Developing a territorial diagnosis and decision-making tool for urban goods distribution

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Introduction

Since the 1970s urban logistics has appeared as an essential function for the development of a city and its citizens.Urban freight transport or urban goods distribution can be defined as « the movement of things (as distinct from people) to, from, within, and through urban areas »(Ogden KW., 1992, 14), movements to and from business units, households, administrations, stores, etc. The urban freight system is extremely complex because of the hundreds of supply chains and the variety of actors involved in it(Patier D., Routhier JL., 2009). As Dablanc puts it, « the urban distribution of goods is organized by private stakeholders (producers, carriers, retailers, final consumers), operating in an environment (the urban space) which is managed by public authorities »(Dablanc L., 2009, 16).
For years urban logistics has become a shared issue in European cities for both researchers and practitioners, even if still an under-addressed problem (Macharis C., Melo S., 2011 ; Dablanc L., 2011 ; Diziain D., *et al*., 2013; Giuliano G., *et al*., 2013). Some cities are trying to better understand the links between the economic and spatial urban specificities and goods distribution to efficiently manage urban freight. However, on the whole, urban goods transportation has been neglected by urban studies, geography and urban planning, contrary to passenger transportation. On the one hand, even if improvements have been made for ten-fifteen years, the number of decision-making tools for urban freight remains relatively limited, and on the other hand, to the best of our knowledge,no urban goods modelling tool puts spatial analysis and geographical features at the centre of its calculation(Woudsma C., 2001 ; Anand N.,*et al*., 2012). The existing urban logistics modelling tools provide information and data about urban goods movements, vehicle trips and tours thanks to data on vehicle type, routes, localisation of the shipper and haulier, traffic volume, consumer behaviour, etc. in order to optimize delivery and improve its efficiency (Gonzalez-Feliu J.,*et al*., 2012). In fact, among disciplines that have tried to understand logistics organisations and urban goods distribution, basically geography and spatial studies have always taken a backseat compared to economy, management, transportation engineering sciences, modeling, etc. (Allen J., *et al.,* 2012 ;

Hesse, 2010 ; Macharis C., Melo S., 2011 ; Hall P.,Hesse M., 2012). Nevertheless, from our point of view, spatial and territorial approaches could complement technical and economic approaches. In fact, we argue that urban freight contributes to shape the city but at the same time city characteristics influence urban goods transportation and distribution. By city characteristics we mean a city's situation, street design, urban morphology and form, urban land use, urban sprawl or density, transportation network, type of housing, etc. Even if cities are specific, they also share common features that have an impact on urban freight and could be generalised in a diagnosis tool in order to help choose the most suitable urban logistics policy and delivery solution.

Furthermore, despite real improvements in data-collecting methods, one of the most important issues for city logistics is the lack of freight data and their suitability to the needs of both researchers and practitioners(Dablanc L., 2011 ; Cherrett T., *et al*., 2012 ; Lindholm M., 2013). The use of various types of data which are not necessarily urban freight data for urban freight modelling, such as spatial data, passenger transit data and parcel providers 'professional' data, could overcome the issue of poor data availability.

In this paper we would like to present the outcomes of a research project conducted by the French Post Operator, La Poste, the aim of which is to develop an efficient decision-making tool for urban logistics in cities of all sizes, drawing on a spatial and territorial perspective and using urban modelling and geographical analyses. The research project is based on the hypothesis that a deeper understanding of urban freight with respect to spatial characteristics of the city will contribute to improving territorial diagnosis, which is essential to the understanding of issues of urban goods distribution before any decision can be made. Moreover, we think that understanding urban freight from a spatial point of view will lead to specific and thus efficient last-mile parcel delivery solutions, whilst avoiding unexpected and negative effects.

Furthermore, in order to overcome the lack of freight data available, we have decided to combine operational data from the French Post Operator with classic spatial and urban data in an innovative way. These data have been analysed and reworked from an urban logistics and geographical point of view. It will enable us to examine the use of various types of datafor urban freight modelling and spatial analysis, and evaluate the relevance of postal data in that context.

The article will be structured as follows. First, we will provide a short review of urban freight modelling, focusing on trends and limitations of current research. Then, we will describe the modelling approach of the decision-making tool. Finally, we will present the main results of the modelling process and an operational case study of the city of Angers. In the conclusion we will discuss some limitations of this research project and research perspectives.

