Evaluate the viability of Urban Consolidation Centre with regards to urban morphology

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Abstract

City logistics is a difficult topic for public decision makers who often lack relevant information and knowledge to make their decisions. Among all available solutions, Urban Consolidation Centre is an appreciated one. Indeed, it is supposed to reduce pollution, trucks’ congestion and to improve the livelihood of city centre. Nevertheless, it is far from obvious that UCC are efficient and viable. The aim of this study is to provide answers to two questions: can an UCC be viable? Does the shape of a city affect the profitability of an UCC? We present a preliminary work based on a comparison between three morphologies to give some clues.

Keywords: Urban Consolidation Centre; Profitability; City Logistics; Economic Assessment

1. Introduction

More than 20 years ago, Ogden (1992) already pointed out the necessity to elaborate sustainable urban freight transport policy to face the urbanization. Nowadays, city logistics is becoming a strategic, but always under-used, lever to urban development. Indeed, although a small part of complex supply chains, this last link can represent up to 28% of the total transport cost (Roca-Riu and Estrada, 2012). Moreover, air pollution emissions related to urban freight transport are estimated between 16% and 50% of the overall pollution made by transport activities in a city.
Unfortunately, as mentioned in the OECD report (2003), among more than 200 experiments in Europe, only 15 UCC European cities to deal with city logistics issues (Chwesiuk et al., 2010; Van Duin and Muñuzuri, 2015). The choice for a given business model (i.e. commercial links with stakeholders, market segmentation and pricing) has been pointed out as a cause of successful/failure (Armand et al., 2013; Gonzalez-Feliu et al., 2013). That is why some researchers carried out economics analysis using costs/benefits exploration or other methods (De Assis Correia et al., 2012; Quak and Tavasszy, 2011; Van Duin et al., 2008) to anticipate the impacts of business models onto profitability.

Kawamura and Lu (2007) proposed a new way to evaluate the viability of UCC by using Continuous Approximation models. Based on the logistics analysis described by Daganzo (2005), they developed an approach to calculate per items costs in the case of UCC in the United States. More recently, they proposed an extension of the problem and applied it on larger markets (Chen et al., 2012; Lin et al., 2014). The approach used is able to find tipping point in a comparative point of view. Indeed, they compare two situations: one without consolidation and one with consolidation. They obtained interesting results showing, e.g. the minimum customer demand, customer density or load factor, to reach the cheaper logistics costs. However these mentioned studies are in an US context which is different from the European context, especially for size of flows and capacities of warehouses. That is why Roca-Riu and Estrada (2012) have conducted a similar study in the European case of Barcelona.

In this study, they attempt to check the viability of UCC by exploring if a delivery through the UCC is more economical for each involved actor than the current direct delivery. The aim is to provide a help for predicting the minimum number of contributing carriers to ensure the feasibility of the project. Finally, such studies provide interesting information about the opportunity for transport companies to join collaborative network such as UCC. However, in the competitive and rigorous context of urban delivery, a new organisation has to determine sale price with regards to the market. Thus, at the beginning of the activity, a risk exists in the economic viability of this organisation which has to catch flows to grow. That is why it seems important to complete the information given by Roca-Riu and Estrada (2012) and Lin et al. (2014) with an operational approach. Actually, we suggest looking at the inbound costs of UCC to answer a first question: Can an UCC be viable in a European middle-size city?

To go further, we would like to identify some keys of the economic results of an UCC. We observe in the literature that UCCs known as viable have always some specific particularities often related to the morphology/geometry shape of the city centre: Monaco is completely isolated; Parma owns a tight historical centre with constraints on accessibility, etc… Thus, one may wonder whether the shape of a city is an important clue for successful/or failure of UCC. That is why we propose in this paper to assess the influence of urban morphology on the economic viability of UCC in a medium-size city. In the rest of the paper, urban morphology and shape will be used as synonym. It represents the shape formed by delivery points when looking at a large scale the city centre.
The paper will be organized as follows. The first section introduces the methodology developed and used in this paper. Then the second section presents the chosen case study and hypothesis made on. Results of these cases are presented and discussed in the third part of the paper. Finally, the latest section provides conclusive remarks and opportunities for further research.

