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KEYWORDS: urban logistics, loading/unloading spaces, delivery bays, optimization model, collaborative data.

ABSTRACT

This study presents a real-data approach that aims at optimizing the location of urban loading-unloading (L/U) spaces. The originality of this paper is twofold: first, it proposes a data collection methodology in order to integrate real and up-to-date information regarding cartography, L/U parking demand and existing L/U spaces. Second, an optimization model is developed in order to determine the location of new L/U spaces by taking into account real distances, influence radius and physical constraints. Such optimization model can be used to evaluate the relevance of the existing L/U spaces and/or to determine the optimal location of new ones. For this we propose to combine the use of OpenStreetMap, Google Maps APIs, and Open Data portals. This paper provides a framework composed by 3 models, namely: data collection, demand generation and location optimization. The proposed approach is applied to the city of Paris in order to illustrate different case studies and to assess the effectiveness of the framework.

INTRODUCTION

Urban freight represents between 15% and 30% of the kilometres driven by vehicles in urban areas (Janjevic et Ndiaye, 2013; Russo and Comi, 2012; Dablanc, 2007; Schoemaker et al., 2006; Kenworthy et al., 1999). Despite this relatively low percentage urban deliveries have disproportionally high impacts. Moreover, urban freight confronts numerous difficult problems, such as high levels of traffic congestion, negative environmental impacts, energy consumption, social nuisances, etc. (Lebeau, 2016; Janjevic and Ndiaye, 2013, Taniguchi et al., 2001). Several studies have explored these impacts that can be broken down into three types:

- Environmental impacts: which are related to energy consumption and emissions (Browne et al., 2007). In France it is estimated that freight transport is responsible for between 16% and 50% (depending on the pollutant considered) air emissions (Dablanc, 2007).
- Social impacts: which are related to the emissions of pollutants affecting public health, nuisance such as congestion, noise disturbances, accident rates, visual contamination, smell, vibration. All these externalities leading to reduce the attractiveness of urban

centers. (Kim and Afzal, 2014; Quak, 2008; OECD, 2003; Van Binsbergen and Visser, 2001).

- Economic impacts: which are mainly associated with transportation costs (Janjevic and Ndiaye, 2013; Hicks, 1977). It is estimated that the final transport delivery in town (last mile) represents 28% of the total cost of the transport (Wittlöv, 2012).

In this context L/U, spaces aim at facilitating the logistic operations associated with physical flows within urban areas. Numerous works have explored the problem of optimizing the location of L/U spaces.

Some authors and institutions have worked on determining best practices and recommendations when planning the location of L/U spaces. In 2009, the CERTU (French centre for networks, transport, and urban planning) issued a method to help planning such spaces (CERTU, 2009). The method proposes a rough quantification of the needs for L/U spaces and a set of recommendations for improving their management. Dezi et al. (2010) suggest technical solutions to improve the sizes, quantities and locations of L/U spaces with a practical application to the city of Bologna. Jaller et al. (2013) propose a set of policy recommendations in order to increase L/U spaces availability; New York City is used as a case study.

Other authors have proposed models to optimize the location and/or the management of L/U spaces. Aiura and Taniguchi (2005) propose a model to identify the optimal location of L/U spaces in terms of delay, cost, and traffic. Delaître and Routhier (2010) suggest a combination of two tools (FRETURB and DALSIM) and give an implementation example in the city of La Rochelle. Alho et al. (2014) develop a modelling framework for cases with low-data availability based on six interdependent models. Gadrat and Serouge (2015) present a hybrid method (FRETURB model and the CERTU method) in order to quantify the demand of L/U spaces (often called delivery bays, or delivery parking areas).

The problem of locating L/U spaces still offers scientific challenges, especially due to the heterogeneity of information and the great complexity of logistical flows. This work contributes to the existing literature by proposing an approach that public authorities can use to capture urban needs quickly and effectively. Unlike the aforementioned works, the framework proposed in this paper allows the integration of real-data regarding cartography, logistic demand and existing L/U spaces. As a result, it gives decision-makers the possibility to:

- Quantify the need of L/U spaces by considering up-to-date businesses information.
- Optimally locate new L/U spaces taking into account the real cartography, up-to-date establishments needs, real distances (considering traffic) and current L/U spaces.
- Evaluate the pertinence of L/U spaces' current location.

The main motivation of the proposed approach is to enhance the use of all available data in the planning of L/U spaces. In this paper we suggest using free and/or collaborative data with 3 objectives: expedite the data collection process; feed the optimization model with pertinent inputs and allow a simple replication of the proposed framework in other cities.

PROPOSED APPROACH

This approach is developed from the standpoint of local authorities, that aim at finding a trade-off between sustaining the commercial dynamism related to local businesses and the scarcity of parking surfaces for inhabitants (CERTU, 2009). The objectives of other stakeholders are also related to the notion of commercial dynamism; for instance, logistics providers and transporters need available L/U spaces closer to their drop-off points.

The proposed framework for L/U spaces location and evaluation is divided in three steps: 1) data collection (information on the urban area); 2) demand generation (needs regarding L/U spaces); 3) optimization (locations of L/U spaces), as shown in figure 1.

