How the location of urban consolidation and logistics facility has an impact on the delivery costs? An accessibility analysis

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Jesus Gonzalez-Feliu[a*], Josep-Maria Salanova-Grau[b],

[a]*Laboratoire d'Economie des Transports, CNRS, 14 Avenue Berthelot, 69363 Lyon Cedex 07, France*

[b] *Hellenic Institute of Transport, Center of Research and Technology Hellas, Tessaloniki, Greece*

Abstract

Urban consolidation is a popular subject in city logistics. Moreover, public authorities need adapted decision support methods to analyse the interaction between their land-use choices and the transformations in trip behaviour, for both personal and commercial trips. This paper proposes a simulation method to carry out a land-use and transport interaction analysis based on the notion of accessibility, and applies it to the real urban network of Lyon. First, a literature review on accessibility and simulation of goods flows is made. Second, the proposed method is presented on the form of a sequential procedure. First, a demand generation model estimated the weekly number of demands to deliver to each customer, to what we convert the generated number of deliveries into a daily number of freight transport demands including a quantity of goods to deliver and a customer, via an empirical procedure. Then, a spatial analysis to choose the most suitable sets of potential logistics facilities is proposed. Finally, each platform is associated to a distance-based accessibility indicator. Computational results are presented and discussed. Finally, recommendations to public authorities for their land-use policy assessment in terms of impacts on freight transport are proposed.

Keywords: urban consolidation; simulation; scenario assessment; distance-based accessibility

Résumé

La consolidation urbaine est un sujet populaire en logistique urbaine. En outre, les pouvoirs publics ont besoin de méthodes d'aide à la décision adaptés pour analyser l'interaction entre leurs choix d'utilisation de l'espace et les mutations et impacts des comportements de déplacement, tant pour les personnes comme pour les marchandises. Cet article propose une méthode de simulation pour analyser l'interaction transport territoire basée sur la notion d'accessibilité, appliquée au cas réel de l'aire urbaine de Lyon. Tout d'abord, une revue de la littérature sur l'accessibilité et la simulation du transport de marchandises en ville est proposée. Ensuite, la méthode envisagée est présentée sur la forme d'une procédure séquentielle. Premièrement, la méthode utilise un modèle de génération de la demande de transport de marchandises, puis une méthode empirique pour obtenir la quantité journalière de marchandises à livrer. Ensuite, une analyse spatiale pour choisir les centres de distribution urbaine les plus appropriés est proposé. Enfin, chaque plate-forme est associée à un indicateur d'accessibilité basé sur la distance parcourue. Enfin, des recommandations pour les acteurs publics dans leur évaluation des politiques d'utilisation de l'espace urbain en termes d'impacts sur le transport de marchandises sont proposées.

Mots-clé: centres de distribution urbaine ; analyse de scénarios ; accéssibilité type distance.

[*] Corresponding author. Tel.: +33-4-72-72-64-44; fax: +33-4-72-72-64-38.
E-mail address: jesus.gonzales-feliu@let.ish-lyon.cnrs.fr.

1. Introduction

Urban consolidation is a popular subject in city logistics as shown in recent works (Allen et al., 2012; Morana et al., 2014). However, the classic concepts of urban consolidation centres (UCCs) with a public service vision present several limits and need to be revised (Ville et al., 2012). Moreover, the complex context and the wide variety of alternatives to classical UCCs justify the need of assisting public authorities to be supported by decision aids methods to analyse the interaction between their land-use choices and the transformations in trip behaviour, for both personal and commercial trips. More precisely, the last trends in urban consolidation (micro-consolidation, single-carrier schemes and collaborative systems) need to be assessed and estimated in a coherent way. One of the main questions that arise is that of better choosing the consolidation points to deliver an urban zone, mainly in case of collaborative schemes.

