Cluster analysis and spatial modeling for urban freight. Identifying homogeneous urban zones based on urban form and logistics characteristics

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Abstract

Confronted with the issues of the ‘last mile’, delivery providers have to adapt their logistics organization in cities for more economic and environmental efficiency and in order to meet consumer requirements. A better and systematic use of the providers’ knowledge of the local conditions and of their expertise of cities’ specificities and delivery conditions is one way to reorganize logistics more efficiently and deal with urban logistics challenges. This article develops a preview of a decision-making tool using spatial modeling and clustering which help organize delivery regarding city’s characteristics. The framework could help distribution providers achieve relevant and complete territorial diagnosis, prior to the settlement of efficient logistics organizations that suit cities’ characteristics.

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1. Introduction

Courier, express and parcel players are currently facing strong challenges within cities regarding urban logistics and last-mile deliveries (new shopping and logistic patterns) leading to growth in deliveries (Weltevreden, Rotem-
At the same time, recipient requirements have become more and more complex and B2B and B2C logistics requirements regarding delivery speed, reliability and simplicity are converging (Ducret (2013)). Moreover, firms and stores have modified their supply chains in cities (Menge, Hebes (2011); Dablanc (2011)). Finally, for fifteen years, public authorities in urban areas, informed about the essential role of urban goods distribution in cities (Lindholm, 2012; Cherrett, et al., 2012), have implemented measures and projects to deal with externalities and enhance the urban distribution efficiency (Macharis, Melo, 2011; Russo, Comi, 2012; Diziain, et al., 2013).

Confronted with the issue of the ‘last mile’, CEP players have to adapt their logistics organizations in cities for more efficiency – economic as well as environmental – and in order to meet consumer requirements. Mobilizing the CEP knowledge of the local delivery conditions and analyzing cities’ spatial organization and specificities could be new vectors of innovation for CEP logistics organizations within urban areas. Bringing urban analysis and spatial studies closer to urban logistics could help reorganize logistics more efficiently and finally meet urban logistics challenges. Among disciplines that have tried to understand the organization of urban logistics and urban goods distribution, geography and spatial studies have always taken a backseat as compared to the economy, management, political science and transportation engineering sciences (Ogden (1992); Hesse (2010); Macharis, Melo (2011); Hall, Hesse (2012)).

In that context, the global objective of the paper is to find new ways of innovation for urban parcel deliveries and urban logistics. The main goal of the paper is to demonstrate that spatial modeling can help better organize logistics within cities. It aims at describing in details the preview of a decision-making tool for urban deliveries structured by a spatial clustering based on urban form and logistics characteristics. It also aims at arising questions for an efficient spatial modeling process for urban freight.

The article will be structured as follows: first, we will provide a short review of urban logistics from a spatial and geographical point of view in order to demonstrate the relevance of a new approach. Then, we will describe and explain the methodology of the decision-making tool for urban logistics based on urban modeling, geographical analyses and operational data that has been developed during a research project. We will finally present an operational case study of the decision-making tool for the city of Angers and discuss the limitation and perspectives of this work.

2. Urban Freight and Spatial Modeling: Trends and Gaps

2.1. Relationships between urban freight and spatial characteristics: an opportunity for urban freight management

Urban logistics researchers have observed that until recently geography and spatial studies have not sufficiently investigated urban freight as a research field and tried to understand the role of spatial organizations in distribution (Ogden (1992); Woudsma (2001); Macharis, Melo (2011); Hall, Hesse (2012)). Contrary to urban passenger transport studies and the interactions between passenger transport and urban form that have been largely explored in urban studies and more broadly in geography, freight transport has been neglected until now (Allen, et al. (2012)).

More recently, when exploring the link between urban characteristics and urban logistics, researchers have established that urban freight is more influenced by the nature of economic activities in cities than by features of spatial organization (with the exception of the size of the city) (Dablanc (2011)). But some researchers have argued that urban transport activities are also affected by spatial and geographical factors and certain “urban form prerequisites”, like the city's size and density, layout and urban form, street design, urban morphology, the land use, and the position of the city in the supply chain (Allen, et al. (2012); Lindholm (2012); Dablanc (2011)). Precise case study and research are rare. Allen, et al. (2012) have subsequently demonstrated that several geographical, spatial and land use factors such as the facility’s location, the city’s size and location in the city network, street design, settlement size and density, city layout, and commercial and industrial land-use patterns are likely to influence the efficiency and intensity of freight journeys. Moreover, relationships between the size of the city, the street design of the city center and the efficiency of the last-mile delivery has been studied by Tozzi, et al. (2013) for the city of Parma in Italy. Even if over the past few years, geographers as well as researchers in urban freight have become aware of the impact of geographical features on logistics organizations, so far very few researchers have tried to apply and verify those assumptions. Among others, we can quote Macario’s concept of “logistics profile”
Despite its spatial approach, the logistics profile appears to be incomplete, especially regarding spatial features, and does not exactly correspond to what could be expected when referring to a geographical analysis.

