A review on transportation last-mile network design and urban freight vehicles

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Abstract

Last mile logistics also referred as city logistics or urban logistics, concerns to the optimization of urban freight transportation systems. This relatively recent concept responds to the need for feasible and sustainable last mile logistics solutions that contribute to reductions on not only costs but on congestion and environmental effects, particularly in dense cities. Decisions on a supply level involve network design, which includes urban facilities location. In this context facilities are called urban or city distribution centers, micro distribution centers, satellites platforms or just satellites. On other hand, vehicle fleet related decisions need to be also customized to this particular urban distribution context, specifically dealing with multi-mode selection, fleet size, smaller vehicle capacities (i.e. city-freighters), power technology, vehicle autonomy, and inclusive, vehicle design, etc. Literature suggests there is still an opportunity in terms of optimization modeling and methodologies to address these issues. This work revises the drivers motivating the topic, the last mile distribution network elements, and establishes an explicit connection between urban network design and the actual development and use of more environmental and suitable vehicles for urban freight.

Keywords
Last-mile logistics, urban logistics, urban delivery, urban distribution centers, electric vehicles, systematic review, distribution networks.
1 Introduction

Last Mile (LM) logistics also referred as city logistics or urban logistics, concerns to the optimization of urban freight transportation systems. LM logistics is currently regarded as one of the most expensive, least efficient and most polluting sections of the entire supply chain (Gevaers et al, 2014). According to Joerss et al (2016), the LM market is growing at a rate from 7 to 10% in mature markets. The increased urbanization and the awareness of freight transportation impacts have stressed the importance of City Logistics (CL) as a comprehensive approach aimed at mitigating the negative effects of distribution activities without penalizing social, cultural, and economic issues (De Marco et al, 2014).

Several terms have been coined to refer to LM distribution logistics. The LM term is often used when dealing with the distribution or delivery process inside a city. For example, Traditionally, LM delivery has referred to the distributor / retailer delivering to the customer's home instead of using a package carrier (Chopra & Meindl, 2016). LM distribution also refers as the last part of the supply chain, and is important cause involve the final transaction between company and costumers, so last-mile logistic is the last stretch of a (business-to-customer) B2C parcel. It takes place from the order penetration point to the final consignee’s preferred destination point, for reception of goods. On other hand, the “City Logistik” concept, developed in Germany and also applied by a number of Swiss cities, corresponds to ‘spontaneous’ groupings of carriers cooperating for consolidation and distribution activities with very light government involvement. City Logistics (CL), defined by Crainic et al (2009), is the process for totally optimizing the logistics and transport activities by private companies in urban areas while considering the traffic environment, traffic congestion and energy consumption within the framework of a free market economy. To Taniguchi (2016), it is based on the systems approach that involves a number of technical processes including modeling, evaluation and the application of information technologies.

According to Saenz (2016) there are three characteristic aspects that condition the urban distribution: Infrastructure influence, distribution strategy and vehicle characteristics. Logistics Service Providers (LSP) can act in the last two and perceive the effects (either benefits or barriers) of the first one. As part of the LM distribution strategy, a key factor is the Urban Distribution Center (UDC). An UDC is a logistic facility strategically located for the LM collection and distribution of goods, which is situated close to or inside an urban area. Large freight transport service providers use them for operational purposes, functioning as a junction between urban and interurban parts of the transport chain (Foltynski 2014). In these spots, large trucks deliver the merchandise which is separated in small trucks for the final delivery. It is expected that with these UDCs is possible to increase the load factor, decrease traffic problems and decrease pollution.

To achieve the last goals, the “green” focus in logistics has also recently received increasing and close attention from governments and business organizations. There are many varieties of problems concerning green transportation, such as the promotion of alternative fuels, electronic vehicles, green intelligent transportation systems, and other eco-friendly infrastructures (Lin 2014).

At a strategic level, designing LM logistics systems implies decision making processes on several elements of the network design such as: scope of the system, agents involved in the supply chain, facilities settlement, fleet dimensioning, among others. When the problem is a redesign of an existing system, the last two elements are usually the most susceptible to be changed. In addition, they are usually considered as known parameters when other tactical or operational problems are to be solved (e.g. routing, inventory management, etc.).

Therefore, it is perceived the need to address this research in urban distribution centers and how their capacity and location are defined; and fleet dimensioning; specifically, how fleet size and vehicle capacity are defined, together with the power technology selection (i.e. fuel, electric, hybrid, etc.).

This study makes a systematic review on last mile distribution logistics, from the perspective of the LSP, with emphasis on the decisions of logistics networks design related to urban facilities and green fleets.