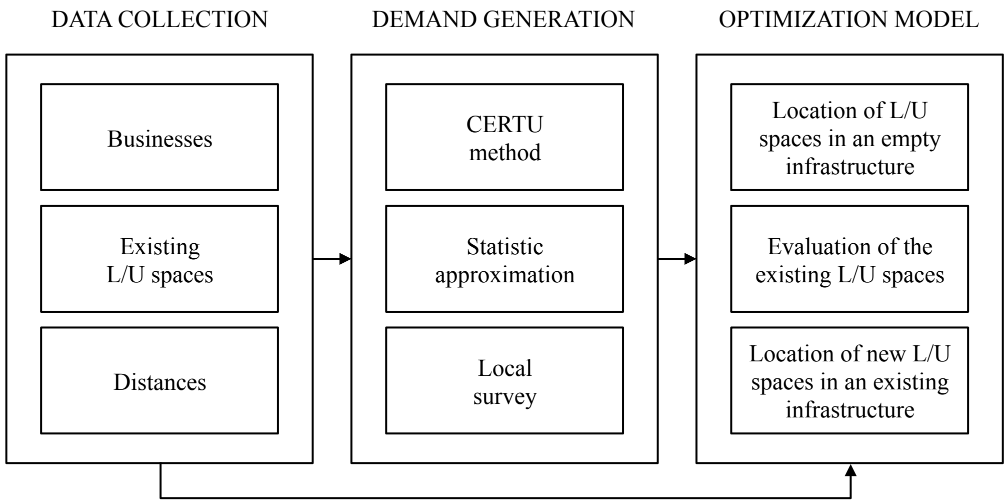

Figure 1. Structure of the proposed framework

In each step of the framework, the decision-maker has different choices that should enhance the flexibility process of locating and evaluating L/U spaces. In the data collection step, it is not necessary to gather all the information. For instance, it is possible to collect only the information regarding the businesses and do not take into account the existing L/U spaces (if such information is not available) or the real distances (as they can be estimated with an Euclidian calculation).

In the demand generation step, three options are available to quantify the needs of the businesses and the decision-maker can choose the most convenient.

Finally in the optimization model, three use cases are proposed:

1. Evaluation of the existing spaces, i.e. are the actual L/U spaces well adapted to the needs of the urban zone?
2. Optimization of the location of L/U spaces with no information about the existing ones, i.e. where to locate a given number of L/U spaces?
3. Optimization of the location of new L/U spaces, taking into accounts the locations of the existing spaces, i.e. where to add new spaces?

In the following sections each step of the framework is explained with more detail.

DATA COLLECTION

The data collection aims to numerically replicate important features of the area of interest. It consists in gathering information about: the businesses (location and activities), the location of existing L/U spaces (if any), and the distances between businesses and L/U spaces (which will be walked by delivery employee). Performing a local survey to gather such information can be tedious and expensive. Today's online cartography services, APIs and Open Data portals are reliable sources of information. We propose using these sources of information in order to carry out the data collection.

The typical outputs from the data collection for the businesses and existing L/U spaces would be similar to those shown in Table 1. In this example, information about businesses is obtained from OpenStreetMap and Google Maps (Google Places API), and information about the existing L/U spaces is obtained from the City of Paris Open Data portal (opendata.paris.fr).

Table 1. Data collection outputs regarding businesses and existing L/U spaces

Businesses		**Existing L/U spaces**	
Coordinates	**Type**	**Coordinates**	**Size**
48.8461174, 2.3396435	Fast food restaurant	48.847232, 2.341162	10.0 x 2.0 m
48.8463961, 2.341408	Hotel	48.847232, 2.341162	7.0 x 2.0 m
⋮	⋮	⋮	⋮

The data collection should also identify the potential spots in which new L/U spaces could be added. The aim is to determine the coordinates of the potential L/U spaces; which can be obtained by either a discretization of the roads in the area of interest; or by manually determining specific points. It is important to note that in this step the decision-maker can adapt the data to fit the local of policy of parking management. For example parking locations assigned to other uses (residential, disabled, banking, police, etc.) can be removed from the list of potential spots.

The final step of the data collection consists in calculating a distance matrix between the L/U spaces and the businesses. The distance matrix can be obtained by querying an online service cartography API such as Google Maps API, or it can be simply calculated with Euclidian distances for simpler applications. An example of the obtained matrix is shown in Table 2.

Table 2. Distance matrix between L/U spaces and businesses

	Business 1	**Business 2**	**Business 3**	**…**
L/U space 1	15.6 m	0.6 m	0.6 m	…
L/U space 2	13.8 m	234 m	234 m	…
⋮	⋮	⋮	⋮	⋱

The distance matrix allows an easy access to the information about the proximity of business around each L/U space. For instance, one row represents the distances of all businesses from one L/U space, and if we know which businesses are the most demanding in terms of frequency movements, we can efficiently locate new L/U spaces. This leads us to the second step of our framework presented next.

DEMAND GENERATION

The demand generation aims at quantifying the generated flow of loadings and deliveries for each business. In this part of the framework, the parking demand of each business can be calculated with a statistic-based estimation (2 choices are proposed in the next section) or with a local survey. The output of the demand generation is a list of all the businesses in the area of interest with their coordinates and their demand (i.e. frequency of loading or unloading operations). Visualizing the demand in a map allows the identification of areas with a high concentration of delivery needs.

Statistic-based estimations

Statistic-based estimations are basically time-series extrapolations of past demand. This approach is based on surveys and statistical analysis. In our framework, two options are available to quantify the demand of each business following a statistic-based estimation, namely (1) the CERTU method and (2) a statistic approximation based on an adaptation of the report of Allen et al. (2008). As these are estimations, the information they generate will inevitably be imperfect in terms of level of precision; but it is to note that the cost of generating such information is practically insignificant.

CERTU Method

The CERTU method is comprehensive guide for quantifying, locating and dimensioning L/U spaces. In this method onsite survey is carried out in the studied area. Each business is associated with a type of activity, which is accordingly related to an average number of logistic movements per week. In total, CERTU proposes fourteen types of activities, each having its own frequency of movements as shown in Table 3. This table was generated from an update of a national survey done in France in the 1990s. The update has been achieved by using the French national register of businesses (*SIRENE*).

