In the last decades, the composition and the variety of fuels has changed, and cars have become more available to people. The changes in living habitudes have raised the usage of the private cars, and the traffic congestion and air pollution are two of the main problems of many European city centres. We can observe different polluting substances, which are directly related to fuel. The first group of polluting substances is the group of Nitrogen oxides, also known as NO_x, which proportions in fuel smokes are variable in the different fuel products.

Another important category of air pollution substances is that of sulphur oxides, or SO_x, less important in quantity than NO_x but having not negligible contributions to air pollution and global warming. Other substances that are being reduced with the new generation fuels are less common nowadays, and constitute an example of the contribution of research and development

[2] The Kyoto Protocol was adopted in 1997 at the third Conference of the Parties to the UNFCCC (COP 3) in order to achieve a stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climatic system. This protocol established that the countries which had signed it were to reduce the emission of CO2 by 5% in 2010, target not met at a global level.

to the pollution decrease. The last fuel Euro standards (Euro 4) and the new gas fuels, like GPL and GNV, are good examples of this contribution.

The last identified polluting substance is not a gas, but consists of solid particles, the most common ones known as that are produced by both fuel and tires. In City Logistics, the different types of solutions can influence the air pollution levels in different ways. The organization strategies and the restricting and incentive policies act on the traffic congestion, and consequently on the air pollution. The technological strategies, which arise on the combustion energies for transportation vehicles, can also contribute to reduce the levels of some of these substances. However, not all the "ecological vehicles" are able to reduce in a significant way some of these substances (for example, the reduction of solid particles is a question that have not been studied deeply, and GPL produces less CO_2 and NO_x but these emissions are not close to zero). Another problem is the indirect pollution emission (for example, for hydrogen vehicles, the hydrogen creation process requires big quantities of energy which is not always obtained in non polluting ways), but these indirect pollution levels are difficult to estimate. The best solution to reduce pollution seems to be a combination of organization and technological strategies.

The emission quantities are easy to estimate for NO_x and SO_x, since they can be estimated in the greenhouse gas overall emission estimation calculations. The conversion tables can then give the overall emissions of these gases, aggregated for each category. however, the total emissions of the city logistics system have to be compared to the urban goods movement emissions in the urban area. Since this estimation seems easy to estimate for congestion and greenhouse gas emissions, it is more delicate for these gases, but it is however possible to estimate with enough accuracy the overall local pollution emissions for these gases.

3.2.3. Noise measurement and limits

Another factor that has to be considered as an environmental aspect is the traffic noise. At first sight, it seems that noise it's a measurable factor, which can be used to provide objective data.

Actually, what is important for human health and for city comfort is not the absolute value of the noise emission but the perception of that noise. Some studies proved that the perception of noise cannot be expressed in absolute values (for example, in dB). The type of noise (frequency, duration), and the nature of the sound respect to the environmental noise can influence the sensation of disturb in each person. Also physiological (illness, weariness, etc.), psychological and social (noises in stations, airports, marketplaces are better tolerated than noises in parks, libraries and other socially considered "quiet" places) factors can modify the perception of the noise in each situation. In this case we can consider noise as a factor that can be used to rank the different solutions, from the less disturbing to the most disturbing, or we can create an indicator which considers not only the quantitative but also the qualitative factors of noise (to differentiate the noise in the day time from the noise at night, or to consider the effects of a general traffic reduction compared to a solution which reduces only the freight transportation traffic.

3.3. Social aspects

Other factors that are to be considered, and could be very useful in some situation, are related to restriction and comfort levels for different categories of people. In city centers, where the main problem is the reduced space and the need for many people to accede or pass through, different categories can be involved in freight transportation problem. We present three of them: transportation carriers, involved commercial activities and other citizens. The first category, the transportation carriers, is often the less considered in the organization of urban freight distribution.

However, these carriers are the main actors of urban transportation, and its needs and opinions have to be considered, at least to avoid big conflicts between transportation carriers and public administrations, which can produce other diseases. For this category, restrictive normative policies are not considered as a good solution, but they can be open to alternative solutions as incentive measures or a freight distribution organization which will not affect their economy in a considerable way. The second category, the commercial activities, is the most affected by the freight distribution strategies. For them, freight transportation is necessary to their activity, because their customers will depend on their product offer and availability. They have fewer instruments to block the system in respect to transportation carriers, and in general these activities are small or medium (big commercial activities have their own transportation service which in general can be compatible with the service provided by the public administrations), so their economy cannot survive without the goods they are proposing. The third group, which is in general the most important for politicians, is the rest of the people, who do not participate directly to the freight transportation but they divide the same transportation network. Trucks blocking a street, problems to park because of freight transportation, and other situations will be considered negative by the usual drivers of city centres. On the other hand, a system which reduces congestion and produces more parking areas, or only the perception of no big commercial vehicles in the city centre can be seen as good solutions. Note that all these three indicators are not quantifiable in an empirical way, because they are more related to sociological aspects. For this reason, we will not take into account social indicators in the present study, which is an exploratory simulation and scenario assessment.

