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Strategic scenarios for sustainable urban distribution in the Brussels-capital region using urban consolidation centres

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Abstract

This paper describes a methodology that was used in order to establish strategic scenarios for city distribution of goods in the Brussels-Capital Region (BCR) using Urban Consolidation Centres (UCCs). Recently, UCCs received a lot of attention as a solution to decrease the environmental impact of urban freight transport in the Brussels-Capital Region. However, despite the growing interest from both public and private actors, many questions regarding their practical implementation remain. In fact, there are a large number of uncertainties with regards to the implementation of the consolidation scenarios, such as the number, location and size of the UCC(s), the vehicle fleet, the regulatory and market framework or the operational agreements. This leads to a large number of possible scenarios. In this paper, authors describe a scenario-planning methodology that was applied in order to select a limited number of scenario themes. Authors present several quantitative models that were used to evaluate possible scenarios and select the most relevant ones.

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Keywords: urban freight transport; urban consolidation centres; scenario planning; strategic planning

1. Introduction

The Brussels-Capital Region (BCR) is increasingly aware of the negative impacts of freight vehicles on the urban welfare. Vans and trucks were indeed estimated to be responsible of a third of fine particles generated by the transport sector and of a fourth of CO_2 emissions (Lebeau and Macharis, 2014). They account also for 14% of the vehicles on the road. Given the important contribution of these vehicles on mobility, air quality and climate change, different type of solutions have been planned by the authorities in their strategic plan for urban freight transport in

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the BCR (Bruxelles Mobilité, 2013). Among others, the Urban Consolidation Centre (UCC) receive a specific attention in that plan. It has been one of the most investigated solutions in the Region. Several research papers (Hubert et al., 2008; Debauche and Duchateau 1998; Van Mierlo et al., 2004) have indeed addressed the implementation of a UCC in Brussels. Recent years have also seen some concrete steps, with the setting-up of several small UCCs in the region, run by private companies. Still, regional authorities require more insights in the possible future developments. In order to take decisions, they must address a large number of questions such as: (1) how many consolidation centres are necessary to service the Region? (2) what is the optimal size and location of these centres? (3) what part of the freight demand are they likely to capture? (4) is their operation possible without public subsidies? (5) what is the impact of other accompanying measures on their development? (6) what are the environmental impacts of such schemes? (7) what type of vehicles are best suited? (8) how will the urban stakeholders respond to different policy options? The multiplication of options leaves the decision-makers in front of a large number of uncertainties and dimensions of analysis. Hence, the paper has the objective of giving a method to tackle this complexity. A scenario-planning methodology is described and applied on the case of the BCR in order to select a limited number of scenario themes that can be evaluated. The different quantitative models that support that methodology are also presented.

2. Methodology

The methodology that was used for constructing strategic scenarios is scenario planning and comes from the field of strategic planning. Scenario planning is a systematic methodology method for designing possible futures that simplifies the avalanche of data into a limited number of possible states (Schoemaker, 1995). It differs from other planning methods as contingency planning which examines only one uncertainty and the sensitivity analysis that examines the effect of a change in one single variable (Schoemaker, 1995). According to Chermack et al. (2001), the two academic approaches most often cited in the field of scenario planning are those by van der Heijden (2011) and Schoemaker (1995)). Although different scenario planning approaches differ in their details, they share certain characteristic process steps (Wulf et al., 2010): (1) Definition of the scope; (2) Perception analysis; (3) Trend and uncertainty analysis; (4) Scenario building; (5) Strategy definition and (6) Monitoring. Scenario planning is an iterative methodology, but for better reader comprehension, this article will be structured around the subsequent steps. The article focuses on the first four steps of the process that lead to the elaboration of strategic scenarios. In the fifth step ("strategy definition"), public stakeholders can use results of the scenario building and evaluation to define and communicate a proper strategy in terms of public policy required to promote the shift towards the optimal scenario, while private stakeholders can use these results in order to anticipate market developments and adapt their business strategy. The last step of the scenario building methodology ("monitoring") corresponds to the development of performance measurement system with specific KPIs that allow overseeing the implementation of different strategies.