Table 3. Movements of goods per week for each type of activity (CERTU, 2009)

Type of activity	**Movements**	**Type of activity**	**Movements**
Supermarket (≥ 400 m2)	83.94	Local craft and SMBs	7.81
Pharmacy	31.76	Others (jewellery, sports, …)	7.53
Wholesale	21.67	Furniture store	7.5
Bookshop, office supplier	13.8	Cafés, hotels, restaurants	6.25
Butcher	10.5	Clothes shop	3.53
Supermarket (< 400m2)	9.53	Tertiary and artisans	2.43
Bakery	8.07		

The CERTU method has a practical approach to characterize the need of L/U spaces: besides the frequency of delivery, each type of activity has specific need in terms of organization, size and/or regulation. For example, although jewellery and furniture stores are relatively similar in terms of frequency, the deliveries for the latter are made with larger trucks.

Statistic approximation based on an adaptation of the Review of UK Urban Freight Studies

In the proposed framework, the second option to generate the demand of the urban zone consists in using historical data to approximate the frequency of movements of each business. In this study we propose an adaptation of the report of Allen et al. (2008). It is important to note, that this type of approximation gives only an average estimation of the demand. As the logistic need has local specificities and varies from one city to another, there is inherent error when adapting existing estimations to new cities.

The Review of UK Urban Freight Studies (Allen et al., 2008) summarizes the results of 30 UK urban freight studies carried out between 1996 and 2008. This report proposes a broad view in different cities in UK of urban freight activities: number of movements, type of deliveries, type of vehicles, patterns in vehicle deliveries, etc. Allen et al. highlight some difficulties when using existing surveys: first, many of the studies have a relatively small sample sizes, which might not be representative of the reality. Second, one must be careful before using studies when raw data are not available. Indeed, one topic can be investigated using different techniques (i.e. observation survey and establishment survey), and even when the same technique is used, questions can be phrased in different ways. Table 4 presents an adaptation of Allen et al. (2008) in which, for each type of establishment the number movements per week is approached by taking into account historical data. In order to adapt this data to the city of Paris, the types of establishments were adjusted to match the categories of businesses used by online cartography services, APIs and Open Data portals.

Table 4. Movements of goods per establishment, adaptation based on Allen et al., 2008

Establishment	Movements	Establishment	Movements
Convenience grocery	92.5	Department store	12.0
Supermarket	60.0	Bakery	10.0
Chemist/pharmacy	37.0	Pizza restaurant	10.0
Bulders merchant	35.0	Other services	9.7
Book shop	32.5	Office supplies shop	9.0
Newsagent	25.0	Florist	8.0
Hotel	24.5	Printing/photocopy shop	6.0
Furniture shop	22.0	Shoe shop	5.5
Public house	19.5	Clothes shop	4.0
Computer shop	18.0	Fast food restaurant	3.0
Hardware shop	18.0	Gift shop	3.0
Pub/café	16.0	Travel agent	2.0
Variety store	15.0	Dry cleaning	1.0
Cinema	12.0		

It is important to note that the use of the estimations in the literature as an input for the demand generation must be done watchfully. The delivery estimations and especially their segmentation can contain a bias that will influence the optimization outputs.

Local survey

Local survey consists in creating a questionnaire to assess the logistic needs of businesses in the urban area. The main advantages of preforming a survey are acquiring up-to-date data with an important level of precision (i.e. distribution of the movements of goods in the week and in the day? volume? special requirements? etc.). This would help to avoid the bias of using data meant for another purpose and collected in another city or country. Nevertheless, performing local surveys for every L/U spaces planning decision, would lead to important costs for local authorities. Therefore statistic-based estimations seem to be a reasonable trade-off between cost effectiveness and level of precision.

OPTIMIZATION MODEL

The goal of the optimization model is to locate L/U spaces close to businesses with higher logistic demand. As shown in the previous section, this demand is modelled by the frequency of movements of goods for each business. A genetic algorithm (GA) is used to determine the optimal (or pseudo optimal) location of the L/U spaces. Such tools have proven their pertinence when solving facility location problems (Fernandes et al., 2014; Tosun, 2014; Lalla-Ruiz et al., 2016).

Mathematical model

The objective function for the localization of L/U spaces is the minimization of the weighted distance between them and the businesses creating the demand. The distance can be calculated either using the Euclidian distance between the two points, or the real distance can be queried using Google Maps API. The function considers that each L/U space has a range of action, in which all parking demand is fulfilled. To model this range, we use an influence radius parameter.

Each solution of L/U spaces allocation is represented by a binary vector in which each position of the vector is linked to an available spot (the size of the vector is equal to the number of available spots). A value of 1 indicates that there is an L/U space in the current position. The total number of ones in the vector will be equal to the L/U spaces to locate in the problem. The mathematical model is described as follows:

$$
\begin{aligned}
&Minimize:\\
&Z=\sum_{j=1}^{m}\sum_{i=1}^{n} x_j w_i d_{ij}\\
&with:\\
&x_j \in \{0;1\}\\
&\sum_{j=1}^{m} x_j = Q\\
&d_{ij}(b_i,x_j)=f(lat_{bi},lon_{bi},lat_{xj},lon_{xj})\\
&w_i d_i\big|_{\forall j}=\begin{cases}0, & if \quad d_{ij}(b_i,x_j)\le r_{ij}\\ w_i d_i, & if \quad d_{ij}(b_i,x_j)> r_{ij}\end{cases}
\end{aligned}
\tag{1}
$$