I. Modelling tools for urban logistics: “trends and gaps”

1. Urban freight modelling: a short review

Among the urban logistics tools for city planners and transport and logistics stakeholders, freight models have been developed since the mid-seventies: the first models of urban freight movements were proposed by Hutchinson in 1974. First developments have been slow and mainly designed by and for research purposes. Since the 1990s and especially 2000s, as urban goods movements became a significant issue for researchers and practitioners, urban freight modelling developed(Anand N*., et al*., 2012 ; Russo F. ,Comi A., 2004 ; Ogden KW., 1992).

Basically, urban logistics modelling tools built over the past twenty years provide information and data about urban goods movements, modal share, vehicle trips and tours, traffic flow, loading rates, emissions levels, consumers’ behaviour, thanks to data recording vehicle type, delivery routes, location of the shipper and hauler, traffic volume, loading rates, location, consumers' and stakeholders' movements, etc. (Gonzalez-Feliu J., *et al*., 2012 ; Anand N., *et al*., 2012 ; Ambrosini C.,Routhier JL., 2004). Different typologies have been proposed to classify the great variety of models which differ in their goals, the descriptors used, the stakeholders involved, and the modelling approach. We can distinguish models by the object studied: commodity-based models(Gonzales-Feliu J., Routhier J-L., 2012 ; AnandN.,*et al*., 2012 ; Ambrosini C., Routhier JL., 2004), truck-based models (Holguin Veras J., *et al.* 2010 ; Taniguchi E., *et al.* 2010), and behavioural-models (Marcucci E., Gatta V., 2013). We can also identify differences by looking at their functions, thus distinguishing operational models, evaluating models, estimation models and simulation models. As such, urban freight modelling trends have followed urban freight changes toward operational research and the evaluation of practical measures and initiatives, namely urban distribution centres, time-windows delivery, environmental regulations, etc. Anand et al. provided a differentiation regarding the models’ perspective, that is to say the point of view on urban freight : planning perspective, policy and technology perspectives, behavioural perspective, etc., or their objectives : economic efficiency, environment, road safety, etc. (Anand N.,*et al*, 2012). There are also multiple model building approaches. First models were multi-step models or gravitational models used for passengers but adapted to urban freight to provide estimation of generation trips or for distribution. There were also input-output models among others. Following from this, more specific and urban freight oriented models have been implemented in recent times (Russo F. et Comi A., 2004).

2. Urban freight modelling: limitations and opportunities

Contrasting with the fact that relations between urban transport and urban planning have been studied since the 1970s and modelled in various ways since then through successful land-use transportation interaction model (LUTI) (Batty M., 2009), links between spatial organisation and goods distribution in urban areas have been overlooked, and urban studies and planning still have little interest in urban freight (Macharis C., Melo S., 2011). To the best of our knowledge, no urban goods model puts spatial analysis and geographical features at the core of its calculation, trying to match land use, city's organization characteristics and urban freight transport. Even in the French model Freturb, which is a land-use transportation based model, spatial characteristics of cities are blurred because the main descriptors are the economic and functional features of the city (Routhier JL., Toilier F., 2010). In a literature review, Anand et al. have analysed the descriptors of a great number of city logistics models, that is to say indicators that are analysed and measured in models to represent urban goods movements. They 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, which are more spatial oriented descriptors, are used comparatively little. Even planning models for urban freight are not always based on spatial oriented descriptors. Moreover, geography and spatial studies have not sufficiently investigated urban freight as a research field and tried to understand the role of spatial organisations in schemes of distribution (Woudsma C., 2001; Hesse M., 2008; Macharis C., Melo S., 2011;Hall P.V., Hesse M., 2012).

The hypothesis of the research project is that conducting a deeper analysis of the link between spatial studies and urban freight will contribute to improve territorial diagnosis, which is essential to the understanding of urban goods distribution issues before any decision can be made; and that understanding cities' specificities and urban freight from a spatial point of view will favour the settlement of specific and thus efficient last-mile parcel delivery solutions. Urban areas, their spatial and geographical organisation and layout at different scales, their morphology at a very large scale, have been forgotten in the majority of last-mile delivery solutions currently implemented in urban logistics. In practice, even if some territorial-based innovations or initiatives can be observed, for example in the urban parcel delivery sector, very few urban freight providers show sufficient interest in precise territorial diagnosis (Ducret R., Delaître L., 2013). And local governments, with a few exceptions, under-estimate the use of urban studies and diagnosis prior to making decisions regarding urban distribution, whilst conducting traffic diagnostics, cost analyses and surveys mapping stakeholders' needs and requirements. 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 (Lindholm M., 2013 ; Diziain D., *et al*., 2013).