We will now address each of the first four steps of the scenario building methodology and explain their application to the particular case of scenarios for sustainable urban distribution in the BCR using UCCs.

2.1. Definition of scope

The first step of the scenario-planning methodology is the definition of the scope that sets the foundation for the analysis and strategy definition phases by specifying important characteristics for the scenario planning project such as the time frame, the commodity type and the market segment, geographic area or scope of analysis (Wulf et al., 2010; Schoemaker, 1995; Van der Heijden, 2005).

We will delimit the scope of scenarios using the following elements: (1) which types of UCCs are to be considered for the strategic scenarios? (2) which market segments are to be targeted by the UCCs in the BCR? (3) which is the geographical coverage of UCC services? (4) what is the time frame of the implementation of the strategic scenarios?

2.1.1. Type of Urban Consolidation Centers

Allen et al. (2012) describe three generic types: (a) UCCs serving all or part of an urban area (b) UCCs serving large sites with a single landlord (c) Construction project UCCs. Scenarios presented in this paper focus on the first type of UCCs, i.e. UCCs serving all or part of an urban area since the two latter types of UCCs should be established on a case-to-case basis.

2.1.2. Market segments

UCCs are likely to be better suited to some types of goods and vehicle movements than others (Browne et al., 2005). In order to define relevant market segments, we will discuss the product/commodity type and the supply chains that are best suited to the UCC concept.

The product/commodity type has been found to be an important explanatory variable in almost all the freight transportation choices (Holguin-Veras, 2002; Holguín-Veras et al., 2008). First of all, the product/commodity type determines the way in which the cargo is handled (Holguin-Veras, 2002; Holguín-Veras et al., 2008). Several authors (Boudouin, 2006; Browne et al., 2005; Panero et al., 2011; Van Duin, 2009) find that UCCs are not suitable and cannot handle all types of products. Indeed, it is difficult for a single centre to be able to handle the wide range of goods moving in and out of an urban area, for example due to different handling and storage requirements (Browne et al., 2005). For this reason, most of the existing UCCs have started by distributing only parcels, as this doesn't require specialized handling - although sometimes additional types of goods are handled by the UCC, either when it has proved successful, either in order to increase its volumes and reduce operating deficits (Panero et al., 2011). Secondly, the product/commodity type can be seen as a proxy for the market segment and the behaviour of actors and as such will have a major importance in the carriers' decision to use the UCC (Holguin-Veras, 2002; Holguín-Veras et al., 2008). The empirical evidence with regards to the type of products that could benefit from the UCCs is however scattered, such as observed by Danielis et al. (2010), in a literature review that presents several studies on the subject. A detailed study performed for the city of Mestre, Italy (near Venice) evaluating the possibility to adopt a UCC scheme similar to Padua, concludes that they are likely to be clothing, specialised retails and dry food (Danielis et al., 2010). A survey among 118 retailers in Broadmead Bristol in the VIVALDI project found that the most suitable goods for the UCCs were of medium size, non-perishable, and not of high value (Hapgood, 2005). Marcucci and Danielis (2008) find that clothing and other specialised goods other than food are most likely to accept to use the UCC, while Ho.Re.Ca is more unlikely to use it. With regards to these elements, Danielis et al. (2010) conclude that pharmaceutical products and fresh food will not make use of a UCC, while clothing and footwear and Ho.Re.Ca, especially when supplied via own-account, might accept to use a UCC. Another study performed in Manhattan and Brooklin by Holguín-Veras et al. (2008) shows that food carriers (with exception of large food carriers), chemical carriers, household good carriers, textile carriers and plastic carriers are inclined towards using the joint delivery services. Finally, Panero et al. (2011) summarize some generic limitations to the type of goods that can be consolidated in UCCs: (1) perishable goods (with some exceptions such as Stockholm UCC which can handle cold foods, Heathrow airport UCC which has chilled and frozen facilities and one of the two UCCs in Siena (Italy) which is specialized in food products); (2) heavy and bulky goods which are not suitable for certain types of vehicles used by the UCCs and (3) high-value products whose transhipment is often prohibited by insurance companies. With regards to these elements from the literature, the strategic scenarios for urban distribution in the BCR will therefore focus on goods that do not require special holding conditions, are of medium-value and are transported in form of parcels or pallets.