This paper proposes a simulation method to carry out a land-use and transport interaction analysis based on the notion of accessibility, and applies it to the real urban network of Lyon. First, a literature review on accessibility and simulation of goods flows is made. Second, the proposed method is presented on the form of a sequential procedure. First, a delivery-based demand generation model estimated the weekly number of demands to deliver to each customer, to what we convert the generated number of deliveries into a daily number of freight transport demands including a quantity of goods to deliver and a customer, via an empirical procedure. Then, a spatial analysis to choose the most suitable sets of potential logistics facilities is proposed. To each facility, a number of vehicles is assigned, using a statistical method derived from French National Surveys of urban Goods Movement. Finally, each platform is associated to three accessibility indicators: a cost-type, a gravity-type and an utility-type. After that, routes are estimated using a semi-greedy algorithm for the consolidation 2E-VRP (Two-echelon vehicle routing problem, see Gonzalez-Feliu, 2012). Since instances are of real size and the number of tests of the accessibility is elevated (about 100 tests with more than 400 customers and non-euclidean travel times), the semi-greedy algorithm allows us to have a basis of comparison for all tests, and reproduce the computations in an acceptable time period. Computational results are presented and discussed. Finally, recommendations to public authorities for their land-use policy assessment in terms of impacts on freight transport are proposed.

2. Background and context

The notion of accessibility has been used and analyzed since long time in urban transport planning but also in urban development analysis (Gonzalez-Feliu and Mercier, 2013). We observe in literature several definitions of accessibility, some of them derived into quantitative indicators, others related to qualitative studies. In our study, we aim to focus on the definition of Geurs and van Wee (2004) who defined accessibility as “the extent to which land-use and transport systems enable individuals to reach destinations by means of a transport mode”. The authors identify four categories of accessibility indicators, mainly focused on personal transport.

The first category is that of infrastructure-based indicators, largely used in transport planning studies made by public authorities. These measures deal with service level related to a transport infrastructure, as for example the congestion level or the average travel speeds on a road network (Geurs and van Wee, 2004). The second is that of location-based measures, analyzing accessibility at physical locations, usually on a macroscopic perspective. The measures usually describe the level of accessibility to spatially distributed activities, and are largely used in urban planning and geographical studies. Two main groups of indicators can be distinguished in this category: distance based indicators and potential accessibility measures. The distance-based indicators, also called connectivity measures, represent the degree of which two locations are connected. Several distance measures can be defined, as for example the line distance between two points, other non-linear distance measures, the travel time or the transportation cost required to access a number of opportunities (Ingram, 1971; Pirie, 1979). The potential accessibility, also called gravity-based measures, estimate the accessibility of opportunities in zone i to all other zones. These measures take into account both the number of opportunities and the transportation costs to reach them (Geurs and van Wee, 2004). The third category contains person-based measures, which define accessibility at the individual level. This type of accessibility measures limitations on an individual's freedom of action in the environment. The fourth one is related to utility-based measures, which derive from the main benefits that people derive from access to the spatially distributed activities. This type of measure has its origin in economic studies, and interprets accessibility as the outcome of a set of transportation choices. Two main types of measures are used: logsum indicators, which study the desirability of the full choice set, and doubly constraint entropy models (Geurs and van Wee, 2004).

Regarding urban goods distribution, the gravity accessibility has been used to analyze the suitability of optimizing urban goods transport systems with cross-docking, relating them to vehicle routing optimization methods (Gonzalez-Feliu, 2008; 2012; Crainic et al., 2010). All authors define the opportunities as the quantity of freight to deliver, and no generalized costs are defined (only travel distances are considered). Since the works are carrier based and aim to study the suitability of route optimization approaches based on the only distance and cost factor, those indicators offer a good vision of the problem.