In her PhD, Ducret has conducted a large and precise survey of delivery providers and local authorities in nineteen different French cities in order to verify and develop city characteristics, spatial and morphological characteristics of an urban area influence urban goods distribution (Ducret (2015)). She points out the elements of the spatial and morphological organization of cities influencing the UGD, the way those elements are influencing the logistics organization and the strategies of adaptation CEP players are setting up. She notes that the city's and urban area’s size, the settlement density, the urban morphology and development of the city, the land use, the street design, as well as the type of housing – collective housing versus individual house - are likely to influence last-mile delivery. Those characteristics have an impact on the type of delivery vehicle (design and size), the design of the tours (length and duration as well as layout), but also the localization of logistics facilities regarding the delivery zone, etc. Finally, the efficiency (economic as well as environmental) of the delivery is impacted by those elements. She also points out that economic and functional profile of an area and the level of urban freight policy are factors to be taken into account too (Ducret (2015)).

Spatial approach for urban freight is an innovative approach that has, for the moment, never been explored in detail by urban freight researchers or parcel providers. In practice, very few urban freight providers show sufficient interest in precise territorial diagnosis. Moreover, local governments, with a few exceptions, under-estimate the use of urban studies and diagnosis prior to making decisions regarding urban distribution. However, the lack of a geographical comprehension of urban freight, as a part of a global diagnosis, can lead to unpredicted and sometimes negative long or short-term effects (Diziain, et al. (2013); Lindholm (2013)).

Even if CEP providers organize its daily delivery activity based on the local expertise of its agents, this has never been studied in detail by researchers, nor systematized and industrialized in a decision-support tool. However, mobilizing the CEP players’ knowledge of the local delivery conditions and local spatial organization as well as analyzing cities’ spatial organization could be new vectors of innovation for urban logistics organizations within urban areas.

2.2. Urban freight modeling and spatial studies: a gap

Regarding urban freight modeling, with the exception of LUTI models (land use transportation interactions models), most of urban freight models, have few connections to cities’ characteristics or spatial criteria (Anand, et al. (2012)). Even the French model Freturb, which is a land-use transportation model supposed to be based on spatial characteristics (i.e. land use patterns and the city size), geographical features are blurred and the main descriptors are the economic and functional features of the city (Gardrat, et al. (2013)). Among the various urban freight model typology provided in review papers (Comi, et al. (2012); Gonzalez-Feliu and Routhier (2012); Taniguchi and Thompson (2012)), one has analyzed the descriptors of a great number of urban logistics models and have shown that the most commonly used descriptors are traffic flow and commodity flow, freight and trip generation, loading rate, pollution level and transportation cost. Location and land use, that are more spatial oriented descriptors, are used comparatively little (Anand, et al. (2012)). Descriptors commonly used for spatial models for passenger transport, such as the density of inhabitants, accessibility and connectivity of the road network, the urban and street network design, the type of housing, etc. (Ewing, Cervero (2001); Stead, Marshall (2001)) are scarcely mobilized for urban freight. More recently, Sanchez-Diaz, et al. (2013, 2014) have assessed the effects of spatial features such as geographic location and network characteristics (distance to different types of routes, width of the street) on freight trip attraction and, based on that relationship, have proposed a modeling process that seems to enhance freight trip generation modeling (Sanchez-Diaz, et al. (2013, 2014)).

We think that if city characteristics influence urban goods transportation and distribution, thus, spatial approaches could complement technical and economic approaches for urban freight efficiency. In that context, we would like to open urban freight to spatial studies and simultaneously urban freight modeling to spatial data.