With regards to the type of supply chains, Routhier et al., (2001) characterize the supply chains of urban goods movements with regards to the activity sector (small retail, wholesale, handcraft and services, supermarkets, industry, transport and warehouses, offices and agriculture) and the type of transport management mode (own account shipper, own account receiver or hired transport). With regards to the type of activity sector, Browne et al. (2005) find that the biggest potential beneficiaries of the UCC are retailers who are not part of supply chains in which deliveries are already highly consolidated at distribution centres, and/or are receiving full vehicle loads. Major supermarkets and similar outlets who operate their own stock consolidation centres are not envisaged as being beneficiaries of UCCs since they essentially transfer full vehicle loads (Browne et al., 2005). A similar conclusion can be taken for the industry, transport and warehouses and agriculture activity sectors. On the other hand, handcraft and services and offices can be suitable goods to be handled by a UCC since they mostly receive parcel deliveries. Browne et al. (2011) present a micro-consolidation centre that is focused on delivering office equipment and Janjevic et al. (2013) confirm that office supplies and equipment are a relevant sector for micro-consolidation initiatives. A similar conclusion is made by Belouannas (2014) that concludes that retail, offices and crafts and services are all relevant for the use of a UCC in Saint-Etienne (France). The wholesale sector is not typically considered to be a potential beneficiary since wholesalers tend to provide themselves consolidation services (Browne et al., 2005). However, the acid test will be whether or not the final deliveries are so geographically focused that a high vehicle utilisation for a specific urban centre can be achieved (Browne et al., 2005). Moreover, there seem to be some empirical evidence of wholesalers being users of UCCs such as in Aachen (Browne et al., 2005) and in Brussels (information gathered during an interview with regional transport authorities). With regard to these elements, the following activity sectors will be considered for the strategic scenarios in the BCR: small retail, offices, handcraft and services and wholesale.

With regards to the type of management, Browne et al., (2005) performs an extensive review of 67 UCC schemes in the world and mentions UCCs that are used by carriers (e.g. Tenjin, Kassel, Basel, Tokyo, La Rochelle, Monaco, etc.) or shippers (e.g. Munich, Basel, Zurich, etc.). However, there are no examples of UCCs used by receivers that previously performed transport for their own account. That could be explained by the difficulty of capturing goods movements performed by own account receivers since they do not tend to perceive the actual cost of transport that they perform. For this reason, strategic scenarios in the BCR will focus on the two following transport management modes: own account shipper and hired transport.

2.1.3. Geographical coverage of UCC services

Due to the specific form of the BCR with urban sprawl outside the administrative borders of the Region, it is not sufficient to consider goods movements (delivery or pick-up) that take place within the administrative boundaries of the BCR. We will therefore consider the BCR and the 13 municipalities that are adjacent to the Brussels ring road.

2.1.4. Time frame of the implementation

The local authorities, in their Strategic Plan for Urban Freight Transport in the BCR (Bruxelles Mobilité, 2013) have established goals for a more sustainable distribution with aims in decreasing 10%, 20% and 30% of vehicle movements by 2020, 2030 and 2050 respectively. The design of the scenarios is therefore made in a prospective setting. We selected a time frame to 2030 for the possible implementation of the scenarios.

2.2. Perception analysis

This step of the scenario planning methodologies aims in identifying major stakeholders participating in the scenario project and in analysing their perceptions, roles, interests, and power positions (Wulf et al., 2010; Schoemaker, 1995). For strategic scenarios in the BCR, we can identify two main groups of stakeholders: private stakeholders (carriers, shippers and receivers) and public stakeholders (administrators).

We can highlight several important elements with regards to the perceptions of private stakeholders and public stakeholders that will have a major impact on the way we construct the strategic scenarios.