2. Methodology

2.1. Overview of the methodology

The approach used is composed of four steps (see Fig. 1). First of all, we generate instances of virtual city configurations (step 1) that means description of city, number of delivery point, configuration of road network, etc…. Then, the Vehicle Routing Problem (VRP) is solved to determine each round (step 2). The aim of this step is rather to find a feasible solution close to drivers' behaviour than any optimal solution. The third step is the assessment of an economic model computing the profitability of the tested solution. Finally, some levers to improve this viability are identified and proposed (step 4). In this paper, we choose to focus the attention on the third step, which concerns the economic model, although step 1 and 2 will also be used.

2.2. The developed economic model

Our economic model is based on the observation of the logistics costs to operate a UCC in real life. That means that we adopt the point of view of an UCC’s manager. To do so, we focus on logistics operations made by the delivery-driver: from the loading/unloading of freight at the UCC to the trip back after the round. The study of these different steps in the working day of delivery-drivers gives elements to calculate the margin rate obtained by UCC each month. This is the chosen Key Performance Indicator to assess the profitability/viability of UCC.

The margin rate (equation (1)) is defined as the difference between revenues (equation (2)) and the sum of fixed costs (equation (3)) and variable costs (equation (4)). Equation (2) describes revenues. It depends on the sale price per parcel and the number of delivered parcels per day. To calculate fixed costs (equation (3)), we decide to consider a situation where UCC does not own the warehouse, vehicles and software. That is why these costs are composed by rent costs for these three parameters. This assumption is based on the observation of Saint-Étienne’s UCC (Saint-Étienne is a medium-size city in France) and matches the reality of numerous small and young organizations. Number of employees and vehicles are reported as fixed costs, although varying step by step so as to meet the required capacity to deliver all the parcels. Finally, variable costs (equation (4)) depend on the energy cost and the total travelled distance. No cost for wear of tires is considered because vehicles are rent so this is included in the rental contract.

Fig. 1. The proposed approach
\[ \text{Margin rate} = \text{Revenues} - (\text{Fixed costs} + \text{Variable costs}) \]  

\[ \text{Revenues} = \left( \frac{\text{Sale price}}{\text{Parcel}} \times \frac{\text{No. of parcels}}{\text{Position}} \times \frac{\text{No. of positions}}{\text{Stop}} \times \frac{\text{No. of stops}}{\text{Working day}} \times \frac{\text{No. of working days}}{\text{Month}} \right) \]  

\[ \text{Fixed costs} = \left( \frac{\text{Cost of vehicle rent}}{\text{Month}} \times \frac{\text{No. of vehicles}}{\text{Delivery driver salary}} + \frac{\text{Cost of platform rent}}{\text{Month}} + \frac{\text{Cost of software rent}}{\text{Month}} \right) \times \frac{\text{No. of delivery drivers}}{\text{Month}} \times \frac{\text{No. of logistics coordinator}}{\text{Month}} \]  

\[ \text{Variable cost} = \left( \frac{\text{Energy cost}}{\text{km}} \times \frac{\text{Distance}}{\text{Working day}} \times \frac{\text{No. of working days}}{\text{Month}} \right) \]  

As mentioned then, each cost is calculated per month. To do so, we defined a “typical day” which is generalized within a month. This approach is used to obtain values that economical partners can easily understand. Also, it is a common scale to compare results and build forecasts.

It is interesting to observe more precisely equation (2) which calculates revenues. Actually, the number of delivered parcels per day is split up in three ratios: the number of parcels per position, the number of positions per stop and the number of stops per working day. We distinguish concepts of position and stop. A position can be considered as clients whereas a stop is a place where vehicle stops to deliver several clients who can receive several parcels. These ratios can be called “pooling parameters”. They represent levers of profit for an UCC compared to carriers.

Among these parameters, we note two categories: the exogenous parameters and internal parameters depending on the logistics organization of the UCC. The sale price and the energy cost are some exogenous parameters defined by the market’s law of each city. Numbers of parcels per position or position per stop as well as the total travelled distance are consequences of the geography of the city and cannot be chosen by the board of the UCC.

On another hand, numbers of stop per day or employees are the result of board’ choice and so are internal parameters. Obviously, there are linked with the external parameters, but they also result from the strategy of the logistics coordinator.