Concerning urban consolidation simulation, it has been traditionally modeled using vehicle routing approaches (Toth and Vigo, 2002). However, few works address the connection problems at consolidation centers, i.e. the relations between vehicles arriving and departing at each consolidation points (Gonzalez-Feliu, 2012). This is based on the assumption that urban consolidation centers are managed by different stakeholders than those shipping goods to UCCs, and that the coordination of all stakeholders is difficult and non-necessary for the good function of the platform (Crainic, 2008). However, in collaborative systems, coordination and collaboration among all actors is crucial to the success of the distribution schemes (Gonzalez-Feliu and Morana, 2011) and VRP approaches combining two stages where in the first several transport carriers converge on consolidation platforms are needed. To the best of our knowledge, we observe only few works on it (Gonzalez-Feliu and Salanova, 2012; Thompson and Hassall, 2012) and all cases consider that consolidation platforms are located.

Urban consolidation is a popular subject in urban logistics but, as shown by several authors, consolidation centres are often non-efficient and have difficulties to be deployed and maintained economically (Gonzalez-Feliu and Morana, 2010; Zunder and Marinov, 2011; Allen et al., 2012; Morana et al., 2014). When regarding in-depth to the development of such platforms, its location has been a priori decided, without an analysis of the best area to locate it, and although some authors indicate accessibility analysis as a good tool to support such decisions (Crainic et al., 2010; Gonzalez-Feliu, 2008, 2012) they use complex tools not able to be deployed by non-OR experts. To deal with lack, we aim to propose an accessibility analysis with an algorithm easy to deploy and tools easy to implement by non-OR experts.

3. The proposed framework

The proposed framework is an accessibility analysis based on a distance-based location accessibility indicator. The choice has been made because gravity indicators are based on O-D trips, which are direct trips, and in urban freight transport is organized in routes containing several trips.

First, the demand is estimated using a delivery-to-commodity model (Gonzalez-Feliu, 2013). The model works as follows. Given a city, divided into representative zones, we associate to each of them its population density, its commercial supply in terms of number of employees in each commercial activity class, its level of industry and distribution activity and its position with respect to the city center. Then we define a set of retailing activities that will be involved on logistics pooling strategies, for example the grocery distribution sector. Using a delivery generation model (Holguin-Veras et al., 2011; Gonzalez-Feliu, 2013), the number of deliveries per establishment can be estimated. Then, from Gonzalez-Feliu et al.'s (2012) ratios, we assign a quantity of freight to each establishment being delivered. The same procedure is made to each pickup.

After that, we define the accessibility indicator related to the location of each consolidation platform. The chosen accessibility indicator is the total traveled distance of all routes (from the 1st and 2nd echelon). To do this, we propose a sequential algorithm that works as follows: First, all customers are grouped, assigned then to a second-stage vehicle, using a Sweep algorithm. After that, each vehicle is assigned to a satellite (or cross-docking platform), taking into account the composition of the route and its total load. After that, a heuristic algorithm (either a semi-greedy or a genetic algorithm) is run to build second-stage routes, then, according to such routes, first stage vehicles are defined and corresponding routes built, using a dynamic programming approach (since the number of first-stage routes are small, a dynamic programming method can be run in realistic times and allows us to obtain more performing results than a heuristics procedure). Since the aim of the paper is to compare semi-greedy and genetic algorithms, we do not focus on the general algorithm structure but aim to detail both route construction algorithms.

After assigning customers to vehicles, a Semi-Greedy algorithm is built to build a first set of routes via a constructive procedure that adds each customer to a route. This algorithm is described more in-depth in Gonzalez-Feliu (2012) and Gonzalez-Feliu and Salanova (2012). The semi-greedy algorithm is then improved by a combination of classical local-search heuristics, (Toth and Vigo, 2002). In the specific, we combine 2-opt, 3-opt, switch and or-opt moves. The algorithm has been tested in a set of instances (Gonzalez-Feliu, 2008) where optimal solutions are found (Jepsen et al., 2013). We observe an important average gap. However, the aim of the paper is not to solve an optimization problem but to provide a quick indicator.