The first issue is the financial viability of the UCC. As noted by Verlinde et al. (2012), many pilots and test cases show that many of the UCCs are granted only a short life because the cost of an additional transhipment prevents them of being cost-effective. Moreover, even if the introduction of the UCC produces net benefits for the overall transport chain, the fact that the benefits for different users are more difficult to quantify and allocate between the different stakeholders than the costs reinforces the status-quo and has probably been a factor inhibiting the development of UCCs in the past (Browne et al., 2007). In fact, Allen et al., (2012) mention that one of the major barriers concerned with making UCCs financially sustainable is the extent to which the various participants (carriers, receivers and local authorities) are willing and able to meet the financial costs of the UCC in return for the benefits that they receive.

With regards to the financial intervention of the public stakeholders, we can highlight a certain paradox: on the one hand, the general consensus shows that UCCs must be financially viable in their own right in the medium-to long-term and that subsidies are not a desirable solution (Browne et al., 2007), but on the other hand there is no evidence that any truly UCC self-financing schemes yet exist (Browne et al., 2005; Van Duin, 2009). Still, the authorities of the BCR are not willing to support structurally a UCC. They prefer to stimulate the development of self-sustaining privately run UCCs. Some support for the setting-up of the UCC could be offered (e.g. by renting public space at a decreased cost), but no long-term subsidies are intended.

On the private side, the allocation of costs and benefits between supply chain participants leads us to a wider issue of power relations between the supply chain actors. Traditionally, UCCs have been focused on carriers (Van Rooijen and Quak, 2010) but only a few of these initiatives were realised in practice (Quak, 2008). However benefits of the consolidation centres for carriers have been demonstrated (Quak, 2008). Moreover, carriers acknowledge indeed the advantage of delivering a site rather than multiple points (Boudouin, 2006). According to Holguín-Veras and Sánchez-Díaz (2015), two independent surveys (Regan and Golob, 2005; Holguín-Veras et al., 2008) have estimated that carrier's willingness to participate in UCC is in the range of 16%-18%, which is significantly larger than the observed participation. Holguín-Veras et al. (2015) show that the ability of carriers to change behaviour is in fact constrained by the other participants in the supply chain and that shippers and receivers have a great deal of power to specify how the transportation is to be done. Receivers are unaffected by a UCC scheme (Holguín-Veras and Sánchez-Díaz, 2015) and will not proactively push for it as they are currently served in conditions that already meet their needs, even if they are aware of the problems associated with it (Boudouin, 2006). On the other hand, shippers could be negatively impacted by participation because of factors such as the lost of the control of their deliveries and loss of the direct interface between suppliers and customers (Holguín-Veras and Sánchez-Díaz, 2015; Browne et al., 2005). The fact that the agents that yield the most benefits from the scheme are the ones with the least power can therefore be an important hindrance to the development of UCCs.

These elements from the literature lead us to the following conclusions for the strategic scenarios in the BCR: (1) UCCs are only feasible if they present net benefits for the transport chain as a whole; (2) no long-term subsidies are currently available for their operation; (3) the mechanism of the allocation of costs and benefits between the private supply chain actors is essential for their adoption; (4) regardless the possible financial benefits, other considerations must be taken into account in the implementation of the UCC scheme.

With regards to the first element, strategic scenarios for the BCR will only consider transport chains for which the UCC(s) decrease(s) the total cost of transport. This is in fact considered as a prerequisite to their adoption. The second element signifies that only financially self-sustaining schemes shall be considered for the strategic scenarios. Finally, the last two elements reaffirm the need to consider stakeholder acceptance of the proposed scenarios beyond the financial measures. For this reasons, once that they are constructed and evaluated in a quantitative manner, strategic scenarios must be evaluated based on a consultation of the local stakeholders in order to assess their acceptance.

2.3. Trend and uncertainty analysis

All major approaches to scenario planning include an analysis of the most important trends and uncertain elements (Wulf et al., 2010). This process stage is sometimes conducted in two distinct steps, as in Schoemaker's phases 'Identify basic Trends' and 'Identify Key Uncertainties' (Schoemaker, 1995), or combined into one 'Data Analysis' step (van der Heijden, 2005). We will now present some of the most important trends and uncertainties that were identified for strategic scenarios for urban distribution using consolidation centres in Brussels.