2.3. Paper focus

In this paper, we focus on steps 1 to 3 of the methodology described in Fig. 1. Indeed, the fourth step can be seen as a second level in the approach: first the instance is assessed, and then some levers are identified and suggested to improve the performance. The economical evaluation is a crucial stage for it gives decisive information about the viability of a given UCC. An application of the methodology with a particular focus on the fourth step is available in Faure et al. (2015).

In this study, we aim at answering two questions: Can an UCC be viable in a medium-size city? And, can the shape of a city influence the viability of an UCC? That is the reason why we choose comparing three particular but typical shapes of city centre. The next paragraph presents the selected shapes as well as the different hypothesis that we made in the case study.
3. Cases study

3.1. Selected configurations

As the main question of the paper is to validate, or not, the assumption that the shape of the city can influence the viability of UCC, we decide shaping three theoretical cities representing city centers of medium-size cities. The general idea is to overstate the point to observe impacts. Of course it is a first study so cases should become more refined in future papers.

Among medium-size cities all over the world, we isolated and assessed three stylized geometrical configurations: circular shape, rectangular shape and elliptical shape (see Fig. 1).

3.2. Hypothesis

3.2.1. About the geometrical configurations

The morphologies that we study have to be comparable. To do so, we choose designing a 2km*2km grid served by a road network. The road network is based on a regular 20m*20m grid independently of the considered morphology. In this first approach, every way in the network is a two-way street. Then, inside this 4km$^2$ grid, a 1km$^2$ area is materialized to model the city center we want to study. All the considered morphologies have the same area (1km$^2$) and only differ due to the shape of the rim of each city.

Inside this area, one UCC is located at the west of the city (purple star in Fig. 2) and 50 delivery points are generated in a first time. Each point is characterized by a number of parcels, an average weight and average volume and corresponds to a stop in the economic model. That means that when 50 stops are designed, much more than 50 clients are actually delivered (approximatively 150 clients).

The number of required rounds is calculated thanks to vehicles’ capacity and quantities of goods to be delivered at each point. Concerning instances, several geometrical configurations for each morphology have been generated so as to get statistical results and also to avoid a bias due to repartition of points in the considered area. This study is based on the evaluation of 10 instances for each type of shapes.

3.2.2. About the economic model

We had to attribute numerical values to each exogenous and internal parameter of the model. To obtain realistic results we used some data concerning the functioning of the UCC of Saint-Etienne. For example, we had to define...
the number of delivery drivers to deliver all the parcels. Thanks to data from Saint-Etienne, we tuned the model to 1 delivery driver and so 1 vehicle can make approximately 3 rounds.

In this study, electrical vehicles are considered. So, the cost of energy is defined by the product between the price per kWh and the energy consumption of the vehicle and is equal to 0.0345€/km (calculated as: 0.07€/kWh*0.50kWh/km).

Other assumptions concern the sale price and salaries. A benchmark around the region of Saint-Etienne has been made and the sale price vary between 0.80€ and 1.5€. To play it safe, simulations are made with a sale price of 1€ per parcel, whereas salaries are based on the current French regulations and market.

Moreover, the UCC is supposed to be open 21 days per month.

Next section describes the results obtained when assessing the economic model.

4. Results

As describe in Fig. 1, to make the economical assessment we had to solve Vehicle Routing Problem. To do so, we choose applying a two-steps algorithm. First, shortest path between each point of the graph is calculated using Dijkstra’ algorithm. Then rounds are made by choosing the closest neighbour as long as capacity of vehicle is not reached. For each round, the first and the latest delivery point are the UCC. The used algorithm does not give the optimal solution but a feasible and ordered solution that we consider as fair enough to compare different shapes. In order to not overdo the paper with figures, only an illustration of one instance for the circular morphology is represented in Fig. 3. The difficulty to solve our problem was not the VRP solution but the transformation of a real road network to a VRP graph (with node and oriented curves). More details about this work are available in the paper of Azami et al. (2015). Finally, the VRP solution provides total travelled distance for each instance.

The first analysis that we made is based on the study of this total travelled distance per day. The average number is calculated for each shape. We observe a difference between the three geometrical configurations. Indeed, the total travelled distance is longer for the rectangular shape than for the elliptical and circular shapes (see Fig. 4). This can be explained when looking at the composition of this distance. We distinguish two types of distance which composed the total travelled distance: the inter stops distance and the approach distance. This last one is calculated by addition of the distance between UCC and the first stop and distance between the last stop and the UCC.
We note that inter stop distances are almost the same apart from the shape whereas the difference is made by the approach distance. This can be explained: the density is nearly the same in each shape because we choose an equal-area and an equal stops’ number. The rectangular shape is penalizing because stops are more and more far away from the UCC. Finally, more extensive the area is more the approach distance will be high.