1.1 Research Questions

To understand the distinguishing characteristics of LM distribution logistics approaches from the conventional ones, three research questions (RQ) are addressed: RQ1: What are the drivers that motivate the development of the city logistics solutions? And from a logistics service provider, RQ2: What are the considerations to take into account when designing a LM distribution network, including variables and solution methodologies, and RQ3: How
decisions on urban facilities and green fleet composition are related in LM distribution? To answer these questions, this study characterizes recent literature in LM logistics and CL, with focus on the distinctive and novel criteria and conditions of design of an urban distribution network.

2  Systematic review methodology

In order to make a systematic review of the literature, two methodologies were considered: Tranfield et al (2003) and Keathley et al (2016). They were adapted to the one presented in Figure 1, and is similar to the one followed by Lagorio et al (2016). This review shares with this work not only the systematic review process but the topic. It is a review on urban logistics. However, following Tranfield among others systematic reviews’ authors, they answered different questions, focused on the evolution of the literature and to identify the most relevant papers in the field.

2.1 Scoping Study

For this research, first it was decided to make a selection of journals before going to the papers. Table 1 summarizes the criteria for selecting the journal’s list. The following keywords were used: Logistics, Supply Chain, Distribution, Transportation, Urban, and Electric Vehicle. We selected Scimago Journal Rank (SJR) as the main ranking source because it gives us the Q and H index of the Journals.

Even we have keywords that are related with our subject this does not mean that all the titles they are given to us were what we were searching. Just entering each one of the six keywords Scimago gives us a total of 485 titles of Journals. The next step was making a filter because at the end we will just keep the relevant journals. In this point is where we start building the first matrix. A first filter was to exclude titles themes really far from our subject such as medicine, maritime transportation, air transportation, water issues, land issues, and forestry. So our matrix starts with 311 titles of Journals.

The second filter step was to exclude proceedings, publication older than year 2000, an H index equal or bigger than 3, and journals in last quartile (Q4). At this point, another areas not related with our subject were also excluded, as
are civil engineering, aerospace engineering, chemistry, architecture, math, education, psychology, history, geography and tourism.

After applying these criteria we reduced the number of journals to 41. In order to give more validity to the selected journals list we made a second check searching the titles we kept up to now in another ranking source: the Journal Citation Report. From this ranking source we added 8 Journals. So from our 485 starting Journals we decided to work with a list of 49 journals.

2.2 Searching Strategy

In order to search the papers we used two databases, EBSCO and ScienceDirect. To start searching for the papers we ordered the Journals by highest H index. The strategy used is based on the Boolean search presented in table 2.

<table>
<thead>
<tr>
<th>Databases:</th>
<th>ScienceDirect, EBSCO</th>
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<tbody>
<tr>
<td>Search:</td>
<td>Boolean Phrase</td>
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<tr>
<td>Type of document:</td>
<td>Original articles and reviews</td>
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<tr>
<td>Language:</td>
<td>English</td>
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<td>Date:</td>
<td>&gt;2000</td>
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<tr>
<td>Pertinence:</td>
<td>After analyzing the scope and papers.</td>
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<tr>
<td>Additional inclusions:</td>
<td>Snowballing. Proceedings and specific conferences</td>
</tr>
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</table>

Table 2. Searching strategy

2.3 Criteria Selection

In the 49 journals chosen in the previous section, we found 172 related articles. After reading title and abstract, if necessary, we kept 53 articles. From them we got complete access to 33. Then, as part of a snowballing process, we decided to make an exception in the exclusion criteria, and we considered articles from, for example, Transportation Research Procedia and Procedia Social and Behavioral Sciences from the last 5 years, since they include recent advances in conferences completely related to our topic. With this inclusion, 23 articles were added to the corpus for a total of 56 articles. These articles went through a searching process showed in Figure 2, until no more new articles were added. For each of them, a summary data sheet was filled.

Figure 2. Searching process
3 Descriptive analysis of the corpus

To describe the corpus, we decided to describe the papers through the following: a) publication year, b) frequency of paper per journal, c) keywords, and d) places where the research is done, and where the researchers are from.

In Figure 3 we have the articles distribution by year. Even there are some fluctuations in the period, we can appreciate the increment of contributions regarding LMD, and this confirms an increasing trend. Of course, there is a peak in the last years because of the inclusion of proceedings; however there is also an increase in the number of selected papers in the last year. Papers from 2017 are not included in Figure 3.

![Figure 3. Articles frequency per year](image)

Figure 3. Articles frequency per year

Figure 4 shows the journal’s names where the articles were published. We observe again the great contribution from proceedings, and from the series of Transportation Research journals. On other hand, when reading the articles, we extracted our own keywords to identify them. Figure 5 shows these keywords and their frequency. In this case, papers could be classified in more than one keyword.