Table 1. Summary of computational results on Gonzalez-Feliu (2008) instances

Group of instances	Literature distance	Algorithm distance	Gap	Computational time
20 customers	5.59	5.17	7.60%	0.08
31 customers	8.98	7.89	12.19%	0.12
50 customers	46.91	41.86	10.77%	0.11

The choice of this type of algorithm, which is not optimal but remains a quick way to estimate the total traveled distance, is motivated by two facts. The first is that we need a fast algorithm in order to simulate tens even hundreds of instances in few seconds, and the second is that we need to compare situations using the same basis, so this algorithm is fast and has a similar behavior if instances are similar (which is the case here). Moreover, the algorithm reproduces in a suitable way the driver's behavior and if we compare such routes to a set of real ones, we observe that the traveled distances and the composition of routes are similar to reality.

Once the algorithm is calibrated, we can define the scenarios to simulate. In this work we aim to compare different potential locations of consolidation and/or collaboration centers. Each scenarios is then assessed using the algorithm and a "distance-based" accessibility indicator is assigned. Then the accessibility analysis itself can be carried out. To do this, all scenarios are compared to state on the best location(s) of consolidation centers. To illustrate it, an example is shown in section 4.

4. Application results

To illustrate the proposed method, we present an example of application. We suppose 5 different operators (representing each a realistic transportation carrier). Each operator has a depot, located in a different area of the conurbation. The total number of customers is 136, but each of them is served by various operators, which makes a total number of 439 deliveries every day. Each operator has a different fleet of vehicles, composed by big and small trucks. Each operator has the same vehicles, respectively for big and small sizes, but their characteristics differ between operators. In order to propose a realistic set of scenarios, we used a real urban network: that of Lyon (France). If we aim to make them collaborate using the existing facilities, we have the choice among several consolidation platforms, located in the peripheral areas of the city.

Table 2. Characteristics of the simulated operators

Operator	Number of Big vehicles	Capacity	Number of small vehicles	Capacity	Number of customers
1	2	7500	8	1200	95
2	3	4000	12	750	115
3	1	7500	5	1200	86
4	2	4000	8	880	78
5	4	2500	8	850	65

The city of Lyon has a particular configuration for which the South and the East are more industrialized areas where it is easier to find logistics platforms or terrains to develop urban consolidation facilities. The urban area is divided into 750 zones from where 148 are potential zones to locate a collaborative urban consolidation center. The demand of each customer is obtained using the method proposed in Gonzalez-Feliu and Salanova (2012).

Three groups of simulations are made. The first aims to locate one consolidation center among the different locations, the second two facilities, and the third three platforms. For each group of simulations the different possibilities are simulated, except (for the second and third set) those having two satellites at a very close distances and so being not convenient with respect to a solution with less satellites. For each scenario to simulate, the proposed algorithm estimates both big and small vehicle route distances, and calculates a distance-based accessibility indicator, defined as follows: $A_i=100/d_i$

Where d_i is the total traveled distance estimated with the proposed algorithm.