These observations introduce the necessity to look at the impact of this difference on the cost. We evaluate for each instance the economic model. It appears that variable costs (equation (4)), which directly depend on the travelled distance, are insignificant on the margin rate (equation (1)). Indeed, its only depends on the energy cost which is extremely low in comparison with fixed cost (equation (3)) and revenues (equation (1)). Finally, for a fixed number of delivered parcels, we can conclude that the margin rate’ difference between shapes will not be due to the increase of variable costs but of fixed costs. That is the reason why the contributing margin’s (red curve on the Fig. 5) is the same for each shape. The contributing margin is defined as the difference between revenues and variables costs.

Actually, fixed costs are depending on the number of delivery drivers who are required to meet the demand. This number is calculated thanks to two parameters: the total time of one round and the working time of one delivery driver. We assume that working time is fixed whereas the time of one round can be impacted by several external constraints as the congestion, the speed or the distance. Thus, it is obvious that the number of drivers will be influenced by the total travelled distance. Finally, the difference between shapes comes from the risk to need one more delivery driver to deliver the same number of parcels. Moreover, this observation is interesting in a context where some carriers compete to obtain bigger revenues whereas it means more fixed costs. In fact, it shows the necessity to anticipate and to calculate correctly the additional cost implied by this decision. We illustrated this phenomenon drawing the evolution of fixed costs on a month depending on the number of delivery parcels per day (see Fig. 5). To do so, we increased sequentially the demand (the number of delivery parcels per day) and assessed the economic model for each point. Finally, we obtained two curves: the contributing margin (linear) and the fixed costs (evolution by steps). The shape of each curve is discussed in details in Faure et al. (2015).

The blue curve represents the fixed costs per month for the circular and the elliptical shapes. These costs are the same because the difference of total travelled distance is not long enough to require more (or less) drivers for the same number of parcels. The green curve shows the fixed costs’ evolution in the case of the rectangular shape.

We can see that for the same number of parcels (ex: 1000) the rectangular shape requires more drivers than circular and elliptical (in the given example 6 vs. 4). Moreover, the breakeven point, which corresponds to the cross of curves of contributing margin and fixed costs, is achieved faster, i.e. less parcels to deliver in a day, in the case of circular and elliptical shapes. Even if inter stops distance is almost the same in each case, the rectangular shape is more expensive than others because of the bigger approach distance. Finally, this shape is less easy viable than the two others. Indeed, the margin rate is negative whereas it is equilibrium for elliptical and circular shape.
5. Conclusion

Of course, it is difficult to provide definite results about the impact of the shape because a lot of indirect parameters also play a role (vehicle speed or congestion…). Nevertheless, an UCC can apparently be viable under some given conditions (the number of delivery parcels, the approach distance and so the urban sprawl…). Moreover the morphology of the city could influence somehow the performance of UCCs.

However, we highlight the fact that productivity efforts shall address fixed costs rather than variable costs, and that viability is a thin equilibrium subject to variations due to small perturbations such as disturbance on activity level.

Several extensions of this preliminary research are currently in progress. First of all, a sensitivity analysis of the model should be conducted to quantify the impact of each parameter and validate the stability of the model. Then, the location of UCC should be discussed and tested. The current obtained results seem to show that the location strongly affects the efficiency. Another interesting question to solve is the number of required UCC. Indeed, we can imagine placing UCC all around the city so as to create proximity rounds and reduce approach distance. Finally, it is certainly useful to study the influence of demands quantity and location on the viability of UCC. Can we found situations where UCC will never be viable?

The work presented here participates in providing information in the beforehand phase of an ANR project (French Agency for the Research) related to freight distribution called ANNONA. In future work, other urban contexts will be simulated. More precisely, this method will applied to actual city centres with accurate traffic flow numbers. The prototype will be transformed into a more sophisticated decision support system to obtain accurate ex ante assessments of city logistics actions impacts and to be used by researchers and urban decision makers alike.

Acknowledgements

A part of this work has been financed by the French Agency for the Research (ANR) as a part of the ANNONA project.
References