![Figure 4. Papers per journal](image)

Figure 4. Papers per journal
In Figure 6 we can see the countries where LML has been study. We can see that in Europe is where more projects have been implemented. In North America, this theme is more recent than in Europe, but currently there are many projects in the main cities. Meanwhile Latin-American is starting taking care about this subject, especially in some megacities, where congestion and pollution are the main concerns. In Asia, the problem before it become a big problem, for example the bicycle have been a delivery system since centuries before, but now the EV are trend in all the world. In Figure 7, the map shows the cities where the authors work. We can see a natural similarity with Figure 6. We can also find that some papers written by groups of authors from different universities and nationalities.
Last mile logistics' drivers

To answer the first RQ1, we conclude from introduction and justification sections of the corpus, the main ideas that seem driving the interest for working on last mile distribution logistics. They are grouped in four: 1) the urban density increasing, 2) the e-commerce market boom, 3) the sustainability awareness, and 4) the pursuit for better cities. These drivers are developed below:

4.1 Urban density increasing

The global population is increasingly concentrating in cities (Foltynski, 2014). Cities are continuously confronted by a variety of challenges caused by the urban transport that is why we must face the challenge of reducing traffic congestion and pollution emissions. Cities are growing at a rapid pace, paired with an increase in residential and business needs, with around 80% of the population living in cities, with the majority in medium-sized cities. This has produced an increase in the movement of goods into the city from external producers.

Approximately 75% of the energy and 75% of CO2 is consumed in cities. Therefore, they play a key role in achieving the EU objective of 20% energy saving by 2020 and developing a low carbon economy by 2050. In Europe, around 75% of the population lives in urban areas and this is predicted to increase to about 80% by 2020. Talking about world’s population, 70% will be living in cities by 2050 (Foltynski, 2014). These Urban population growth and rapid urbanization have generated an increasing freight transportation demand within cities. These cause environmental and mobility problems linked to air pollution and traffic congestion (Browne, 2012, Benjelloun & Crainic, 2008).

Furthermore, megacities, which are cities with a population of over ten million, are increasing on number and size. Whereas in 1950 the only megacities were Tokyo and New York, currently there are 28; it is expected to have 41 in 2030 (Kin, 2017). In emerging markets is a new phenomenon; the size of these cities combined with the high growth rates provides substantial sustainability challenges. Urban freight transport contributes to these challenges (Kin, 2017). Nanostores are an essential part of the economy ecosystem in emerging markets. Nanostores do not only offer products, to the mass market at the right price-point but they also provide income to small business owners. Understanding the operational characteristics and the supply chain requirements of the nanostores is an essential step in effectively reaching over 5 billion consumers in emerging markets.
4.2 E-commerce market boom

E-commerce is all electronically mediated information exchanges between an organization and its external stakeholders. E-commerce in general is a developing process from information and communication to transaction, integration and automation (Enarsson, 2002). E-commerce has become more popular in business using Internet. Sales in physical stores grew only 0.9% globally, while online sales grew 14.8% between 2007 and 2012 (Visser, 2014). This growth of Internet shopping Business to Consumer (B2C) affects urban delivery systems (Taniguchi 2016). E-commerce (B2C) is creating a surge in home deliveries that is increasing the social and environmental costs of goods distribution systems.

The characteristics of the e-commerce service are: small packages, high frequencies, decreases shopping trips by customer, failed deliveries, low utilization of vehicles, attended home deliveries. One of the major challenges here is the delivery cost. According to Kämäräin (2001), the cost differences generated when comparing deliveries with and without windows time are of 42%, while Boyer (2009) shows that the distance traveled in routes increases to 2.15 times when going from scenarios without time windows to others with windows of one hour.

4.3 Sustainability awareness

More than a half of the papers are concerned on sustainability issues. They look for improving not only the logistic process but to take care on the effects on the environment. The potential benefits are both economic and environmental (De Marco 2014). As an example, we can mention Rao et al (2015) that integrate the economic, environmental, and social dimensions of sustainable development.

In the modern society, reduction of the CO\textsubscript{2} emission is a major challenge. Annual European Union greenhouse gas inventory states that total CO\textsubscript{2} emission due to road transportation increased 123 million ton between 1990 and 2012 for 28 member countries of EU (Afsar, 2016). In addition, global transport emissions have risen annually by nearly two billion tons of CO\textsubscript{2} equivalent since 2000, with freight transport generating between 20\% and 60\% of local transport-based pollution (International Energy Agency, World Energy Outlook 2013).

According to this agency, cities are where 69\% of Europe’s CO\textsubscript{2} are emitted and urban transport accounts for 70\% of the pollutants and 40\% of the greenhouse gas emissions from European road transport (Green Paper: Towards a new culture for urban mobility, 2007).

Using electrical vehicles (EVs) seems to be the option to CO\textsubscript{2} emissions and reduce noise pollution. EVs and other low carbon vehicles are expected to have an important role- in meeting CO\textsubscript{2} reduction targets. EVs are an energy-efficient alternative for the traffic in the cities caused by the urban freight transport; also they help to reduce emissions and noise. According to Foltynski (2014), the advantages of EVs are more pronounced when switching to more efficient ways for the last-mile delivery of goods in city centers.