where,

x_j : binary variable indicating if an L/U space is located in the available location j

b_i : business i

Q : quantity of L/U spaces to locate

w_i : weight of the business i, given by its frequency of movements of goods

d_{ij} : distance between the L/U space j and the business i

r : radius of influence

n : number of businesses

m : number of possible locations for L/U spaces

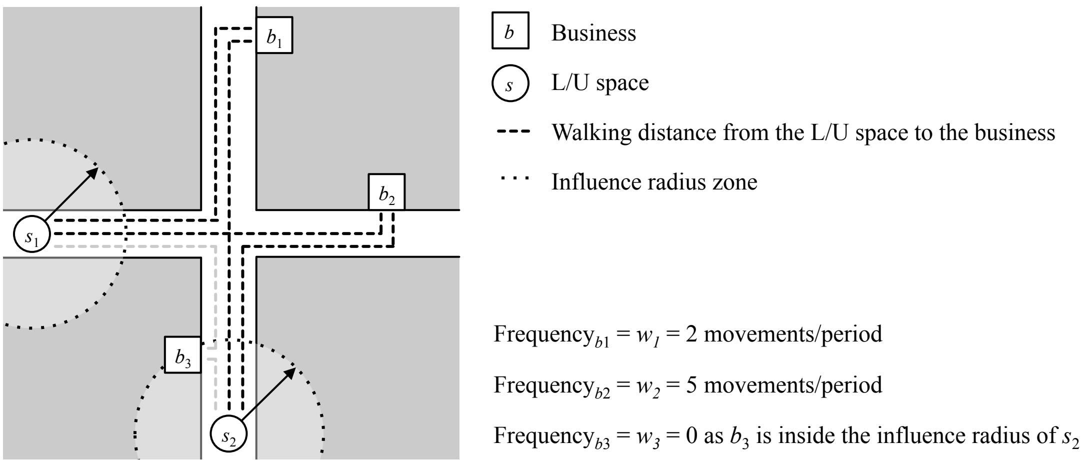

Figure 2. Example of the objective function

In the example of Figure 2, two L/U spaces are located: s_1 and s_2; in order to satisfy the demand of three businesses: b_1, b_2 and b_3.

The weight of each business is given by its frequency of movements per period: w_1=2; w_2=5; w_3=10. The distances d_{ij} between the spaces i and the businesses j are: d_{11}=80m; d_{11}=70m; d_{13}=55m; d_{21}=90m; d_{22}=75m; d_{23}=10m. b_3 is within the influence radius zone of $s2$, as a result its demand is considered as fulfilled (w_3=0). The weighted function of this configuration is:

$$Z = (80 * 2) + (70 * 5) + (55 * 0) + (90 * 2) + (75 * 5) + (10 * 0)$$
$$Z = 1065 \; meters * movements / period \tag{2}$$

Optimization algorithm

The optimization is carried out using a genetic algorithm (GA). This allocation problem belongs to the family of Quadratic Assignment Problems, in which there are a set of facilities and a set of locations. For each pair of locations, a distance is specified and for each pair of facilities a weight or flow is specified. The objective is to assign all facilities to different locations with the goal of minimizing the sum of the distances multiplied by the corresponding flows (Grosnan and Abraham, 2011). This problem is known to be NP-complete (Garey and Johnson, 1979) for which genetic algorithms have proven their performance to provide good solutions in reasonable computation time (Tate and Smith, 1995; Tosun, 2014; Lalla-Ruiz et al., 2016).

Genetic algorithms are metaheuristic methods inspired by the process of natural evolution. They apply the principles of natural selection by "evolving" a population of potential solutions to the optimization problem (Tamayo et al., 2016). According to the evolutionary principles, after a certain number of generations, the solutions of the population will be more and more adapted to the problem. The main steps of a genetic algorithm are:

- Selection: which is intended to keep information from the best individuals, i.e. the solutions that are most likely to reproduce and survive. In our application, the best solutions are the ones that locate L/U spaces closer to businesses with higher logistic demand; the selection operator ensures that such solutions will have more chances of reproducing and surviving.
- Reproduction (crossing): which allows generating new solutions from the selected individuals (parents) by "inheriting" their information. The new solution (son) will have a part of the L/U spaces located in the same places as its father, and the other part in the same places as its mother.
- Mutation: which is applied to randomly modify the solutions. This helps the algorithm in escaping local optima of the optimization landscape. The mutation operator changes the location of one or more L/U spaces in the mutated solution according to a given mutation rate.

These operators have been developed to meet the specificities of the L/U spaces location problem. Figure 3 illustrates the encoding of solutions as well as the operators of reproduction and mutation. In this example there are 18 available spots for locating 5 L/U spaces (m=18, Q=5). The solution "FATHER" locates the new spaces in the spots 2, 6, 7, 13 and 16. The solution "MOTHER" locates the new spaces in the spots 3, 4, 8, 10 and 17. As shown in Figure 3 the crossover operator must combine the locations of the two parent solutions while producing a valid son (i.e. all solutions must have the same number of L/U spaces). The output of the crossover is the solution "SON", that locates the new L/U spaces in spots 2, 6, 8, 10 and 13. Subsequently this solution undergoes a mutation in which some of the locations are randomly changed; in this case the L/U spaces of spots 6 and 13 are relocated to spots 5 and 13 respectively.