2.3. Research hypothesis: bring urban studies and urban freight closer

The research project is based on the hypothesis partially verified that city characteristics, spatial and morphological characteristics of an urban area influence urban goods distribution. The second hypothesis is that
modeling urban freight from a spatial point of view is a relevant approach to tackle urban logistics issues and that a deeper understanding of urban freight premised on spatial characteristics will contribute to improving territorial diagnosis, which is essential to the comprehension of issues of urban goods distribution before any decision can be made. The final hypotheses is that spatial approach of urban freight will lead to specific and thus efficient last-mile parcel delivery solutions, whilst avoiding unexpected and negative effects and finally meeting urban logistics challenges.

In order to demonstrate that spatial modeling and analysis can help better understand and organize logistics within cities, a decision-making tool for urban freight has been created, that will be described in the following sections of this article. It is supported by a majority of spatial data and by the relationships between urban spatial organization and urban goods movement identified by various authors as described in the previous subsections.

3. Methodology of the Decision-Making Tool

The aim of the research project is to develop a first draft of a decision-making tool, thanks to a territorial and spatial diagnosis and a precise understanding of the influence of cities’ specificities on urban freight organizations, in order to formulate specific and efficient last-mile delivery solutions. The tool is composed of two modules (Fig. 1): one module of territorial diagnosis based on a clustering analysis of the city addressed and one recommendations module for urban delivery logistics organizations adapted to specific zones in the city.

3.1. Methodology of the territorial diagnosis tool/ Module 1: spatial modeling for urban freight

Module 1 is based on spatial descriptors and develops an innovative spatial modeling approach for urban freight. The modeling approach is constituted of four main steps (Fig. 2). At the different steps of the clustering process and by the choice we have made, we attempt to bring spatial study and urban freight closer in order to verify the reliability of the research hypothesis. Thanks to the empirical study of the links between urban freight and the urban form conducted in nineteen French cities (Ducret (2015)), we have been able to identify the spatial characteristics of a city that influence urban logistics. Model’s criteria have been selected thanks to this empirical study and a literature review on spatial modeling. Spatial characteristics quoted several times in the survey have been transformed in model descriptors while criteria that have been sparsely summoned have been ignored.

Then we have carried out a principal component analysis (PCA) (that identified correlated parameters and redundant parameters) on an extended list of descriptors (Step A). Finally, after those two steps of selection of the descriptors – the survey and the PCA- seven spatial criteria and logistics criteria, among the twenty available, have been chosen and mixed: population density, density of the road network, verticality of the housing, linear density of the distribution points, proportion of business and households, income and age of the population (Table 1). Population density and the linear density of the distribution point give information about the settlement density of the area, its layout and development, whereas the street design and the accessibility of the area are represented by
the density of the road network descriptor. The type of housing is represented by the level of verticality of the housing. Land use patterns (half geographic descriptor and half economic descriptors) are described by the linear density as well as the proportion of business distribution points. Two descriptors are strictly economic and social: the age and the income. They give information about the type of delivery requirements and demand. They are more relevant to help the delivery provider imagine new services adapted to the economic situation of an area.

In order to build those descriptors, we have used open data from the National Institute for Statistics and Economic Studies (INSEE) and from the National Institute of Geography (IGN) and we have added spatial-oriented data from the National Post operator (Step C). Work with spatial data is also one way to solve the data availability problem in urban freight modeling (Ducret (2014)).

As for the zoning, we have worked on a 200 m x 200 m square grid (Step B). This large scale (in geography) is easy to work on and also gives an accurate image of the last-mile. Whereas INSEE data already fitted the 200 x 200 meter grid, an important work of data collection has been made to adjust the geo-localized postal data to the grid. Finally, we have worked on around 700 000 squares for the sixteen cities studied in this research project. An important work of data processing, projection and correction of errors has been done to make the data fit the grid (Step C).