We have conducted twenty-two interviews with urban goods parcel distribution providers in different French cities. The aim was to understand what kind of spatial and morphological features of a city influence freight delivery. Basically, the conclusions of these interviews have revealed that they are true geographers and that their knowledge of spatial organisations is pivotal to their activity and its efficiency. But none of them are explicitly aware of that ability. For the moment, most of them underestimate urban organizations in location strategies and new services implementation. Based on those interviews, we have been able to highlight that city size, settlement density and urban sprawl, urban morphology and layout, land use; transport network, street design, type of housing, as well as city location within the city network and the logistics network are likely to influence last-mile delivery efficiency (Ducret R., 2014). Besides, the economic and functional profile of an area and the level of urban freight policy and governance are factors to be taken into account (Ducret R., 2014).

The intuition that urban freight studies should be reinforced by urban studies and geographical analyses is shared by more and more researchers in the urban logistics community. However, so far few researchers have tried to apply and verify this hypothesis (Woudsma C., 2001 ; Dablanc L., 2009 ; Macário R., *et al*., 2008 ; Allen J.,*et al*., 2012 ; Rodrigue J.P., 2006).In that context, we would like to open urban freight modelling to spatial data and generalise spatial study for urban freight, providing a decision-making tool based on spatial data and territorial analysis to demonstrate the significance of spatial analysis prior to urban logistics decisions.

3. Urban freight: a data issue.

Though relevant improvements have been made over the past few years in the collection of data and more broadly in the expansion of knowledge of urban freight around the world (Dablanc L., 2011), urban freight modelling is also limited by the availability of data, whether public and private. Regarding public data, the frequent absence of an urban freight authority, the lack of interest of local authorities in urban goods movements and the lack of regular public survey could explain it. Moreover, data collection is an extremely complex process when it comes to aspects such as truck loading, truck origin and destination, greenhouse gas emission levels but also consumer behaviours or stakeholder responses to different measures. Long, heavy and expensive surveys have to be carried out. Besides, regarding private data, especially parcel providers 'professional' data, in the competitive context of freight transport and the last-mile market, sensitivity and confidentiality of the logistics and operational data limit its use for cooperative model. Scarce cooperation and lack of dialogue between private stakeholders, local authorities and researchers also prevent the use of these highly significant and revealing data. In fact, operational data are stable, most of the time on a long time step, precise, provided at different scales and above all available. Nevertheless this data is not always urban freight-oriented and need to be re-worked with respect to the goal and perspective of the model, its scale and zoning, as well as its level of confidentiality.

In this study we will make us of operational data collected and geo-referenced by the French Post Operator and composite index built by the postal firm. The database is based on geo-referenced distribution and delivery point for business and households (address).This represents an exhaustive and rich database. Data is used by La Poste to optimize its supply chain and tours and the use of its delivery vehicles. This database facilitates the carrying out of an effective analysis of urban logistics issues without necessitating a heavy and complex data-collecting campaign.This will also allow us to provide an example of the way in which various types of data, in our case operational data collected by a firm, can be used in a process of urban freight modelling and also contribute to urban logistics analysis.

II.The modelling approach of the decision-making tool for urban freight

1.Presentation of the decision-making tool for urban freight

Thedecision-making toolis composed of two modules: one module of territorial diagnosis based on the construction of a territorial urban logistics profile; and one recommendations module for urban freight delivery solutions.

The goal of the decision making tool is to propose specific and efficient last-mile delivery solutions and logistics organisations depending on well-identified and precisely characterised zones of the urban areas listed in the urban sub-groups segmentation.