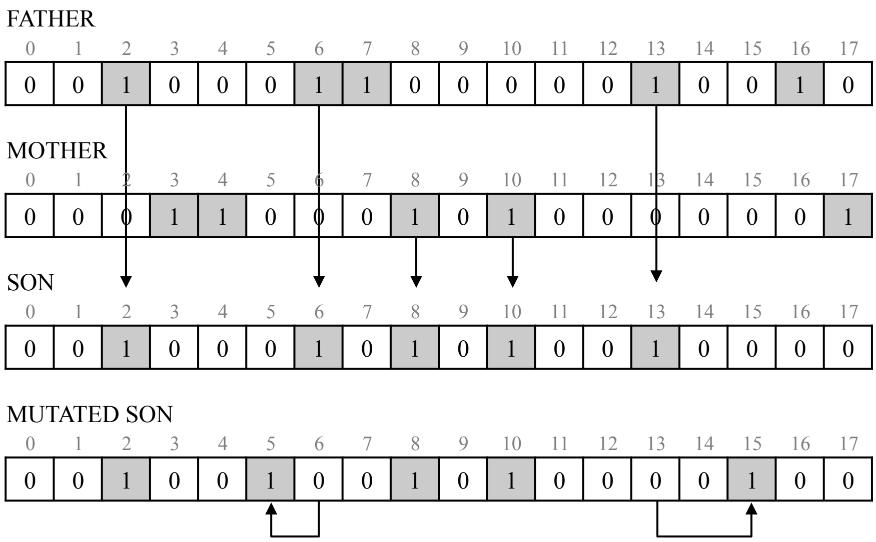

Figure 3. Operators of the genetic algorithm

As individuals with smaller weighted distances are more likely to reproduce, after a certain number of generations the population of individuals converges to the optimal allocation of L/U spaces, as shown in Figure 4. The average weighted distance of the population (in green) varies because of the mutation operator, this variation allows the optimization algorithm to escape local optima and therefore evolve towards better configurations.

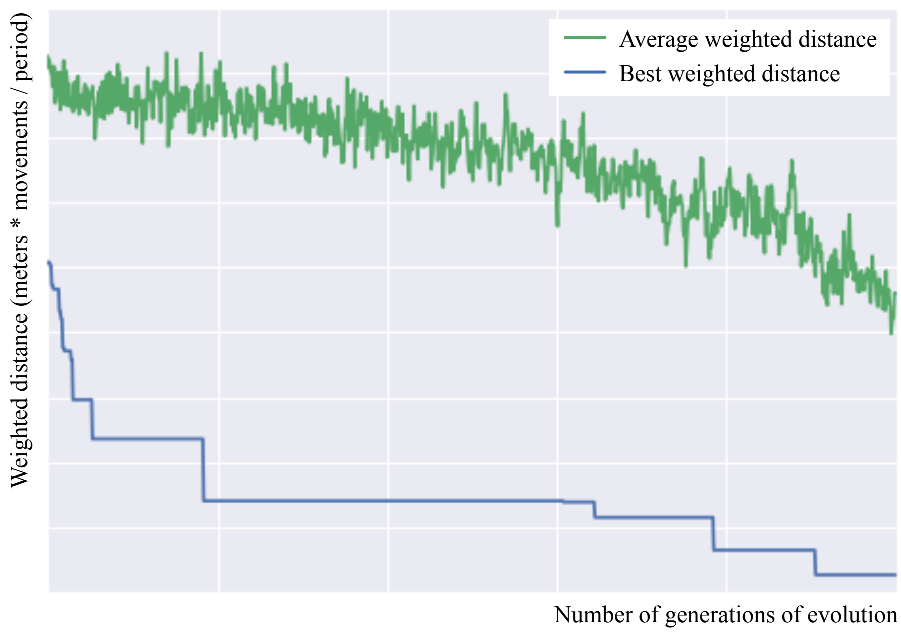

Figure 4. Convergence of the optimization algorithm

Evaluation of existing L/U spaces

In order to evaluate the pertinence of a given set of existing L/U spaces, the following evaluation process is performed:

1. The existing L/U spaces are ignored and optimal localizations are computed for the same number of spaces.
2. A paring function is used to compute the number of “real” L/U spaces within the influence zone of “optimal” spaces. The pairing function measures the distance between each “real” place and the nearest “optimal” place, if this distance is less than or equal to the radius of influence, then the locations are considered to be equivalent and the function validates the pairing.
3. A pertinence indicator P is computed by comparing the validated pairings (i.e. the relevant L/U spaces) to the total number of L/U spaces as follows:

$$P = \frac{number\ of\ validated\ pairings}{number\ of\ existing\ L/U\ spaces} \tag{2}$$

Application And Findings

The proposed framework was applied to the 5th arrondissement of Paris. Three scenarios were explored (1) the location of 10 L/U spaces if there are no prior spaces in the area; (2) the location of 2 new L/U spaces taking into account the existing spaces and (3) the evaluation of the existing L/U spaces in the area.

Data collection and demand generation

OpenStreetMap and Google Maps (Google Places API) have been used to gather the location and the type of businesses (red dots in Figure 5 left). The locations of the L/U spaces are available on the City of Paris Open Data portal (grey dots in Figure 5 left). Google Maps (Google Distance Matrix API) has been used to evaluate the real distances between the businesses and the L/U spaces. The locations of the potential spots for new L/U spaces have been obtained by discretizing the streets in the local area (black dots in Figure 5 right).