With respect to the modeling approach (Step D), we have realized a double multidimensional analysis based on a PCA, and then two K-Means analysis to provide the clustering (Fig. 3). Those methodologies are usually used for spatial statistics analysis but not properly from an urban logistics point of view. Clustering analysis and zone definitions from a freight and logistics point of view have nonetheless received increased attention in recent years (Macario (2013)). At Step 1, thanks to a PCA on the list of seven descriptors, we have identified two major axes of
analysis of cities from a spatial and logistics point of view: a geographical one and an economic/demand-oriented one. At Step 2, we have carried out two K-Means based on the results of the CPAs: one on the spatial descriptors and the other one on the socioeconomic and activities descriptors. The first methodological approach we have tested was to carry out a K-Means for all the descriptors and squares in a single movement but the result did not allow the identification of clear urban sub-groups with homogenous spatial and functional patterns. So two K-means were applied to all the squares and to all the sixteen urban areas studied in a single movement according to the two axes identified. In fact, we were searching for a model providing a general image of the city regarding urban freight. The hypothesis was that some general urban sub-groups will appear for all cities and some of them will be more specific to a precise group a city. We have decided not to introduce a notion of distance between the squares or an image processing algorithm, assuming that homogeneity and connectedness would appear between same-featured squares and give the segmentation coherence. This gives two maps of the same city from two different points of view and two clustering. The crossing of those two axes of analysis and clustering provides twenty-five clusters – called in the article urban sub-groups or urban zones – (step 3). Each cluster is described by spatial and socioeconomic descriptors which we know the influence on urban logistics organization. This first result was difficult to read because of the great number of cluster. So we have decided to carry out a statistical analysis in order to keep the most representatives cluster. Moreover, clusters that are geographical relevant representations of the reality have been also selected thanks to a cartographic analysis. Finally, we have clustered and mapped nine coherent and homogenous urban zones regarding their urban form characteristics and some logistics and socio-economic criteria (Step 4). We have decided to limit the clustering to a nine-urban areas typology after conducting tests with a greater number and a fewer. Such a number favors an easy comprehension of the cartographic result and also allows a precise and geographically relevant differentiation of the city.

![Diagram](Fig. 3. The modeling approach)

Table 2 describes the segmentation in detail regarding spatial characteristics, socioeconomic elements and information about economic activities. Basically, Zone 1 describes areas of the city dedicated to “heavy” economic activities such as industry, shopping centers, logistics activities, and so on. The other eight zones are rather residential but can shelter some economic activities such as convenience stores, city center shopping malls,
restaurants, banks, offices, and so on. Those residential areas are divided in horizontal and vertical ones (zones 2 and 3). They can be differentiated based on the density of the settlement and of the distribution points or of the street network. For example, areas 4 and 5 are considered to be the densest in terms of inhabitants and potential distribution points but also in terms of network, while zones 8 or 9 have the lowest density. At the end of this modeling process, we have empirically added to each definition some information about the level of governance regarding city logistics. Economic and social information complete the description giving insight about the level of income and the age of the population.

The framework can be used to identify homogeneous and coherent urban areas considering the spatial context and some economic elements. As we know the relationships between those elements and the logistics organization thanks to empirical study and surveys, the framework can also be used to describe logistics situations.

Table 2. Description of the nine urban zones from the clustering

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Zone 1</th>
<th>Zone 2</th>
<th>Zone 3</th>
<th>Zone 4</th>
<th>Zone 5</th>
<th>Zone 6</th>
<th>Zone 7</th>
<th>Zone 8</th>
<th>Zone 9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industrial and commercial zone</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Dense collective housing zone</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
</tr>
<tr>
<td>High density collective housing zone</td>
<td>High</td>
<td>High</td>
<td>Medium</td>
<td>High</td>
<td>High</td>
<td>Medium</td>
<td>Medium</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Medium to high</td>
<td>High</td>
<td>High</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Medium to high</td>
<td>High</td>
<td>High</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
</tr>
<tr>
<td>Medium to high</td>
<td>High</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
</tr>
<tr>
<td>Very high</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
</tr>
<tr>
<td>Medium to low</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
</tr>
</tbody>
</table>

4. Empirical results and case study of the city of Angers

Sixteen territorial cluster analyses in different French cities have been provided based on this methodology. Further tests have been conducted in two French cities. During those tests, maps and clustering have been verified with local parcel distribution providers and thanks to geographical analyses, to assess the efficiency of the tool. In this article, we will focus on the case study of Angers.

The capacity of the tool to provide well-differentiated, contiguous and homogeneous spatial zones has been examined. The cartographic result of the modeling approach has been analyzed in order to decide whether or not the model gives a coherent picture of the spatial organization of the area. Besides, thanks to an analysis of the local logistics organization and issues, we have verified that the identified zones, whose features are considered to have an impact on urban freight, present truly specific characteristics regarding urban freight and provide a coherent picture of the logistics aspects.