A wider CL vision suggests a more integrated logistics system, where shippers, carriers, and movements are coordinated, and the freight of different customers and carriers is consolidated into the same green vehicles (De Marco et al, 2014).

4.4 Pursuit for better cities

Logistics service providers’ main activity consists in undertaking freight distribution to customers (Ehmke & Mattfeld, 2012). They are expected to offer high quality and reasonably priced delivery services in urban areas, which present several peculiarities like traffic congestion and restricted traffic areas (Benjelloun & Crainic, 2008).

“Freight vehicles compete for the street and parking space capacity and contribute significantly to congestion and environmental nuisances, such as emissions and noise (OECD, 2003, Patier, 2002, Figliozzi, 2007). These nuisances impact the life of people living or working in cities, and the productivity of the firms located in urban zones and of the associated supply chains. They also contribute to the belief that “cities are not safe” that pushes numerous citizens to move out of the city limits”.

Travelers suffered travel delay of 4.8 billion hours, using extra 1.9 billion gallons of fuel (Jaller et al, 2015). Urban areas are experiencing rapid development and expansion. Economic activities are increasing demanding more consumer goods and services. Private and commercial vehicle demand has also increased.
The reduction of freight vehicle trips during peak hours has been a common policy goal. Policies have been implemented to shift logistics operations to nighttime hours. The purpose of these policies has been to mitigate congestion and environmental impacts. Off-peak policies can be environmentally improving or damaging, depending on traffic speeds and meteorology (Sathaye, 2010). As an example, Holguin & Sánchez (2016) show that switching deliveries to off-hours (7 PM to 6 AM) can reduce emissions and can also reduce CO\textsubscript{2} emissions by 200 million tons/year. Currently there are already many congestion problems in the city, but in the future deliveries are expected to increase (Marcurri and Danielis 2008).

5 Last mile distribution logistics Network

To answer RQ2, we first identify the components to be considered in the design of logistics; then, we identify the main considerations and variables when facing the challenge of designing (or redesigning) a LM distribution logistics network, and present the lists of papers that deal with each topic.

5.1 Distribution Network

The main elements that integrate a distribution network are the distribution channels, the facilities, the fleet and the transport network.

5.1.1 Distribution channels

A Last-mile distribution system involves linear movement of merchandise from the source of merchandise to customer homes. There are three basic forms for these movements’ push, pull and hybrid (Lim 2015).

Changing the distribution network design affects different costs in the supply chain, such as inventories, transportation, facilities and handling, and the information (Chopra, 2016). In a direct store delivery, the flow of cash information and products is handled by a manufacturer’s distribution person, usually the delivery person. In the wholesaler and distributor channels, manufacturer has no visibility to the nanostores.

Push-Centric System: N-Tier Direct to home, send to customers’ homes by someone other than the customer. Is when the retailers are responsible to fulfill the orders and ensure products are ‘pushed’ or delivered to the customers’ doorsteps. The trade-offs in decision-making of distribution channel selection are centered on level of inventory, transportation cost and level of responsiveness achievable. The nearest the picking spot is from the consumer segment, the more responsive the channel would be but at the expense of lower level of inventory aggregation; translating to higher inventory level and cost.

Pull-Centric System: Customer Self-Help, fetched from the source of merchandise by the customer. This is when the customers perform ‘self-help’ service to make purchase and collect their products from the fulfillment point (order fulfillment), and perform the “last-mile delivery”. Here the customers perform the last-mile themselves. This comes at the expense of customer satisfaction. The study by Kämäräinen et al. (2001) affirms that customer satisfaction is typically lower compared to attend home delivery (AHD) as customer should travel to and from the store.

Hybrid-Centric System: N-Tier to Customer Self-Help Location, sent to some intermediate site from which the customer fetches the merchandise. The hybrid system attempts to locate the middle ground and leverage on the attractiveness of both a wholly push- or pull-centric distribution structure. For instance, it permits the use of more economic transportation such as full truck load vehicles for delivery of large quantity of goods to the DC, DC sorts the orders, and have the goods delivered using smaller vehicles to the designated shared recommended pick up point for customers to collect.

This classification can be seen as a new version of classical Chopra’s classification of distribution network in a supply chain (Chopra & Meindl, 2016). The push-centric system by Lin is to the Chopra’s network called Distributor storage with last-mile delivery. It worth noting that this scheme, also referred as “traditional channel” is the most used in developing countries, where there is a strong presence of small shops attended directly by their owner. These shops are called nanostores (Blanco & Fransoo, 2013). For example, it represents about 61 percent of the market share in all Latin America (Nielsen, 2009).
5.1.2 Facilities

Concerning to facilities in the distribution network one major finding of this study is to recognize that it is not enough to only consider the main facilities as manufacturer, warehouse, distribution centers, retailers and customers as Chopra (2016) used to classify distribution networks. New elements need to be added such as urban consolidation centers (UCC) or urban distribution centers (UDC), satellites, pick-up or collection points, and load / unload zones.