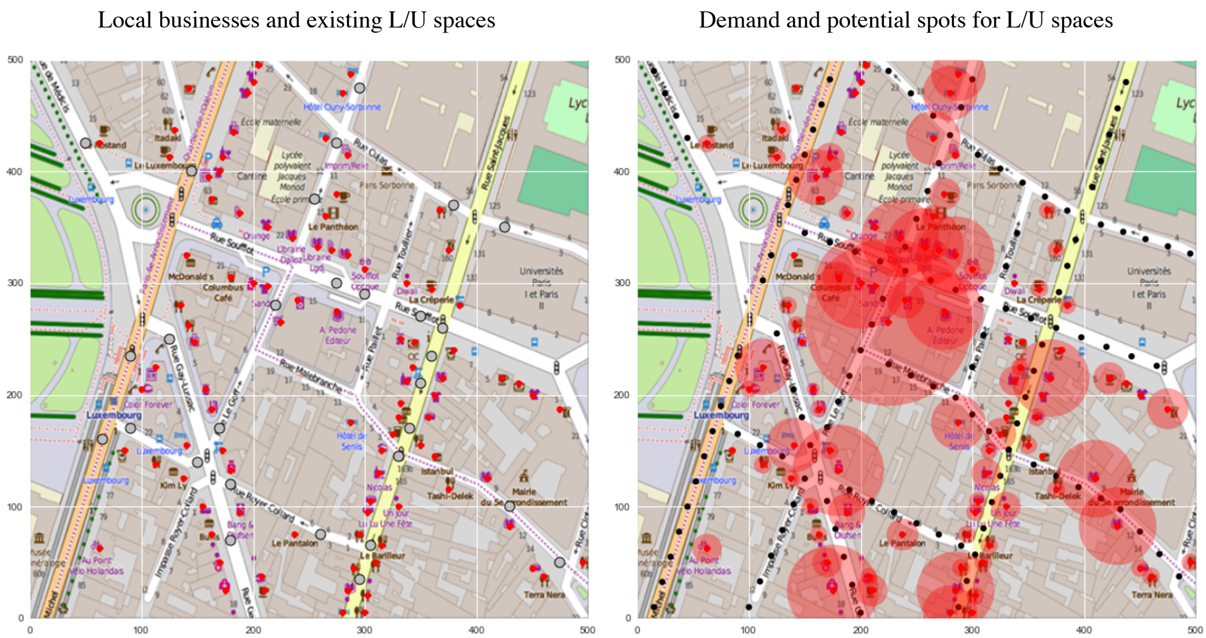

Figure 5. Data collection results for the 5th arr. of Paris

The demand generation was performed by statistic estimation. The report of Allen et al. (2008) was adapted to the City of Paris and such adaptation was used to assess the number of movements per week for each type of business. It is important to note that the obtained frequencies are similar to those indicated in the CERTU method. Authors chose to use Allen et al. (2008) as the diversity of businesses characterized was more relevant. In Figure 5 (right) the halo around each business represents its logistic need. At this point it is easy to have a rough idea if actual L/U spaces are well located.

On-site survey showed that none of the businesses in the area had a private L/U space. If it were the case, as the logistic need would be fulfilled, the weight of establishment would be marginal (see equation 1). On-site survey also revealed that the information gathered about almost every business and L/U spaces were correct.

Given the characteristics of this area of Paris, only on-street L/U spaces have been considered. For this purpose, the streets have been discretized in order to propose candidate locations. The discretization was set to one L/U space every 20 meters along a street (this density of possible spots is a parameter that can be modified if need be). In order to better fit to the specificities of each urban area, it is possible to remove candidate locations (e.g. in front banks, next to police stations, etc.) or to add candidate locations (e.g. off-street L/U spaces). For the use cases given hereafter, the radius of influence was set to 50 meters. This assumption is made to imply that drivers will use L/U spaces if they are less than a half a block away from the delivery points.

Location of 10 L/U spaces if there are no prior spaces in the area

This use case considers the location of 10 L/U spaces in an area where no L/U space yet exists. The algorithm considers the original demand (Figure 6 left); it aims at finding the optimal locations of 10 L/U spaces. The white circles indicate the pseudo-optimal locations for this urban zone (Figure 6 right).