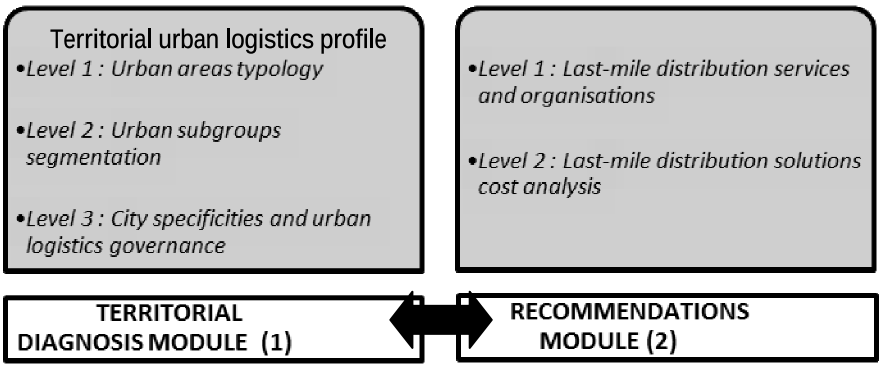

Figure 1. Structure of the decision-making tool for urban logistics

The territorial diagnosis module consists in a territorial urban logistics profile. The territorial urban logistics profile is composed of three levels of analysis in order to provide a diagnosis of urban territories taking into account both generalisation and specificities, immobility and urban dynamics. At the first level -urban areas typology- we have approached urban logistics using spatial and economic macro criteria. At the second level -urban sub-groups segmentation- the goal of the suggested typology is to identify homogenous spatial sub-groups whose spatial organisation and demand features specifically influence the last-mile delivery organisation and the nature of the delivery services provided. A modelling approach is employed at that stage. Thanks to the third level of Module 1, the decision-making tool could also take into account cities' specificities in terms of urban freight policy (i.e. regulation, urban freight planning and dialogue between stakeholders), but also other spatial and economic features (i.e. transportation network, specific activities, and so on) whose impact on urban distribution is equally significant.In this paper we will focus on the first module, namely the territorial diagnosis module, on particular on the second level, the urban sub-groups typology, supported by a modelling approach, and briefly introduce the second module through a case study.

2. Scales of the modelling tool

The urban sub-groups segmentation has been carried out on the scale of the city. We have worked at the administrative level of the urban area. An urban area is a French statistics scale created by the French National Institute for Statistics and Economic Studies. It refers to a group of municipalities – a major urban centre and the municipalities in the urban periphery, in which at least 40% of the population works in the major centre or municipalities polarized by the urban centre.To calibrate the modelling tool we have worked on a panel of sixteen French urban areas (Toulouse, Compiègne, Lille, Montbéliard, Avignon, Orléans, Besançon, Annecy, Royan, Calais, Rennes, Strasbourg, Sens, Dreux, Angers, and Montpellier). We have selected the cities based on a segmentation of the French urban areas. Criteria of the segmentation are the size of the major urban centre (from large cities to medium and small ones), the economic profile of the urban area, its spatial organisation, and the level of concern and actions of the public authorities regarding urban logistics.

We have divided the urban areas in 200m x 200m squares in order to provide a precise representation of spatial features. This 200 x 200m squares grid provided for free by the National Institute for Statistics and Economic Studies (INSEE) presents different advantages : stable on a long-term approach, neutral, easy to implement, analyse, and share and calculations of interactions are similarly facilitated (Lipatz J.L., 2013). The related database recently provided at that scale by the INSEE includes demographic data (number and age of inhabitants, number and size of the households, revenue of the residents). This scale is also the “natural point of view” of thousands of postmen (the “last-mile” in the postal studies): the hectometer is the elementary measure of the postmen, the basic element for the optimization of the delivery routes, the typical length between two crossroads. Historically, the expertise of the postmen was mainly empiric but the recent emergence of optimization software, the needs to understand the territories to optimize delivery services to the citizens, to invent new activities, push the need of precise geographical database.

3. Model descriptors and data collection and processing.

Descriptors of the model have been chosen in order to follow our hypothesis, namely that territorial features influence urban freight. Criteria have been selected thanks to a literature review and the empirical database obtained by means of the interviews with professional delivery providers. Interviews have confirmed that city size has an influence on urban freight (related to the number and density of distribution point). Moreover, it appears that high or low density has a great influence – positive and negative, direct and indirect –on urban delivery productivityand the type of delivery vehicle use. The transport network influences final delivery because it is responsible for connectivity and accessibility to the recipient. Thus, congestion and low density networks are constraints providers have to adapt to. Clearly, city centres have appeared as the main bottleneck for last-mile delivery because core centres frequently concentrates all those issues. City layout and transport infrastructureat small and large scalesare also likely to have an impact on delivery, including the fine street meshing of the city centre, street design and type of housing. Even urban planning projects like public passenger transportation network, pedestrian and quiet zones could challenge urban delivery efficiency, delivery routes and vehicles. Finally, the level of political handling of the urban freight issue by the public authorities (regulations, experimentations, governance, etc.) is also really likely to influence the distribution (Ducret R., 2014).