4.1. Case study of Angers: main results

Angers is a large urban area situated in the West of France. It is a city of 149,017 inhabitants (2012, Insee data). There are around 270,000 movements (pickups and deliveries, business to business as well as business to consumer) of freight per month in the city of Angers. From a geographical point of view, like any other French city, its spatial organization is radial and concentric. At a smaller scale, the urban area of Angers is affected by the phenomenon of urban sprawl. It is considered to be sparsely populated regarding other French dense urban areas.

Fig. 4 shows the cartographic result of the modeling approach. Without any image processing, the typology
provides relatively clear, differentiated and homogenous zones with contiguous squares. Operational teams of La Poste have tested different versions of the model in order to assess its viability. Operational teams of the postal operator have been able to clearly and precisely identify well-known areas such as the Ralliement Place within the city center (zone 4), the La Roseraie district (zone 3) which is one of the biggest collective housing and high rise buildings place in Angers, and commercial areas such as the one near Beaucouzé (zone 1).

Moreover, according to the field, the modeling process has been able to traduce the main element of the organization of the city of Angers. The different densities of the urban area as well as the urban sprawl phenomena are clearly represented from zone 4 to 9. For example, zones 4 and 6 describe different levels of housing type and densities as well as network densities. This is clearly verified by a spatial analysis. The clustering respects the levels of verticality of the housing and gives information about the mixed type of housing (collective and individual). Thus, suburban residential areas of individual houses are well-differentiated from collective housing and even city center areas mix of houses and small buildings (photos a, b, c).

Besides, the clustering method provides coherent areas from an urban logistics aspect while the majority of the database is composed of geographical data. In fact, based on the geographical and morphological description of each zone, a delivery provider is able to anticipate the constraints for the last-mile delivery. For example in Angers, the historical center presents characteristics regarding the network, the street design and the accessibility, which influence the productivity of delivery tours and its logistics organization. Even if the road network is dense (good accessibility), streets can be narrower, the number of intersection of streets higher and then it can lower delivery speed and productivity and then influence the final delivery organization (number of delivery tours for example). The center is also a commercial heart and it remains a central residential area of Angers which is traduced in the clustering by the degrees of mixed land use (residential area and economic activities). The area is precisely shaped in the map by the sub-group 4, 5 and 6 with a high meshing density and a high distribution point density as well as a high population density. Additional information about the level of governance in urban logistics can help providers adapt their vehicle fleet and last-mile organization (location of the facility for example). Within the residential areas, the types of housing, the density of the distribution point as well as the level of income are equally relevant information. For example the duration of a delivery and thus the productivity of a tour is not the same for buildings and individual houses. Besides, the productivity of deliveries is not the same in dense central areas as opposed to low density residential areas. Taking into account productivity levels of each area, thus specific optimizations could be proposed.

The mapping of the sub-groups in Module 1 allows the grouping of spatially closed areas with close features to achieve sufficient demand and efficiency in delivery service.
Fig. 4. Results of the modeling process for the city of Angers
Thanks to the recent works of researchers revealing the relationships between spatial urban organization and urban goods distribution that have been described in part 1 of the article and the results of the empirical survey realized by Ducret in nineteen French cities with parcel delivery providers (Allen, et al. (2012); Tozzi, et al. (2013); Sanchez-Diaz, et al. (2014); Ducret (2015)), we are able to associate the specification of a geographic zone of our spatial model to their constraints and effects on the urban good distribution organization. Thus, for each zone, we are able to describe the assets and constraints regarding spatial characteristics or social/economic/political features (Table 3). The second module of the decision making tool has been built based on those elements.

Table 3. Assets and constraints of zone 4

<table>
<thead>
<tr>
<th>Assets of the zone</th>
<th>Constraints of the zone</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Spatial</strong></td>
<td><strong>Spatial</strong></td>
</tr>
<tr>
<td>- mixed type of housing: solution for different type of delivery services</td>
<td>- dense and constraint network: congestion issues</td>
</tr>
<tr>
<td>- density of the network: accessibility</td>
<td>- high density of inhabitant: low speed of delivery</td>
</tr>
<tr>
<td>- high density of distribution points: volume of delivery</td>
<td>- mixed land use: different demands</td>
</tr>
<tr>
<td></td>
<td>- complex meshing: constraints on the delivery vehicle and on the organizations</td>
</tr>
<tr>
<td><strong>Economic</strong></td>
<td><strong>Economic</strong></td>
</tr>
<tr>
<td>- high and medium income: high value services</td>
<td></td>
</tr>
<tr>
<td><strong>Social</strong></td>
<td><strong>Social</strong></td>
</tr>
<tr>
<td>- aging population: new services</td>
<td></td>
</tr>
<tr>
<td><strong>Political</strong></td>
<td><strong>Political</strong></td>
</tr>
<tr>
<td></td>
<td>- regulations: constraints on the delivery organizations</td>
</tr>
<tr>
<td></td>
<td>- durability issues: constraints of the delivery vehicles</td>
</tr>
</tbody>
</table>