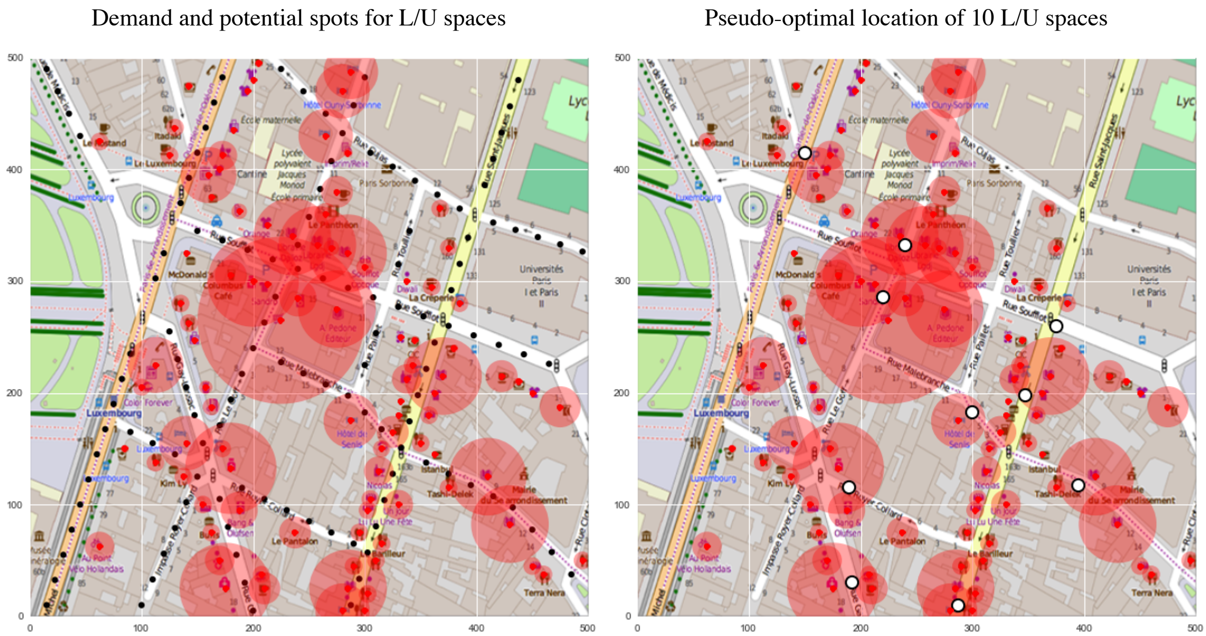

Figure 6. Location of 10 L/U spaces

The obtained locations are coherent to the logistic need of the area, i.e. they are in the hot areas in terms of frequency of movements. It is interesting to note that the calculation time for this optimization is very low (these results are obtained quasi-instantaneously).

Location of 2 new L/U spaces taking into account the existing spaces

This use case explores the problem related to the creation of new L/U spaces while considering the existing ones. As there are L/U spaces in the area, the demand of some businesses is already fulfilled (i.e. the business is within the radius of influence of at least one space); therefore such demand is not considered for the optimization (see Figure 7 left).

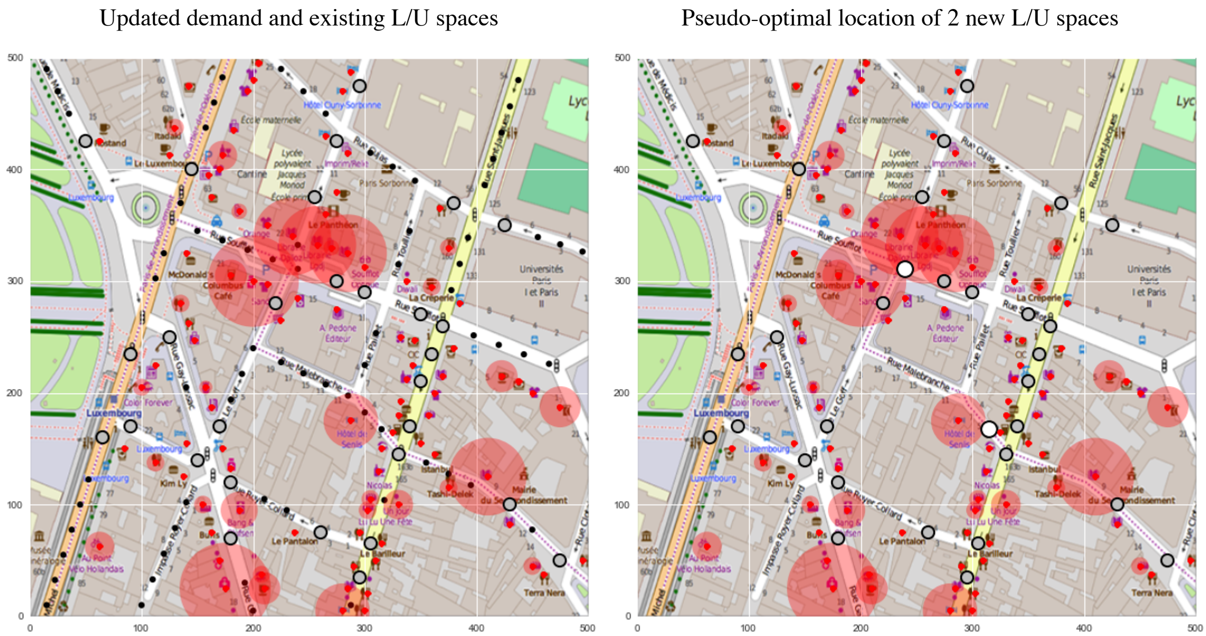

Figure 7. Location of 2 new L/U spaces taking into account the existing spaces

The 2 new L/U spaces seem to be appropriately located (Figure 7 right) as they are placed in high demand zones. These results are encouraging as they allow to better meet the needs of an evolving area that can show a given growth in terms of commercial activity.

Evaluation of the existing L/U spaces in the area

This use case considers the evaluation of the 29 existing L/U spaces in the area of interest (grey dots in Figure 8 left). In order to evaluate the relevance of these "real" spaces, the optimization model is run to locate the same number of spaces without taking into account the existing ones (as done in the first use case). Subsequently, a pairing function is used in order to identify the equivalent L/U spaces, i.e. those within the radius of influence of the pseudo-optimal ones. The validated pairings are shown in Figure 8 (right).

The pairing function returns 22 equivalent L/U spaces. This information is used to compute the pertinence indicator as follows:

$$P = \frac{22}{29} = 76\%$$

This result shows that most of the existing L/U spaces are mostly well located. In fact, most of them are within (or close to) the hot areas in terms of movement frequency. Nonetheless it is important to highlight that the pertinence result does not necessarily indicates that the existing L/U spaces satisfy exactly 76% of the logistic need of the area. This result gives only a rough representation of the correspondence between the existing infrastructure and the pseudo-optimal configuration given by the optimization algorithm. Moreover, it is to note that the pertinence result depends highly on the radius of influence, which in this case was set to 50 meters (roughly half a block). Such radius can be considered larger or shorter depending on the parking behaviour and the sanctioning policies in place.