According to those results, the model have to describe the density and morphology of an urban area, the type of housing and construction and to characterise the street network and road network, its density and level of accessibility which are likely to influence the nature of the delivery service and thus eventually, the logistics organisation of the distribution. We have completed a multidimensional analysis based on a principal component analysis (PCA) on an extended list of ten descriptors. Thanks to a principal component analysis, which identified correlated parameters and redundant parameters, we have been able to determine the model's descriptors presented in the table 1. The list of descriptors is composed of space-related descriptors (population density, number of distribution point-professional and household-, type of housing, density of street network, linear density of the distribution points) and demand-oriented descriptors (median of incomes and identification of business distribution point/ households' areas) which are likely to influence the type of item delivered and the willingness to pay a service.

We have used open data from the INSEE and postal figures to build the different model's descriptors. Some descriptors have also been formulated thanks to the geo-processing tools of the geographical information system ArcGis. The mix of the two flows at the 200mx200m grid was complex because of the volume of the data (the sixteen urban areas studied represent tens of millions of addresses, of households, 700 000 squares), because of some errors or the absence of data (for instance, the geographical position of 100% of the addresses is impossible to obtain). We have developed several specific approaches to detect and to circumvent the errors, the missing data, and the outliers to adjust all the data available to the chosen grid and to implement correctly the algorithms.

Table 1. Model Descriptors

Descriptor	Nature of the descriptor	Nature of the data
Population density (inhab.km²)	Spatial descriptor : density	INSEE data
Number of street sections (per square)	Spatial descriptor :features of the street network, meshing	IGN data processed by ArcGis
Number of delivery point of a distribution point	Spatial descriptor :type of housing, verticality of the housing	Postal data
Linear density of the distribution points(point.hm)	Spatial descriptor : density and morphology Functional descriptor : nature of the demand	Postal data
Median income (individual per year)	Functional descriptor : standard of living	INSEE data
Proportion of professional distribution points	Functional descriptor : nature of the demand	Postal data

4. The modelling methodology

The modelling methodology is quite simple. We have carried out a K-Means analysis of the model's descriptors for the sixteen French urban areas selected to provide spatial segmentation of all the squares of the urban areasinto homogenous spatial sub-groups or areas of the cities, that is to say to group similar spatial and functional-featured squares homogeneously and in a coherent way. K-means is an automated classification algorithm. The algorithm was applied to all the 700 000 squares and to all the sixteen urban areas studied in a single movement because 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.

However, after the first K-means analysis, we discovered that the processing of both spatial and functional descriptors together did not allow the identification of clear urban sub-groups with homogenous spatial and functional patterns. Besides, some descriptors dominated the segmentation. As a consequence, we decided to effect two different segmentations, one spatial and one functional, before combining them. In this way, we can achieve a segmentation of the urban area in several sub-group and areas which are coherent but also convincing when it comes to their spatial and functional features and the way those features are meant to influence urban freight distribution.

To choose the final number of classes in order to obtain a coherent image of the city, we simultaneously carried out the K-means analysis, a deeper statistical analysis and a geographical analysis. In fact, the crossing of the two sub-segmentations provided twenty urban sub-groups, which is not efficient on the one hand to understand the city's influence on urban freight and possibly cities' specificities and on the other hand to read and analyse sub-groups on a map. Consequently, we conducted a statistical analysis and a geographic analysis of the segmentation of the sixteen urban areas in order to identify a smaller number of sub-groups. We eliminated sub-groups which represented low proportions of population but not those which are representative of a specific type of urban area. Finally, we decided to select eight homogenous and coherent urban sub-groups. Table 4 describes each sub-group regarding spatial and functional descriptors related to urban freight. We have also added criteria related to urban freight policy and governance which are likely to influence urban delivery, as operational staff interviewed has confirmed.