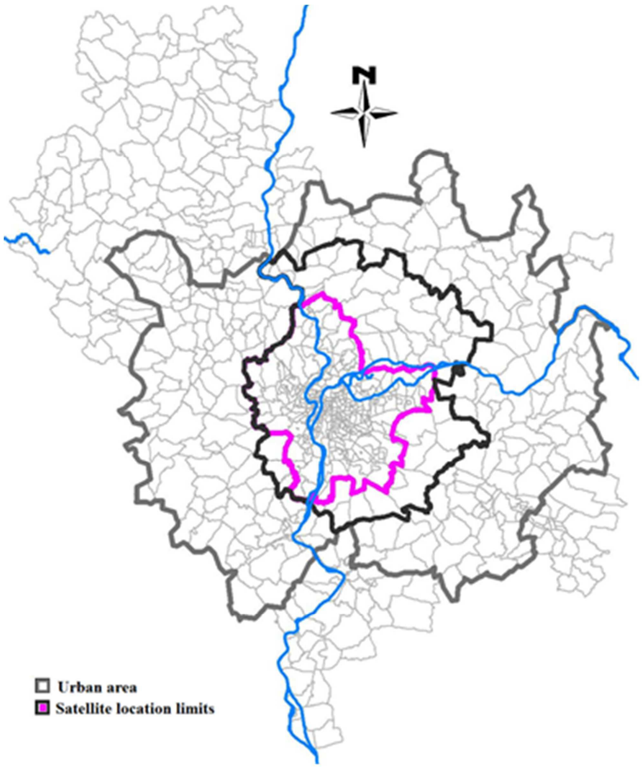

Figure 1. Map of the urban area for computational tests

We report in Table 3 the number of simulated scenarios for each group, as well as minimum, maximum, mean and medium values of accessibility. We observe that the most accessible scenarios are those of group 1. Indeed, it seems that, in the specific configuration and given the total daily demand to deliver to the chosen retailers of the inner city of Lyon (136 customers with a total commodity quantity of 27 508 kg), the configurations with only one consolidation center seem to be in average (and median) more accessible. Moreover, the minimum and maximum accessibilities are quite higher than those of the other two groups.

Table 3. Synthesis of the three groups of simulation

Group of simulations	Number of simulations	Min Accessibility	Max Accessibility	Mean Accessibility	Median Accessibility
1	148	1.8	11.0	4.4	4.1
2	3248	1.5	9.3	3.9	3.9
3	40403	1.5	8.9	4.0	4.0

Those exploratory results, which merit being further investigating and analyzing, show however that for the given customers and delivery quantities, the best configurations are those with a single consolidation center. This can be explained by two factors. The first is the quantity to deliver, which has to be related to the means given companies to deliver it (in the proposed simulation, no cost approach is made, only a distance-based analysis). Indeed, the delivered quantities are small but given the fleets of each operator, the concentration on a sole consolidation center is an suitable solution. However, this has to be confronted to the geographical characteristics of the urban territory. In this case, we have five carriers, each of them located in a different area of the conurbation. Since there is not a concentration of carriers in two points and all carriers serving all the city, in some cases delivering the same customers, the scenarios with one consolidation center allow each carrier to concentrate all deliveries on big trucks making direct shipping shuttle trips. If more than one consolidation center is defined, each carrier needs to deliver two or more points, and the demand distribution will make more or less difficult the entire distance optimization (if the demand to be delivered to one platform is higher than a truck capacity, the carrier will need to put a second truck, and eventually make routes, which will increase the traveled distances). Such distance increases are not always compensated by the reductions obtained in the terminal transport (from consolidation centers to customers) since traveled distances are higher in periphery than in the main city. Single-platform scenarios are then in average more suitable than multiple platform ones, and three-platform ones seem more compact (the differences between them are lower than in the other two groups, and mean and median are closer).

5. Conclusion

In this paper, we presented a method to support strategic decisions in terms of urban consolidation center's location. To do this, we propose a distance-based location accessibility indicator estimated via a semi-greedy algorithm to well show the route nature of freight transport in urban areas. The method allows to simulate the demand to transport via a commodity generation model, then to assess it into routes using a semi-greedy algorithm. Finally, a distance-based accessibility indicator is calculated. Those results show that the method can identify, with a simple and quick method, the main accessibility issues for platform location and then anticipate risks and impacts of locating such facilities in the different parts of a city. To this, a practical example is made and a big quantity of scenarios are simulated and assessed by the method in order to produce comparative results and study the possibilities of location for urban consolidation platforms.

Finally, it is important to relate those results to practice. An accessibility analysis can state on the suitability or not of locating platforms and the proposed example show a result which is not always evident. Indeed, in urban areas of the size of Lyon we can envisage several platforms for urban distribution, but in the given example configurations with only one platform seem more suitable than configurations with more than one. However, it can be strategic for a public authority to define more than one platform. In this case, accessibility analysis can be interesting to choose a good and equilibrate configuration. In conclusion, we aim to remember that a decision support method is made to support decision makers in their choices, not to substitute them, so a decision maker must always have the freedom and possibility to choose the best solution that meets his or her targets, and such method need to help them to understand the impacts of such choices.

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