2.3.1. Physical structure of the urban freight distribution

Regarding the physical structure of the urban freight distribution, based on the Strategic Plan for Urban Freight Transport in the BCR (Bruxelles Mobilité, 2013), we can identify the following types of UCC configurations: (1) A centralized structure where a large UCC serves the entire region; (2) A hierarchical structure where a city distribution centre and several satellites (micro-hubs) are distributed throughout the Region; (3) A distributed system with interconnected UCCs that serve a particular geographic area or deliver specific product categories; (4) A distributed system with independent UCCs that all service the entire urban area. To our knowledge, there are no examples of practical implementations of a hierarchical (or a two-echelon) structure or of the distributed system with interconnected UCCs. This could be explained by the additional step required by these configurations in the transport chain thus resulting in higher costs of deliveries.

The strategic scenarios for urban distribution in the BCR will therefore consider two types of structure: a centralized structure and a distributed structure with independent UCCs. This means that in case of a distributed structure, we will take into account the market competition between different UCCs.

Regarding the number of UCCs required to serve the region, Panero et al. (2011) highlight a certain paradox: on the one hand, it has been noted that enabling a single consolidation centre for the distribution in a large urban area is unlikely to be attractive for many freight flows due to the degree of diversion required from normal route; on the other hand, there are examples of UCCs that failed because the number of customers served was insufficient to reach the break-even volume, like the UCC in Leiden which originally targeted only the city centre. The service area was then expanded to the whole city and later to the surrounding cities in order to attract more freight flows (Panero et al., 2011; Van Duin, 2009). Therefore, the number of UCCs needs to be a compromise between the need to offer multiple accessible locations in order to capture freight flows and the need to reduce the total number of UCCs in order to ensure sufficient market share for each centre in particular. In order to construct our strategic scenarios, we will consider up to 5 UCCs servicing the BCR and determine the number of UCCs that fits best these two requirements.

2.3.2. Possible locations of UCC(s)

Browne et al. (2005) and Van Duin (2009) highlight the importance of the location for the success of the UCC. The important considerations are: (1) their proximity to the area served, especially if the UCC scheme involves the usage of vehicles with a limited range (i.e. electric vehicles); (2) the upstream accessibility (proximity of major roads) and the downstream accessibility and (3) an environment that does not create neighbourhood problems and that is secure. In order to establish a list of possible locations for UCC(s) in Brussels, we have identified a list of 26 zones in Brussels and its periphery that meet these criteria. For some zones, based on the information from the planning documents (such as Bruxelles Mobilité (2013), Région de Bruxelles-Capitale (2014), Région de Bruxelles-Capitale (2002)), it was possible to identify a specific site that could be used for the setting-up of a UCC. For other zones, we have used the geographical epicentre of the zone. Considering that all planning documents mention the establishment of a logistical pole at the site of Schaerbeek Formation (a location in the north of the Region with tri-modal access), a UCC at this location will be considered in all strategic scenarios. This leaves us with 25 additional locations that could be considered for additional UCCs.

2.3.3. Fleet of UCC vehicles

The fleet of UCC vehicles can vary according to their size and vehicle technology. The decision regarding the size of vehicles is extremely important as it highly impacts the vehicle-trips and the congestion in the urban area. Strategic scenarios will therefore consider both vans and trucks. Regarding the vehicle technology, there are a number of possibilities: diesel, hybrid, CNG, electric vehicles, etc. Currently, diesel vehicles are the most commonly used in city distribution in Brussels (Lebeau and Macharis, 2014). However, the local authorities have objectives of reaching free CO_2 logistics by 2050 (Bruxelles Mobilité, 2013). In that context, battery electric vehicles can be considered as the most efficient technology to reach that objective. Browne et al. (2011) have indeed shown the potential that a combination between battery electric vehicles and a UCC has on reducing CO_2 emissions. Besides, Lebeau et al. (2015) have demonstrated the feasibility and the economic relevance of introducing battery electric vehicles in urban distribution in Brussels. Hence, scenarios for urban distribution will consider the two following technologies: diesel and battery electric vehicles.