The UDC concept as physical facility is close to those of intermodal logistic platforms and freight villages, which receive large trucks and smaller vehicles dedicated to local transportation, and offer storage, sorting, and consolidation (de-consolidation) activities, as well as a number of related services, e.g. legal counsel, accounting, brokerage, and so on. Table 3 summarizes the main concepts related to city facilities. Some of them are equivalent in meaning. There are two-tier facilities: the UDCs and the platforms satellites. Urban-trucks move freight to satellites, and city-freighters are vehicles of relatively small capacity that can travel along any street in the city to perform the required distribution activities, both are supposed to be environmental friendly.

Table 3. Main concepts on urban logistics and urban facilities

| LMD / LML / LMD | Last mile delivery/Last mile distribution / Last mile logistics. It refers to the distributor / retailer delivering the Chopra product to the customer's home instead of using a package carrier. | Chopra |
| UL / CL | Urban Logistics / City Logistics is based on the systems approach that involves a number of technical processes including modeling, evaluation and the application of information technologies. | Taniguchi, 2016 |
| UCC / UDC /TP | Infrastructures that allow the consolidation of goods before the last mile delivery. These facilities are usually classified into three main types, namely, urban consolidation centers, urban distribution centers and transit points, depending on how long goods remain in the warehouse and what type of actions are performed regarding freight (i.e. consolidation, transshipment). The ideal location to serve the largest number of commercial activities, their management system and rules for use and booking. | Lagorio, 2016 |
| Load and Unload zone | | Lagorio, 2016 |
| CLC | City Logistics Center: Logistics facility that is situated in relatively close proximity to the geographic area that it serves, be that a city center, an entire town or a specific site (e.g. shopping mall), from which consolidated deliveries are performed within that vicinity. | Crainic, 2009 |
| Pickup centers | Pick-up points are prearranged places where people go to collect their online ordered parcels. Parcel lockers are last generation automatic dispensers that allow the delivery and retrieval of goods and documents around the clock. | Lagorio, 2016 |

Kunse et al (2016) identifies logistics location decisions as a strong positive influence on logistics operations, as well as transport technology on the economic performance of logistics operators and on environmental quality. The success factors for UDCs according to Taniguchi (2016) are the location which should be near to the city or even inside, the subsidy collection, the collaboration with shipper and freight between the same company or different, the financial viable situation which envelope the costs, the service of the UDC, the access permit cost, delay in delivery time, and the distance from the parking bay from the shop.
5.1.3 Fleet

The interest in modern EVs comes from the characteristics that differ from conventional petrol or diesel vehicles. Their ecological impact can be positive when renewable energy such as wind or solar energy is used (Lebeau et al., 2012).

The advantages of EVs are even more pronounced when switching to more efficient ways for the last-mile delivery of goods in city centers (Foltynski, 2014). Table 4 summarizes the definitions of the new vehicles used in city deliveries, and Table 5 describes a classification by Foltynski (2014) of the different types of electrical vehicles. Related with this, Kunse et al (2016) used the concept Treibstoff costs to include cost of gasoline (including other combustibles) and other forms of propulsion energy (as e.g. gas, electricity) including taxes.

Table 4. Types of vehicles

<table>
<thead>
<tr>
<th>Types</th>
<th>Description</th>
<th>Reference</th>
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<tbody>
<tr>
<td>EV</td>
<td>Electrical vehicles present an opportunity to reduce greenhouse gas emissions; due to they don’t use combustible. Their emissions depend on the electrical energy production’s emissions.</td>
<td>Afsar, 2016</td>
</tr>
<tr>
<td>Hybrid</td>
<td>They contaminated less than regular combustible vehicles, because these vehicles use combustible but in majority from a hybrid source.</td>
<td>Lebeau, 2012</td>
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<tr>
<td>Scooter</td>
<td>Two wheels vehicle that work with battery, or a small motor. Recently used to deliver goods in cities or places of difficult access.</td>
<td>Wang, 2008</td>
</tr>
<tr>
<td>Drones</td>
<td>Programmed vehicles without humans. Recently used to deliver goods in cities or places of difficult access.</td>
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</tbody>
</table>

Table 5. Types of Electric Vehicles (Foltynski 2014)