4. Scenario assessment methodology and proposed dashboard

Although collaborative transportation is a promising approach, there are many limits and not all the stakeholders are a priori disposed to enter on such communities (Gonzalez-Feliu and Morana, 2011). For this reason, public authorities and collaborative communities of practise want to develop decision support tools that help the individuals to consider the advantages and risks of collaboration globally, in order to take the decisions having a better knowledge of this field (Thiengburanathum et al., 2010). In order to support public authorities and private actors in their choices concerning collaboration in urban freight transportation, we propose a framework based on modelling and simulation, that feeds a multi-criteria decision support method. From real urban distribution stakeholders, several data can be collected. However, a collaborative decision making multi-criteria analysis have been made to define the main indicators used to assist and support both public and private stakeholders' decisions. This method will not be developed here, the retained indicators being extracted from the conclusions of that study (Morana and Gonzalez-Feliu, 2010).

The proposed framework counts the following stages:

1. Scenario simulation
2. Route estimation
3. Driving time estimation
4. Indicator calculation
5. Quantitative analysis of the economic and environmental impacts

4.1. Scenario simulation

The scenario simulation is carried out adapting the method proposed by Gonzalez-Feliu et al. (2012) to logistics pooling. The method works as follows. Consider a city, divided into representative zones. Each zone is defined by its population density, its commercial supply in terms of number of employees in each commercial activity class, its level of industry and distribution activity and its position with respect to the city centre. We define a set of commercial activities that will be involved on logistics pooling strategies, for example the grocery distribution sector. Using a delivery generation model (Routhier and Toilier, 2007, 2010), the number of deliveries per establishment can be estimated. Then, from Henriot and Routhier's (2010) ratios, we assign a quantity of freight to each delivery (Gonzalez-Feliu et al., 2012). The route construction procedure is described below. From Patier and Routhier's (2008) empiric results we define the involved transportation companies. These companies are defined by a heterogeneous fleet of vehicles, a set of depots and a set of possible cross-docking platforms.

Then, using Gonzalez-Feliu and Salanova's (2011) scenario simulator, we generate the vehicle routing problems that will be solved using the route construction procedure.

4.2. Route construction procedure and driving time estimation

The transportation management system is a tool that builds the routes for each transportation carrier involved in the collaborative transportation system and estimates the travelled distances and the environmental impacts, in terms of emissions of greenhouse gases. This module uses an algorithm for the two-echelon vehicle routing problem (Gonzalez-Feliu, 2008, 2011) adapted to collaborative transportation systems.

The algorithm is a fast heuristics, following a two-step procedure. This has been chosen because the methodology is aimed to support tactical decisions of collaborative communities, so the TMS has to be assimilated to a commercial solver, in order to solve very big problems in a few seconds. First, a sweep algorithm is used in order to make clusters of customers, assigning them to a fist-level route and not to a satellite. When dealing with direct shipping, a classical sweep algorithm as those developed for CVRP applications is applied. For 2E-VRP, the sweep algorithm takes into account the satellite position in order to define the routes (i.e., customers are assigned to a 1^{st} echelon vehicle but taking into account the satellite this vehicle will bring the freight for a cross-docking operation.

Second, the routes are built using a GRASP algorithm. There are two types of routes: the 1^{st}-echelon ones go from the depot to the satellites, and the 2^{nd}-echelon ones from the satellites to the customers. The routing phase is common for all the configurations: once the customers are grouped, a GRASP is applied in order to build the 2nd-echelon routes. Then, the 1st-echelon ones are obtained easily by a combinatorial procedure, since the number of possibilities is very small. Note that in some cases the instances solved are related to heterogeneous fleets. This issue has been taken into account in the route construction. Finally, a small post-optimisation procedure using fast local search techniques is used.