Finally, we choose to map the results of the segmentation with the geographical information system, ArcGis, in order to make the tool comprehensible and to strengthen its geographical component.

Table 2. Description of the eight urban sub-groups

	Urban sub-group	1	2	3	4	5	6	7	8
	Descriptors	**High densityarea (population/network), mix of activities and housing, high incomes, logistics constraints of a high-density**	**Dense areas (population/ network), majority of housing, medium to low incomes, logistics constraints of a high-density**	**Dense areas (population/ network), majority of housing, medium incomes, logistics constraints of a dense area**	**Collective housing areas, mix of activities and housing, medium to low incomes, logistics constraints of a vertical residential areas**	**Wealthy- low-density residential areas, mix of housing and activities, logistics constraints of a low-density residential area**	**Low density residential areas, medium incomes, logistics constraints of a low-density residential area**	**Low and very low density residential areas, medium to low, logistics constraints of a low-density residential area**	**Commercial and industrial area**
SPATIAL FEATURES	**Number of street sections**	high	high	high	high	low density	low density	very low density	-
	Number of delivery points of a distribution point	medium	medium	medium	high	Low	low	low to very low	-
	Population density	high	high	high	medium	Low	low	low to very low	-
	Density of distribution points	very high and high	high	high	medium	medium to low	medium to low	low	medium to high
	Linear density of distribution points	high	high	high	medium	Medium	medium	medium	-
DEMAND CHARACTERISTICS	**Type of housing**	medium to dense housing, no specificity	medium to dense housing, no specificity	medium to dense housing, no specificity	mainly collective housing and apartment buildings	low density single-family housing	low density single-family housing	low density single-family housing	-
	Proportion of professional distribution points	low-medium	low	low	low	low-medium	low	low	high
	Median income	high	medium to low	medium	medium to low	High	medium	medium to low	/
URBAN LOGISTICS GOVERNANCE	**Level of regulation**	medium to high	none or medium	none or medium	none	None	none	none	medium (truck regulation)
	Experimentations and projects	Urban distribution center, innovative logistics organization, etc.	Urban distribution center, innovative logistics organization, etc.	none	none	none	none	none	Urban distribution center
	Land use availability	rare	rare	rare	-	-	-	-	available

III. Decision making tool for urban freight: the case study of the city of Angers

1. Context of the test

Sixteen territorial diagnoses in different French cities have been provided based on this methodology and tests have been conducted in some cities, with operational staff of the Post operator, to assess the efficiency of the tool. The ability of the tool to provide well-differentiated, contiguous and homogenous spatial sub-groups or areas has been examined. Besides, thanks to a geographical analysis and the precise knowledge of the operational staff of their distribution zone we wanted to verify that the identified areas, whose features are considered to have an impact on urban freight, present truly specific characteristics regarding urban freight. Moreover, the cartographic result of the modelling approach has been analysed in order to decide whether or not the model gives a coherent picture of the spatial organisation of the area, whilst logistical data have been used and mixed with geographical data.

Finally, we will briefly evocate how to link the cartography and sub-groups characteristics with well-adapted delivery services and logistics organisations propositions.

In this paper we will focus on the case study of the city of Angers and municipalities surrounding it. Angers is a municipality of 149 000 inhabitants situated in Western France. The city is considered to be a large city (100 000 to 500 000 inhabitants) and the third largest city after Nantes and Rennes in the Western Region.

2. Main results of the case study

Figure 2 represents the urban sub-groups for the city of Angers and large municipalities surrounding the urban centre. City of Angers and its suburbs are described by seven sub-groups over the eight sub-groups provided by the model. From a geographical point of view, the modelling does not provide a new image of city organisation but fits traditional and general urban analyses and city development. At the same time the identified zones could also provide specific information about cities : some urban sub-groups appear for all French cities and some of them appear or do not depending on the characteristics of the area studied. For example, the smaller city of Calais in the North of France is only described by four sub-groupswhile Angers contains seven sub-groups. As for Angers, the map does not present sub-group number 2 but sub-group 3 is strongly represented within the core city – this is specific to this city and corroborated by a socio-economic analysis of the area. Moreover, we can observe that the urban sub-group 5 is strongly represented in the city of Avrillé. In fact, this municipality is the wealthy and residential suburb of the high socioprofessional categories of the urban area and basically the socioeconomic profile of the urban area of Angers is divided between East and West (AURA, 2010). The core centre of the city is well represented by sub-