Existing L/U spaces and pseudo-optimal locations | Result of the pairing function

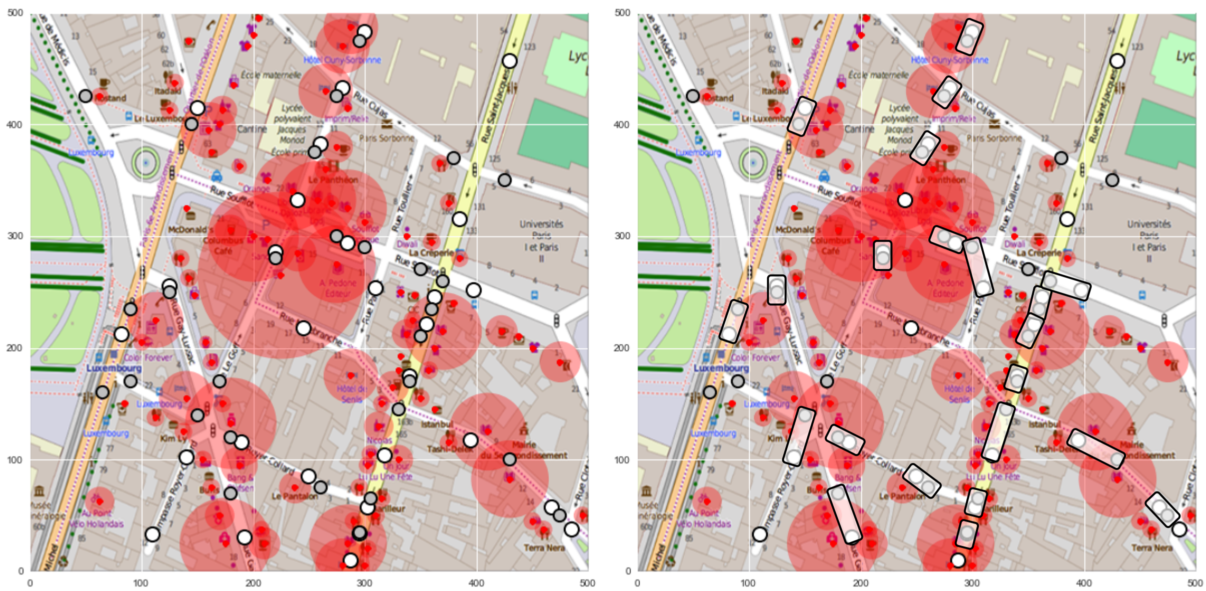

Figure 8. Evaluation of the relevance existing L/U spaces in the area

Conclusion

This paper proposed a framework for evaluating and optimally locating L/U spaces in urban areas. The framework is divided in three parts, namely: (1) data collection, in which relevant information about the urban area is gathered from online cartography services, APIs and Open Data portals; (2) demand generation, in which the logistic need of each business is estimated form its frequency of movements of goods and (3) optimization model, in which the location of the existing L/U spaces can be evaluated, or new spaces can be optimally located.

This paper opens the way to use new information tools for a rather old problem. First, a survey revealed that the information available online is a good representation of the reality of this area. Second, despite the algorithm's simplicity, the application shows that the framework proposes coherent results. It is a promising result for the development of more sophisticated algorithms.

The proposed framework was designed to embody simplicity, openness and flexibility. As the framework is simple, decision-makers (particularly local authorities) can easily apply it to other cities. The openness of the framework allows actors to enhance it and provides easy access to the statistic approximation data. The flexibility of the framework admits the use of exhaustive information, if available, but it can also operate if less information is provided. E.g. the demand generation can be performed by a local survey (exhaustive information) or can be estimated (non-exhaustive information).

The framework has been developed from a local authorities' perspective, which aim at finding an optimal trade-off between sustaining the commercial dynamism (i.e. provide L/U spaces close to local businesses) and cope with the scarcity of parking surfaces. This approach allows decision-makers to satisfy the constraints regarding the quantity of L/U spaces in accordance to the local parking management policy (i.e. preserve some residential parking, provide disabled parking, etc.), while permitting the optimal location of the L/U spaces in terms of commercial dynamism.

There are three strong hypotheses in the proposed framework. First, the model for the location of L/U spaces is fairly simple for it assumes that carriers will park in the L/U spaces in a given influence radius; double-parking is not studied and L/U spaces sizes are not considered. Second, the demand generation is quantified on a weekly average basis. However, previous studies show that urban freight has peak hours during the day (Muñuzuri et al., 2010; Allen et al., 2008). As a result, the proposed estimation of "frequency of movements" lacks the necessary level of detail to model situations such as simultaneous arrivals at a single L/U space, which could happen during peak hours. Third, the size of the businesses has a significant impact on the frequency of movements, which is not yet considered..

As a perspective, upcoming versions of our optimization model should take into account double-parking as well as L/U spaces sizes. Moreover, the next stages in the data collection will explore the possibility of quantifying the parking demand during the different hours of the day. This will allow a better location of L/U places and could set the cornerstone for future models of dynamic allocation of L/U spaces. Moreover, further versions of the framework should take into account the size of the businesses in the demand generation.

Another interesting perspective of this work would be a large-scale application to a metropolis. Such an application would undoubtedly generate interesting results to understand the needs of the different sectors as well as the quality in the location of the existing L/U spaces.

The proposed tool yields partial solutions to a rather complex problem. It is clear that the pseudo-optimal solutions generated by the model lack of detail and could integrate other optimization criteria. However, it should be remarked that the framework presented here allows the integration of different sources of information and helps in tackling, at least in part, the heterogeneity of the urban movements. Indeed, the use of collaborative information opens up passionate perspectives towards integrating the complexity of the urban logistics ecosystem.

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