4.3. Indicators calculation

4.3.1. Economic indicators

Economic indicators are related to two main variables. First is the total travelled distances, that can be divided into two categories: the in-route distance and the access distance. The first distance is the distance travelled from the first customer/satellite until the last one (passing by all the customers/satellites in the defined order); the second distance is the distance travelled from the depot/satellite to the first route point and from the last route point back to the depot/satellite. The calculation of the in-route travelled distances is done by the Euclidian distance between each two consecutive route points, excluding the depot/satellite from the route. The calculation of the access distance is done by the Euclidian distance between the depot/satellite and first and last route points. The cost of the routes are fixed costs (driver basically) and variable costs (length, time, consume and contamination). To estimate the travel time, average speeds are used, with higher values for the access to the route, and lower values for the in-route travel. From these distances, we can estimate the yearly quantity of fuel needed. Second is the total working time, which is composed of total travel time, the time spent for loading and unloading purposes and the driver's pauses imposed by the current legislation. To estimate these times, we define a mean speed between each O/D pair, following the considerations of Routhier (2002) and Presstalis (2011). The travel times are then estimated from the travelled distances. Then, the total work time is calculated associating a loading or unloading time to each pick up or delivery (related to the quantity of freight to pick up or delivery). If a route in terms of travel time does not exceed the legislation working times, we add consequently the corresponding pauses of the driver. If these constraints are not respected, the route is re-optimised, even split, to meet the legislation. From those working times, we can estimate the total number of workers and their annual cost in terms of salary.
Then we calculate the yearly cost by converting the distance travelled of each route to a monetary cost. To do this, we take into account the conversion tables proposed by Generalitat de Catalunya (2011), including fuel costs, maintenance and vehicle insurance (related to the distance travelled) and crew costs, related to travel hours, estimated from the distances travelled and average urban speeds (Routhier, 2002). In cost estimation we have taken into account the following considerations:

- For the estimation of the travel time, average speeds are used, with higher values for the access to the route, and lower values for the in-route travel.
- For the normalization of the vehicles, each truck size is equivalent to 1, 1.5, 2 or 3 private cars.
- Once vehicles are normalized, consume and contamination rates are calculated using average values.

4.3.2. Environmental indicators

Concerning environmental indicators, several possibilities can be taken int account. Because in this work we aim to study the effect of organisational strategies having the same technological support, pollution emissions of the proposed scenarios are only dependent on the trealled distances and the type of vehicles that can be used, which do not vary from one scenario to the other (the variation will be on the usage rates of these vehicles, but the overall set of possible vehicles remain the same in all scenarios). For this reason, we propose an analysis on only traffic issues. From the travelled distances per truck, we can easily estimate travel road occupancy rates. To do this, each truck distance is weighted by a coefficient depending on its weight, as stated in Table 2:

Table 2: Weight factor for traffic issues (adapted from Routhier et al., 2009)

Total on-load weight	Weight factor
Less than 3.5 t	1
3.5-7 t	1.5
7-16 t	2
More than 12 t	2.5

Another indicator that can be calculated is the total number of parking hours in congested city areas. This indicator is directly related to the total loading and unloading time in central areas. In order to take into account the vehicle's surface, we have pondered the total number of hours by the type of vehicle (i.e. weights presented in table 1), to obtain the total number of h.PCU.

5. An example of application

In this section we propose a set of scenarios that will be used to illustrate the proposed framework. In our example we supposed 5 different operators (representing each a realistic transportation carrier). Each operator has a depot, a few satellites for consolidating the cargo, and its own fleet of trucks, with two different sizes of trucks. The total number of customers is 408, and the number of satellites 12. Moreover, each customer can be served by more than one transportation carrier. In order to propose a realistic set of scenarios, we used a real urban network: that of Lyon (France), the second largest in France, only after Paris Metropolitan Region.