<table>
<thead>
<tr>
<th>Types</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>EV or BEV</td>
<td>Electric vehicle or Battery electric vehicle; are powered only by one or more electric motors. They receive electricity by plugging into the grid and stroking it in batteries.</td>
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<tr>
<td>PHEV</td>
<td>Plug-in hybrid electric vehicle; use batteries to power an electric motor, plug into electric grid to charge, and use a petroleum-based or alternative fuel to power an ICE or other propulsion source.</td>
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<tr>
<td>HEV</td>
<td>Hybrid electric vehicle, combine an ICE or other propulsion source with batteries, regenerative braking, and an electric motor to provide high fuel economy. They rely on petroleum-based or alternative fuel for power and are not plugged in to charge.</td>
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<tr>
<td>ICE</td>
<td>Internal combustion engines; generate mechanical power by burning a liquid fuel or gaseous fuel. They are the dominant power source used by on-road vehicles today.</td>
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<tr>
<td>EVSE</td>
<td>Electric vehicle supply equipment; delivers electrical energy from an electricity source to charge an EV or PHEV batteries. It communicates with EV and PHEV to ensure that an appropriate and safe flow of electricity is supplied.</td>
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</table>

Finally, the last element is the transport network. It refers to the road, water, and pipeline infrastructure. It is an element highly strategic driven by the administrative actors, and it is considered out of the scope of this study. When City logistics is seen as a strategic problem, the identification of its stakeholders becomes relevant. Examples can be found in Crainic & Benjelloun, 2009, Vidal et al, 2015, Bebrends, 2016, and Kunze (2016). The last one makes the "widest" classification of stakeholders to model with systems thinking the interdependence of their
decisions on CL. The business part includes producers, resellers and LSP, for individuals it includes customers and citizens, and the administrator includes City Authorities and Lawmakers.

### 5.2 Considerations and variables from the corpus

In this section, we present the analysis from the corpus in four stages: the main focus (or dimension) of the articles, the solution methods used, the objective pursued, and other considerations that should be taking into account. In each stage, we identify subcategories if needed, and present a list of the papers that deal each topic.

Since this study is focused on facilities and fleets in a LM distribution network, Table 6 shows these dimensions, and a sub classification for each one. It can be observed that a third dimension showed up, the demand management. It is related to decisions when facing access or time restrictions, most of them looking for sustainable goals.

Related with vehicles, we found many papers talking about routing; even this topic was out of the scope we wanted to consider. The distinguishing characteristics for urban distribution are the importance of time-dependent routes, length of arcs and variable speeds.

In addition, some papers treat heterogeneous fleets, considering a combination of traditional fleets (i.e. internal combustion engines) with green vehicles (electric or hybrid ones). Loading and unloading areas showed up frequently. One article studies the use of tricycles in urban distribution in China, showing this is an efficient transport and how they are beginning to be recognized as a viable mode to LMD.

<table>
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<th>Table 6. Dimensions</th>
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<td><strong>Dimension</strong></td>
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<td>Urban Locations</td>
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<td>Vehicles</td>
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<td>Demand</td>
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<th>Table 7. Solution methods</th>
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<td><strong>Step</strong></td>
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<td>Modelling</td>
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<td>Tools</td>
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Concerning to solution methods, we found many conceptual frameworks that try to describe or model the situation, as well as many applications in cities whose results are handled as cases because it is recognized that each city has its own characteristics, without pretending that the results can be "extrapolated" to any other city. We also see the consistency of tools with validation methods (cases versus city data). Metaheuristics are often used when the problems is focused on solving routing problems. Other analytical methods are used, such as discrete choice analysis, enumeration techniques, continuous approximation of combinatorial problems, data analytics, etc.

On other hand, when analyzing the objectives pursued by the corpus, cost still appears as the main one. Objective costs refer to any type of cost involved in the LMD, such as infrastructure cost, driver costs, truck costs, travel costs, energy cost, time of delivery, stop time, etc. However, objectives on reducing emissions are almost as frequent as costs reduction. Few papers focus on efficiencies and the quality of life issue is handled as congestion, as well as the delays in the deliveries.

<table>
<thead>
<tr>
<th>Objective</th>
<th>List of papers</th>
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<tbody>
<tr>
<td><strong>Costs</strong></td>
<td>31 148 182 357 358 359 368 372 431 441 451 461 525 1811 1812 3516 3611</td>
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<tr>
<td></td>
<td>54 148 149 182 355 357 368 491 526 1811 1812 3514 3611 3612</td>
</tr>
<tr>
<td><strong>Emission</strong></td>
<td>54 116 149 358 359 526 1131</td>
</tr>
<tr>
<td><strong>Congestion</strong></td>
<td>511 471 3511</td>
</tr>
<tr>
<td><strong>Operational performance</strong></td>
<td></td>
</tr>
</tbody>
</table>

Finally, some considerations are pointed out, and they are classified as endogenous or exogenous to a logistic service provider. The concept of consolidation is when a company put together the delivery from different areas. The collaboration is when different companies share a UDC and information related to the deliveries to reduce their costs. These two concepts are central when thinking on urban distribution networks. The idea of getting benefits comes from the possibility that, through cooperation and collaboration, the share of the distribution network elements will allow increase efficiency and decrease costs and environmental effects.