The decision-making tool aims at providing specific and well-adapted last-mile delivery solution or organization to each specific zone mostly regarding the spatial organization. Thanks to the Module 2, we are able to propose specific logistics organization for each cluster according to their spatial organization and demand/logistics characteristics (Table 4). Module 2 is composed of a typology of logistics organizations and delivery solutions which are potential recommendations for each urban zone. The typology is based on an international benchmark of urban logistics experiments and organizations (Bestufs (2007); SUGAR (2011); Bestfacts (2013)), professional press review and on prospective studies. Besides, operational teams of the French postal operator have participated to the constitution of the typology providing innovative ideas for each zone regarding their characteristics. They have also been invited to evaluate the feasibility of those proposed by the researchers. For each logistics organization and delivery solution we have provided an information card describing in which urban/spatial situation the solution could be most efficient from urban/spatial and professional—economic—points of view.

Table 4. Recommendations for each urban zone

<table>
<thead>
<tr>
<th>Logistics organizations</th>
<th>Urban zones</th>
<th>Delivery solutions</th>
<th>Urban zones</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Urban consolidation center</td>
<td>1,4,5</td>
<td>1. Staggered hours delivery</td>
<td>2,4,5,6,7,8,9</td>
</tr>
<tr>
<td>2. Mobile depot</td>
<td>3,5</td>
<td>2. Mobility pick-up store</td>
<td>1,4,5,6,7</td>
</tr>
<tr>
<td>3. Convenience and pickup stores</td>
<td>3,4,5,7</td>
<td>3. Same-day/high-speed delivery</td>
<td>4,5,6,8</td>
</tr>
<tr>
<td>4. Mobile store</td>
<td>1,2,3,6,7,8,9</td>
<td>4. Scheduled delivery</td>
<td>2,4,5,6,7,8,9</td>
</tr>
<tr>
<td>5. Small and “virtual” urban consolidation center</td>
<td>2,3,4,5</td>
<td>5. Multi-service kiosk</td>
<td>2,3,6,8,9</td>
</tr>
<tr>
<td>6. Vehicle reception point and light small delivery</td>
<td>2,3,5</td>
<td>6. Convenience parcel</td>
<td>2,4,5,6,8,9</td>
</tr>
<tr>
<td>7. Organized delivery to neighbors</td>
<td>2,3,5,6,7,8,9</td>
<td>7. Delivery from the shopping/city center</td>
<td>1,2,4,5,6,7,8,9</td>
</tr>
<tr>
<td>8. Container and locker delivery</td>
<td>1,5</td>
<td>8. Parcel lockers</td>
<td>1,2,3,4,5,6,7,8,9</td>
</tr>
<tr>
<td>9. Crowd delivery</td>
<td>1,3,4,5,6,7,8</td>
<td>9. Parcel drive</td>
<td>1,2,6,7,8,9</td>
</tr>
<tr>
<td>10. Mixed freight flow</td>
<td>1,3,4,5</td>
<td>10. Logistics services for retailers and stores</td>
<td>1,5</td>
</tr>
<tr>
<td>11. Mixed delivery rounds</td>
<td>3,4,5,6,7,8,9</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Based on the one hand on the information regarding each solution, and the other hand on the description of each zone, we are able to propose a corresponding table providing recommendations for each zone. The methodology to
link a zone to an organization and/or a solution is empirical. The principle of this connectivity is to link a last-mile solution/organization to a zone where it can help alleviate the spatial-city constraints and take the best of the advantages identified (drawbacks/advantages analysis). In order to let people on the field decide of the best solution regarding the spatial context to improve their involvement and to fit with the management guidance, the methodology is not constraining. An example has been developed for the case study of Angers (Fig. 5). For example, city centers (areas 4 and 5) are characterized by mixed land use and type of housing which are delivery constraints, high level of urban density and regulatory measures. In order to alleviate those constraints we recommend six different urban logistics organizations such as urban consolidation centers, pickup stores, mixed delivery tours, and so on. In Angers, La Poste has recently started experiments in favor of staggered-hours delivery and mixed delivery rounds. It validates the coherence and relevance of the recommendations provided by the decision-making tool.