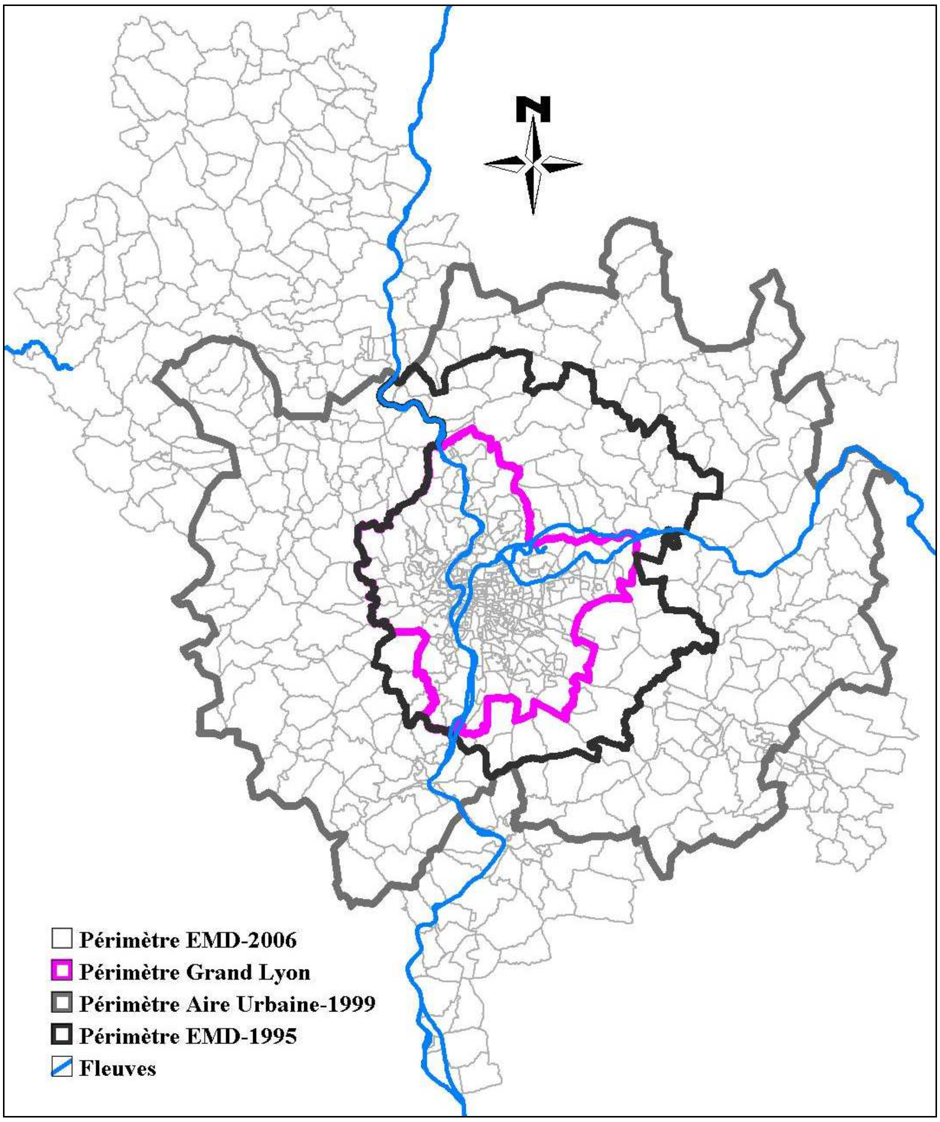

Figure 1. Map of the Lyon urban area and the considered zones (Bouzouina et al., 2010)

In 2006, this area consisted of about 2.000.000 inhabitants and 800.000 households. We use a database that derives from the 2006 household trip survey of Lyon urban area (Grand Lyon, 2006). This file contains several databases from which we can extract information related to the population and the demography, as well as to define the main retailing zones of the urban area (the overall surveyed territory has been divided into a set of about 750 zones, as illustrated in Fig. 3). The information related to the retailing activities (number of employees, dimension, and type of establishment) are extracted from a SIRENE file, the establishment censorial database of the French Institute of Statistics (INSEE). We took the SIRENE file of the year 2005 in order to have results from a similar time period. From the SIRENE file we extracted the data corresponding to the small grocery retailers of Lyon and Villeurbanne (about 400 establishments). These retailers will be the final destinations of the freight to be delivered and are grocery retailers with a total surface lower than 400 m². Then, using FRETURB, we estimate a weekly number of deliveries per retailer. Then we define 12 cross-docking platforms located in the near periphery of city, mainly in industrial zones. The industrial zones are extracted from the SIRENE file. We define the logistics facilities from the SIRENE file and locate them in the near periphery of city, mainly in industrial zones. The depots are located in the peri-urban area, also known as the far periphery of the city. Then, a quantity of freight is associated to each delivery (as seen on Gonzalez-Feliu et al., 2012). We then estimate each company's transport plan using an adaptation of Gonzalez-Feliu and Salanova's (2011) fast heuristic algorithm for two-echelon transport optimization in urban areas, according to a two-step procedure. First, a non-hierarchical clustering method allows assigning customers to a vehicle. Second, the routes are built using a semi-greedy algorithm (Gonzalez-Feliu and Salanova, 2011). We simulate a total of 5 scenarios, described below:

1. A non-collaborative strategy where only the big trucks are used, visiting a large number of clients due to the bigger capacity of the vehicles. Here we solved five different and independent CVRPs.
2. A second non-collaborative strategy where the big trucks are used for distributing the cargo to the satellites, and from there to the final clients using the smaller trucks. Here we solved five different and independent 2E-VRPs, where the capacity of the big trucks is limiting the capacity of the satellites.
3. A partial transportation pooling network where 2 operators are collaborating, while the other are acting as in the second scenario. The collaborating clients share their satellites, and consolidate cargo destined to the same clients, sharing also their fleets of small trucks. Here we solved four 2E-VRPs, one of them with heterogeneous fleet.
4. A collaborative transportation pooling network where all the operators are collaborating, using all the satellites for consolidating the cargo and sharing their fleet of small trucks. Here we solved one 2E-VRP with heterogeneous fleet.