The concept of sustainability refers to the presence of the three pillars of sustainability: the social, economic and environmental ones. On other side, policy and regulation issues remind us the importance of considering their effects on LM performance and how they become barriers or motivators for urban and sustainable solutions.

Detours appear also as an option, and it refers to the option of deviate from the most efficient route, either by congestion, by access restrictions or conditions of the road. At last, logistics performance refers typically to efficiency measures.

<table>
<thead>
<tr>
<th>Considerations</th>
<th>For a LPS:</th>
<th>List of papers</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Consolidation</strong></td>
<td>Endogenous</td>
<td>51 3511</td>
</tr>
<tr>
<td><strong>Collaboration</strong></td>
<td>Endogenous &amp; Exogenous</td>
<td>182 368 451</td>
</tr>
<tr>
<td><strong>Sustainability</strong></td>
<td>Endogenous &amp; Exogenous</td>
<td>54 148 149 182 355 357 368 491 526 1811 1812 3514 3611 3612</td>
</tr>
<tr>
<td><strong>Policy / regulation</strong></td>
<td>Exogenous</td>
<td>356 451 461 511 521 524 3516 3517</td>
</tr>
<tr>
<td><strong>Detours</strong></td>
<td>Endogenous &amp; Exogenous</td>
<td>431</td>
</tr>
<tr>
<td><strong>Load/Unload zones</strong></td>
<td>Endogenous &amp; Exogenous</td>
<td>355 365 369 391 527</td>
</tr>
<tr>
<td><strong>Logistics performance</strong></td>
<td>Endogenous</td>
<td>511 471 3511</td>
</tr>
</tbody>
</table>

5.3 Urban facilities and green vehicles

In order to answer the RQ3, compatibility between urban logistics and green vehicles has been observed. Though, the limited range of BEVs is often considered the most important barrier, it is estimated that more than 80% of freight trips in European cities are shorter than 80 km, which is compatible with those limited ranges of BEVs. Ranges in Europe are assessed based on the NEDC which assumes a more energy efficient driving cycle than in real conditions (Pelkmans and Debal, 2006). On other hand, UCCs are identified as a suitable logistics concept in which BEVs can achieve city-center deliveries (ELCIDIS, 2002); and BEVs behavior also depends on a home base at which they can be recharged during their inactive period.

Green Vehicles and EVs are expensive compared with regular combustible vehicles, and they have less capacity for the merchandise. We need to have in mind that less capacity means we need more vehicles, and this could generate more costs in number of trucks and drivers.

Rao et al (2015) identifies three sustainability criteria when solving the problem of locating facilities in the city. He considers the economic criteria, the environmental criteria and the social criteria. The economic criteria refer to the price of acquiring land, upside delivery flexibility, transportation conditions (connectivity), service level, and human resource condition. Next, the environmental criteria are about the environmental protection level, impact on ecological landscape, natural conditions. Last, the social criteria refer to the public facilities condition, security, comply with environmental regulations, impact on nearby residents, and impact on traffic congestion.

On other hand, Quak et al (2016) review the feasibility of using EV in UFT from a carrier's perspective, including their attitudes towards EFV. They identify five critical elements for the EFV business case. The first element is the technology which involves fewer maintenance efforts, lack of MTT service and repairing, limited availability of heavy EFV. This has four charging methods; the in-house charging, the public charging points, the inductive charging, and battery charging. Some possible extra costs are the high vehicle battery repair, vehicle replacement, charging infrastructure, grid upgrade, and landlord permission. As a benefit is involve low main cost.

As a second element we have the operations, this is the adoption of considerations from logistics view. It involves possible extra costs in the transshipment costs of goods from ICE to EFV. The third element is the economics. The small businesses have problems due to lack of funding, especially for them the production of batteries can also be a limitation. A price of an EFV depending on the ton size compared with a conventional van is showed in Table 10.

Table 1. Relative costs of BEVs

<table>
<thead>
<tr>
<th>EFV</th>
<th>PRICE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 3.5 tons</td>
<td>2 times</td>
</tr>
<tr>
<td>Between 3.5 – 7.5 tons</td>
<td>2 – 4 times</td>
</tr>
<tr>
<td>More than 7.5 tons</td>
<td>4 – 5 times</td>
</tr>
</tbody>
</table>

Some possible extra cost for this element are the higher purchase price, higher vehicle repair, vehicle replacement, heating/cooling equipment, training of drivers/additional hiring, additional procurement costs. While a potential benefit could be the lower operational costs and the lower main cost (20-30%).

The next element is the policy and procurement this refers to favorable taxation schemes, no congestion charge for EFVs, no parking fee or no road tax. In other side the supportive policies such as entering low emission zones, use of bus lanes, parking at non-loading areas, wider time access restrictions, and possibilities to enter pedestrian zones can result in operational advantages. It also involves decrease in stress for the drivers, better performance and fewer mistakes.