2.3.4. Operation hours of the UCC

Boudouin (2006) mentions that a UCC should be open during the entire time of the day when the goods are treated. The same author mentions the following hourly activity of a UCC: first receptions from 7AM and the distribution of goods until 6PM. In their strategic plan for urban freight transport in the BCR (Bruxelles Mobilité, 2013), regional transportation authorities advocate the usage of the night and off-hours deliveries in the BCR. In that sense, off-hour deliveries for delivering goods to the UCC can be considered as a possibility in the strategic scenarios.

2.3.5. Regulatory and market framework

We can highlight two main strategies used by public authorities to promote UCCs: regulatory strategy and market-based strategy.

Regulatory instruments can differ according to the level of public intervention (Panero et al., 2011; Ville et al., 2013): (1) obligation to use a UCC by granting a special status (i.e. the permission to deliver an area) to a single market player, the UCC operator; (2) obligation to use a UCC by granting a special status (i.e. the permission to deliver an area) to a series of market players through a license system for example (Ville et al., 2013) and (3) inducing vehicles to use the UCC by reducing the accessibility of the area served by the UCC (Ville et al., 2013). Some European cities, including La Rochelle in France, Monte Carlo in Monaco, or Vicenza in Italy prefer to implement strong municipal regulations to stimulate the use of the UCC. They consider indeed that a UCC is the only way to ensure a successful rationalisation of urban goods distribution. On the other hand, other European cities do not consider the rationalization of freight delivery to be a municipal responsibility; the UCC should result of market mechanisms and should not require regulations to stimulate it.

Regarding the market-based measures, we can distinguish between two major types of measures: (1) measures targeting carriers (freight pricing) and (2) measures focusing on changing the behaviour of the receivers of goods (mobility credits). De Palma and Lindsey (2011) categorize freight or congestion-pricing schemes according to several dimensions: (a) the type of scheme (facility-based schemes, cordon schemes, zonal schemes or distance-based schemes); (b) the degree to which pricing schemes vary over time (flat, depending on the time-of-day, day of week or season according to a predetermined schedule or responsive and function of prevailing traffic conditions); (c) the differentiation of the scheme with regards to the vehicle characteristics or driving behaviour (differentiation according to the vehicle type, vehicle technology, number of axles, weight of the vehicle or speed of the vehicle). In recent years, London (2003), Stockholm (2006), Durham (2002), Milano (2008), Rome (2001), Valletta (2007), Oslo and Trondheim have all introduced different forms of charging or permit systems to combat congestion and/or environmental problems (Börjesson et al., 2012; Transmodal, 2012). However, despite the growing success of these schemes, road-pricing appear to have a limited impact on the freight transport demand management. Whereas there is ample theoretical support and empirical evidence that show that road pricing is an effective transportation demand management technique in the case of automobile transportation, this is not so clear in the case of freight transportation (Holguín-Veras, 2010; Quak and van Duin, 2010). Still, authorities of the BCR are currently implementing a distance-based freight-pricing scheme planned to come into action in 2016. Under its current form, the distance-based freight pricing concerns only heavy goods vehicles (HGVs). However, it is possible to imagine the extrapolation of this scheme to light commercial vehicles (LCVs). The strategic scenarios for the implementation of UCCs in the BCR will therefore consider only the distance-based freight pricing since this is the most probable measure but the type of vehicles targeted by this measure will vary across the scenarios.

2.3.6. Pricing of the UCC services

With regards to the pricing of the UCC services, we can rely on several sources. Boudouin (2006) reports that an average price of the UCC services is 3 euros/parcel. This order of magnitude is confirmed by Courivault (2004) that reports a price of 3,80 euros/parcel for the UCC in La Rochelle and a price of 4,90€/100kg for the UCC in Monaco. Data from Brussels gathered during interviews confirms a price of 2,5-5€/parcel and of 10-20€/pallet. In a feasibility study of freight consolidation centre in South London, Lewis et al. (2007) use the price hypothesis of £2-5 for an individual parcel and £5-10 for a pallet (2,9-7,1€ per parcel and 7,1-14,3€ per pallet according to the exchange rate in July 2015). This is also in line with the pricing of other urban logistics services reported by Chiron-Augereau (2009). We will therefore use three cost hypothesis for the pricing of the UCC services ranging from 2,5€ to 5€ per parcel and from 10€ to 20€ per pallet.