In the following we propose an analysis based on two indicators: daily treveled distances and daily occupancy rates (Table 3).

Table 3: Main results – distances and road occupancy rates

		Scenario			
	Operator	1	2	3	4
Travelled distances (km)	1	8 872	17 518	16 807	18 053
	2	11 901	25 875	25 875	23 936
	3	18 973	20 846	16 108	15 279
	4	12 432	21 126	21 126	18 893
	5	21 007	23 617	23 617	24 256
	Total	73 185	108 982	103 534	100 417
Road occupancy rates (Km.PCU/week)	1	22 180	93 214	84 835	40 881
	2	23 803	157 662	157 662	40 318
	3	37 946	87 864	77 530	30 558
	4	24 864	91 365	91 365	37 787
	5	42 013	84 283	84 283	42 760
	Total	150 807	514 388	495 675	192 303

We observe that if we consider only distances, without taking into account loading and unloading times, collaboration do not seem to have a positive impact. Indeed, only operator 3 sees a distance reduction when collaborating with other users. This reduction is about 17%; which is significant. If we regard to the other scenarios, i.e., the individual two-echelon transport organization and the partial collaboration, no user obtains a gain. Indeed, distances are increased, in some cases with variations of more than 200%, due to the cross-docking platform location. While converting the travelled distances on road occupancy rates, the trend is similar, and only operator 3 obtains significant reductions in terms of congestion impacts. These results can be explained by two main facts. The first is that we used real data, with a very constrained urban area (Lyon's city centre combines two convergent rivers and two hills, one of them including an important proximity retailing zone (the fourth in the central urban area), a big centric commercial centre, and access limitations to the city centre that constraint the routes configuration). The second is that the vehicle routing algorithm (that builds the transport plans) is not developed to optimize the system but to find a good realistic solution that is close to current practices. This leads to a margin between the current transport costs (in terms of distances) and the real optimum that could be further reduced by more efficient optimization methods.

Table 4: Main results – Working times and costs

		Scenario			
	Operator	1	2	3	5
Working times (h/year)	1	3 072	1 997	1 824	1 709
	2	3 665	2 544	2 826	2 241
	3	3 194	1 844	1 727	1 538
	4	2 805	1 786	2 022	1 782
	5	2 750	2 369	1 987	1 917
	Total	15 486	10 539	10 387	9 187
Monetary Costs (€/year)	1	115 991	98 064	89 249	79 951
	2	145 263	158 905	158 905	137 193
	3	110 309	86 168	76 033	74 991
	4	107 778	79 964	79 964	104 920
	5	110 676	74 958	74 958	116 060
	Total	590 017	498 059	479 110	513 116

When reasoning in terms of working hours (including both driving and stop times and respecting the French legislation in terms of driver's timetables) we observe that the first scenario needs more time to be completed. All the other scenarios present an important reduction in terms of time, due mainly to urban congestion. Using big vehicles in peripheral areas minimizes the number of vehicles and drivers, whereas the usage of small vehicles in congested dense zones leads to an important decrease of stop times (mainly related to parking, loading and unloading, but also to travel distance which increases in small streets because of a better capacity of manoeuvring small vehicles). Total costs confirm this trend. However, the logistics pooling solution is not the best for all operators. We observe that, in the current case, only operators 1 and 3 see an interest on collaboration, for both logistics pooling possibilities (partial and total collaboration). The other stakeholders see the interest of multi-echelon distribution but not necessarily of a collaborative system. We can then state that collaboration is not evident, and the best formula has to be consensually found among all involved partners.

6. Conclusion

In this paper we have defined urban freight transportation pooling systems. Moreover, a framework for collaborative transportation decision support is presented, more precisely to help the urban goods movement decision makers in their strategic choices (for both public and private stakeholders). The proposed method combines several modules. From the simulation, we observe that collaboration is not evident, and it can lead to cost reduction at some conditions. Moreover, it is the most environmental-friendly solution from those taken into account. However, implementing these systems presents risks that have to be evaluated.

In conclusion, although collaboration is an interesting field, it is early to say if it will be well applied to city logistics. For this reason we need to develop decision support systems and sensibilise the public and the private stakeholders in order to find global city logistics solutions in an urban-system point of view.

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