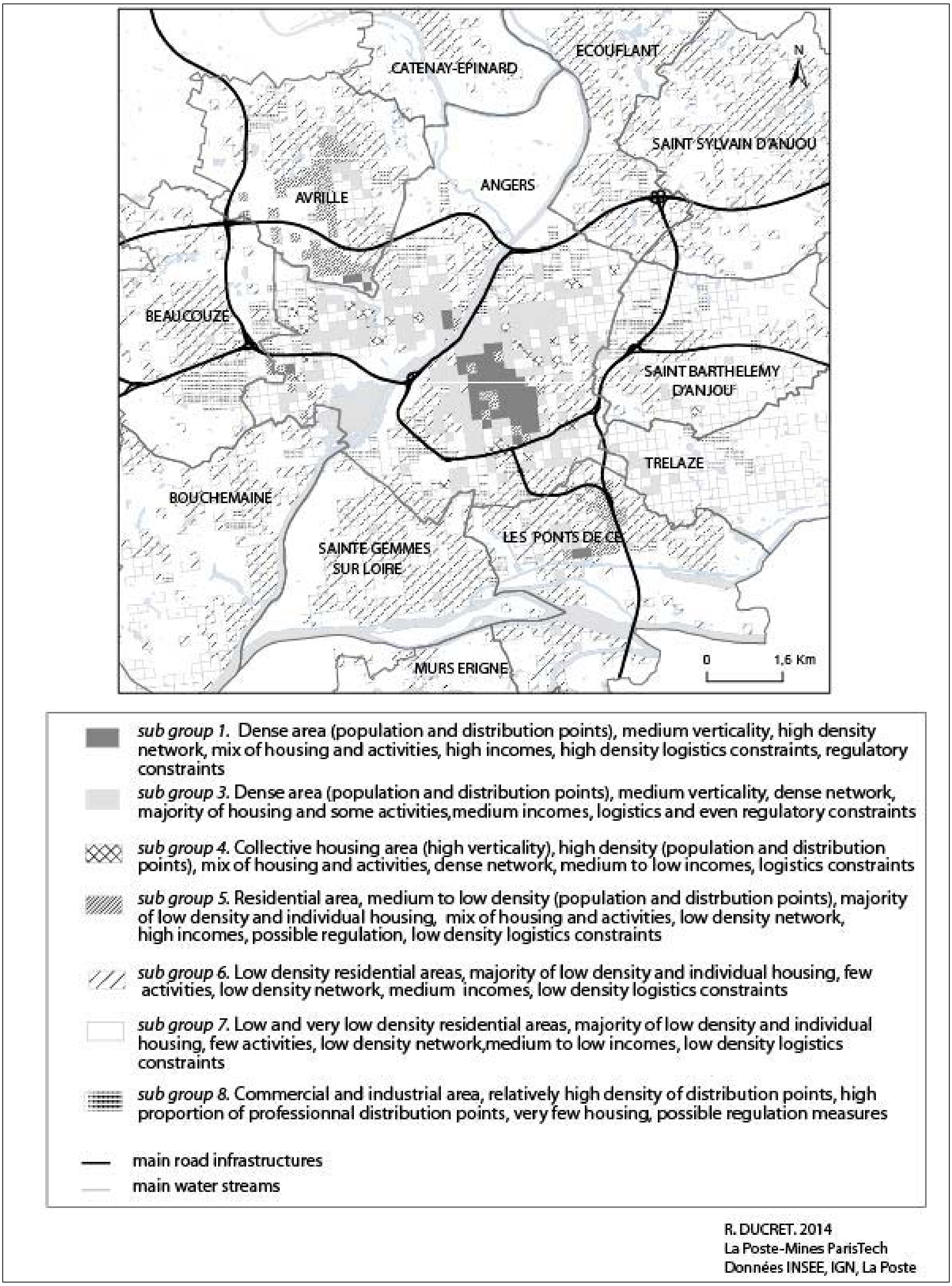

Figure 2. Cartography of the urban sub-groups of the city of Angers and cities of its first ring

groups 1 and 2.Besides, Angers presents low population density levels in its suburbs and is experiencing the urban sprawl phenomenon(INSEE, 2011 ; AURA, 2010). As a matter of fact, urban sub-groups 7 and 6 are well represented by the model. Even the city itself is sparsely dense, low density area can be observed in the city centre and also within the first ring of cities around the major urban centre contrary to, for example, large cities such as Toulouse.Thus, we can conclude that the eight urban sub-groups provided by the modelling are able to precisely and coherently describe spatial organisations but also differentiate cities and give reliable geographical pictures. This means that, from a geographical perspective and despite its simplicity, the modelling tool is a relevant urban modelling tool,thanks to a majority of logistical data turned into geographical data.