The last element is the drivers’ attitude. It is about having happy and stress-free drivers, with positive attitude toward customers.
5.3.1 Green fleets and routing problems

VRP problems involving green fleets are identified as fleet size and mix pollution-routing problem. These problems consider the effect of speed zones, the fact that a shortest path is not always the fastest, least polluting path in CL, and that the faster driving is cheaper and less polluting in the CL context.

It is also found that highest costs are attained when all customers are in the city center, that it is preferable to locate depots outside the city center, and that costs can decrease by up to 17% when using heterogeneous fleet instead of a homogeneous one, while depot capacity utilization levels tend to be higher than the vehicle capacity utilization levels.

6 Final remarks

Coming from the analysis we have done, papers are showing and demonstrating the importance of the comparison of different solutions. The case studies methodology is giving useful information and good data to analysis. The main drawback is that conclusions are totally linked to the special situation and it becomes quite hard to compare different approaches. We also noticed that no distinction is made in the corpus on the type of products to be delivered, whether they are of mass consumption or not, nor on the density of the urban zone. It is generally assumed to be denser than national wide logistics networks but it is not explicitly said. However, the products may or may not be mass consumption. For example, home deliveries may include from supermarket items to infrequent parcels.

6.1 New strategies

Some new strategies to improve the last mile distribution had been recently studied. Those concepts had been developed and now are reaching interests in order to answer the challenges related with the LMD problem.

The first is the collaboration, not only sharing responsibility, but also sharing resources and more importantly, the information. This a known concept that is already recognized as important to LMD but not really appreciated in the literature read.

There is also a new concept that should be explored: Crowdsourcing. This is a “type of participatory online activity in which a person, institution, non-profit organization, or company, proposes to a group of individuals, through an open and flexible call, the free and voluntary accomplishment of a task the accomplishment of the task, of variable complexity and modularity, and in which the multitude must participate by contributing their work, money, knowledge, and / or experience, always implies a mutual benefit. The user will receive the satisfaction of a concrete necessity, whether it is economic, social recognition, self-esteem or personal development, while the crowdsourcing will obtain and use the user's contribution, whose form will depend on the type of activity performed” (Estellés & González, 2006). We have not found scientific literature concerning the logistics problems implied when using this type of distribution strategy.

Another strategy is to use frequent points in the city, such as gas stations and convenience stores as satellite or collection points. This strategy has not been discussed in the scientific literature but is observed in practice and in some white papers.

The last strategy proposed is the co-modality which involves the range of services offered by modes of transport that include the use of public transport as well as trains, buses or taxis to transport goods as well as to transport passengers. This one is exposed by Taniguchi (2016), but not found in the corpus. We did not found either the use of autonomous vehicles in LMD.

6.2 Recommendations for future research

It appears that in order to keep working and go further in this field, the analysis of two major components of this urban logistic ecosystem, people and technology will be relevant. These decisions will totally change the analyzing point of view by moving from a technology-centered approach to an approach focused on reaction and interactions between those majors. So, it can be a relevant point to use a systemic approach showing the interactions with the components instead of an only focus on the components.
To end, it’s worth proposing other interesting topics that appeared not to be well developed in the corpus, such as: a) Fleet composition, considering heterogeneous fleet including motor and non-motorized vehicles; b) Schemes of acquisition of city facilities altogether, such as rental, tertiary, garages, loading zones booking, etc; and c) Implications of logistics decisions in human resource management. The fact that more vehicles with less capacity means more drivers, and the consequent questions, such as: where are vehicles running? What will be the work-basis for a driver? And, what is the best scheme of vehicle’ ownership?

6.3 Limitations

The limited access to complete articles is identified as the main limitation of this study. At least 20 articles were excluded for this cause. Therefore, conclusions and findings are the result of the analysis done exclusively from the corpus described above. However, we think this is a good sample that gives confidence on the generality of the analysis presented in this work.

7 References

7.1 Methodologies sources


7.2 Papers in the corpus


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### 7.3 Other references


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Visser J., Toshinori N. and Browne, M., Home Delivery and the Impacts on Urban Freight Transport: A review, Procedia Social and Behavioral Sciences


Li C., Loscher K., Nagi A.B., Sheerazi H.A., Blair K., Fonseca S. and Millison W., Going the last mile: Best practices of urban freight movement, Columbia University.


7.4 Acknowledgements

To the support from Universidad de Monterrey.

8 Biography

Jessica Calderon is a bachelor student of Industrial and Systems Engineering from Universidad de Monterrey, Mexico. She is also a double–degree student, studying a Master program in Corporate Finance at the Grand École Supérieure des Sciences Comerciales d’Angers (ESSCA), France.

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