![Cluster map of Angers and recommendations](image)

**Fig. 5. Cluster map of Angers and recommendations**

4.2. Discussion and limitations

The preview of the decision-making tool opens questions about how to model urban freight from a geographical point of view. Those questions are: What type of data is more relevant to give information about urban freight? Are geographical data relevant? How can we formalize qualitative and spatial features into quantitative data? What type of mathematic and statistics formalization is relevant? What method could we use to identify relevant solution for each zone of the cluster?

One could argue that information specific to logistics activities, patterns, types of economic activities, residential-generated freight, trip generation are missing and do not allow the model to provide relevant information about urban freight. However, the aim of the research is exactly to represents logistics aspects through another point of view, a spatial one, and thanks to geographical data, which is quite innovative. And in fact, we can see through
the case study of Angers and the tests that the model fully fulfills its mission. Obviously, we can also imagine to add slight logistics descriptors to the modeling process, for example details about the type of economic activities (wholesale, retail, administration, hotels and restaurants, business center) but respecting the original aim of the research project.

5. Conclusion

Bringing urban analysis and spatial studies closer to urban logistics appears to be relevant in order to tackle last-mile issues. In fact, the modeling process and the clustering, based on majority on spatial descriptors, gives a coherent and sturdy image of urban phenomenon and organization but also of urban and spatial constraints on the last-mile delivery and logistics. This work shows that data that is not necessarily freight data, such as spatial-oriented data, could provide relevant information for urban logistics because data has been treated through an operational perspective, under urban freight issues and has been confronted to the field during various evaluation steps.

A spatial analysis coupled with a logistical approach provide a relevant diagnosis for urban logistics practitioners and local authorities, prior to the settlement of logistics organizations or new regulations that suit cities’ characteristics, assets and constraints. Spatial urban modeling of urban freight could help local authorities to better understand logistics and could even provide operational responses to tackle urban freight organizations. It could be useful and used in an independent way by parcel providers and urban logistics providers as well as local governments thanks to the development of open databases at an urban level.

The different steps of the study have been confronted with operational teams of postman (first line management, post office managers) to collect ideas and practical skills. Some technical choices are directly linked with these tests. Vice versa, the study and the capability of segmentation of a city in several zones in line with logistics concerns have push to open the mind of the operational teams for the implementation of a patchwork of solutions to deliver mail and parcels, instead of always applying the historical schemes.

Those conclusions emphasize the necessity for urban logistics studies to include in-depth spatial analyses and for urban freight modeling to enlarge its descriptors to spatial variables. It opens new research questions for both spatial studies and modeling. From a spatial point of view, this work shows that even if French cities have different characteristics and contextual differences, it is possible to build a general analysis based on cities’ spatial and morphological features, a specific geographical analysis in a global approach. This analysis can be used to adapt logistics organizations according to the morphology of the city, as well as to favor the transferability of best practices from a city to another city. Comparisons could be conducted in particular for other European countries or even American and Asian countries to strengthen the general rules of the influence of the spatial organization on urban freight deliveries. Module 1 could be developed in those geographical contexts too.

Moreover, regarding urban freight modeling approach, the modeling process described in this paper is relatively simple and represents an attempt to model spatial features from the point of view of urban freight. Even if this first test raises questions about urban modeling for urban freight, it is encouraging. An interesting work could also be to connect this spatial model for urban freight to demand-estimation model in order to evaluate if there is a link between the urban form characteristics, highlighted by the spatial model, and freight movement. If the relation is positive, this could also help the transferability of goods practices in urban freight from a zone of a city to the same zone of another city.

Finally, the diversification of the last mile delivery methods may be understood as counterproductive from an industrial point of view, but the adaptation to the spatial reality decreases the delivery costs and, moreover, since few years, because the customer power for the e-commerce delivery has increased, logistic must closely fit with these new behaviors. The economy of scale must be recovered at the scale of the entire company and the size of a postal operator is large enough to implement in France around ten solutions for the last mile while capitalizing the economies of scale.

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