Moreover, the model is able to translate differentiated morphological organizations at a larger scale and its influence on last-mile distribution. From an operational point of view, thanks to the tool a parcel provider is able to identify coherent zones with similar spatial and demand features, and could decide to apply specific services or organisation into or for the zone. Areas defined by the sub-group 8, which are industrial and commercial areas, do not need the same services as residential areas (sub-groups 1 to 7). The segmentation provides specific elements about spatial and organisational constraints on urban delivery related to the density and thus level of congestion of the infrastructure network, the accessibility to an area, the density of the distribution point and the verticality of the housing.For example, even if in Angers the city centre is less dense and constrained that in other cities because the historical centre is restraint; nevertheless it presents high population and distribution point density levels, high density road network but morning and evening congestion, and specific constraint like pedestrian zones and time-windows delivery regulationsareaswhich are represented by sub-group 1. 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. Note for example that the duration of delivery is not the same for apartment buildings and individual houses. Besides, the productivity of delivery is not the same in dense central areas and low density residential areas.

Taking into account the advantages and drawbacks of a sub-group (the productivity level of the area, traffic constraints, density of the distribution point, regulation specificities, type of housing, proportion of business and households, etc.), we will be able in the module 2 of the decision making tool to propose specific delivery services, to optimize the logistics organization and to adapt the type of delivery vehicle to the area. Moreover, the mapping of the sub-groups allows the grouping of spatially closed areas with close features to achieve sufficient demand and efficiency in delivery service. Module 2 is currently developed and tested by the French Post operator.

Conclusion, limitations and future research

From a scientific point of view, this tool contributes to enlarging the field of freight and goods transportation to geography and urban studies. Despite the simplicity of the modelling approach and thanks to data related to logistics and mixed with geographical data we have been able to develop a relevant urban modelling tool providing an accurate picture of urban organisation and also relevant rationales about urban freight. Thus, we argue that spatial studies can give highly relevant information about urban goods movement and logistics. These conclusions emphasize the necessity for urban logistics studies and planning to include in-depth spatial analyses and for urban freight modelling to enlarge the descriptors to spatial features and their influence on logistical organisations.

However the structure of the decision-making tool as well as the data mining and the modelling approach could be debated. With respect to the descriptors used in the model, test with operational staff have revealed that more precise data about accessibility or congestion, information about public passenger transport network, as well as index of proximity to stores or other facilities should complete the spatial descriptors in order to enhance the spatial point of view and help adapt services and new organisations. Basically, urban freight modelling should open to spatial databases. Information about age groups and commuting could be added too.That information could also help adapt services depending on the socioeconomic profile of the consignee or its mobility.

As data available to take spatial features into account in urban logistics are scarce, contrary to other research fields, choices made in this research project could be discussed in terms of representativeness and completeness of the data and efficiency of the aggregate indexes created. Nevertheless, this work proves that data that is not necessarily urban freight-oriented, such as spatial data or professional data could provide relevant information for urban logistics practitioners. Logistic data have been used to build spatial descriptors and successfully used to model the way in which spatial organisations and logistics work together influencing the delivery. It may solve the issue of poor data availability for urban freight modelling. In that respect, postal data are highly informative and the French postal operator, which has a very dense location in France and French cities, could be an important data collector. If extra data are needed for a new modelling, postmen may be assigned to a task of collection the information. It could be static data, like in this study, and, thanks to the extreme density of the postal network, dynamic data may be gathered too. This capability may, in the future, complement the postmen's activities transforming historical tasks into a new business immersed in the digital world.

Even though we have used some postal data, the territorial urban logistics profile could be useful and used in an independent way in France and even in Europe thanks to the development of open databases at urban level. In fact, beyond the research project, this tool could help local governments as well as distribution providers to realise efficient territorial diagnosis, prior to the settlement of new regulations or logistics organisations.

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