2.4. Scenario building

The scenario building phase is the core element of the traditional approaches to scenario planning where the previously identified key uncertainties are converted into distinct scenarios that describe different future states of the world (Wulf et al., 2010). In order to build the scenarios, we will proceed in three steps inspired by Schoemaker (1995): (1) Developing initial scenario themes and learning scenarios, (2) Defining research needs and develop quantitative models, (3) Choosing scenarios with the most realistic narrative.

2.4.1. Initial scenario themes and development of learning scenarios

This phase consists in combining the main ingredients for scenario construction. Based on the trends and uncertainties identified in the previous section of the paper, the following options have been selected for the building of the scenarios:

(1) Physical structure of urban distribution: centralized structure with 1 UCC situated at Schaerbeek Formation or distributed structure with up to 5 independent UCCs (1 UCC situated at Schaerbeek Formation and 1 to 4 additional UCCs situated in other areas);

(2) Possible location of UCC: in all scenarios 1 UCC shall be situated in Schaerbeek Formation site; in case of a distributed structure, 25 additional locations for setting-up 1 to 4 UCCs have been identified;

(3) Fleet of UCC vehicles: scenarios will investigate 2 possibilities with regards to the type of UCC vehicles (diesel vehicles or electric vehicles) and 2 possibilities with regards to the size of the UCC vehicles (trucks or vans);

(4) Operation hours of the UCC: strategic scenarios will investigate the possibility of allowing or not allowing night distribution to the UCC by formulating two hypothesis with regards to it operation hours;

(5) Regulatory and market framework: the scenarios will investigate a UCC implementation with no freight pricing, with a distance based freight pricing limited to HGV and a distance based freight pricing extended to LCVs, considering the environmental performance of the vehicles;

(6) Pricing of the UCC services: for the development of the scenarios, three cost hypothesis will be tested: low-cost (2,5 euros/parcel; 10 euros/pallet), medium-cost (3,75 euros/parcel; 15 euros/pallet), high-cost (5 euros/parcel; 20 euros/pallet).

2.4.2. Define research needs and develop quantitative models

The number of possibilities across the different dimensions identified in the previous step leads to a very large number of scenarios that could be considered. In order to reduce the number of possible scenarios, we will develop a series of quantitative models to evaluate each scenario for consistency and plausibility and to quantify the consequences of various scenarios. For evaluating the consistency and plausibility of scenarios, we will look at their operational feasibility (e.g. ensuring that scenarios are feasible in terms of necessary infrastructure, ensuring that scenarios are capturing a sufficient amount of freight flows). For quantifying the consequences of each scenario, we will look at two main elements: the financial feasibility (e.g. ensuring that scenarios are financially sustainable without public subsidies) and environmental impact of each scenario. In order to respond to the aforementioned research needs, several quantitative models have been developed. The overall integration of the models is shown on the Fig. 1. We will now provide a brief description of each model.

Freight routes characteristics

In order to quantify the consequences of the scenarios, we need first to have an overview of the current situation. We have used several primary sources of data. The first one is an origin destination matrix of urban goods movements in the BCR and the municipalities located in the periphery of the city. The data were generated within the European project LaMiLo (see http://www.lamiloproject.eu/) using the FRETURB software (Routhier and Toilier, 2007) for modelling urban goods movements. A second source came from Google Maps API that gave the travel distances and travel times. Finally, a third source came from Gerardin et al. (2000) that provided information about the stop duration of freight vehicles. Following some data adjustments, the combination of these two data sources has allowed us to characterize urban freight routes in terms of origins and primary destinations, average number of stops within a route, average route travel distances and average route times. This characterization has been done for each type of vehicle, each type of management and each route size (direct trip or 6 categories of round sizes according to the number of stops in a round).

Location-allocation model

The location-allocation model uses the data on freight routes characteristics as input. It computes the optimal structure (number, location and amount of captured movements and trips) of the network of UCCs servicing the BCR. The location-allocation model is a bi-level model that simulates two levels of decision: the decision of the planner who aims in selecting the locations of the UCCs that capture the highest amount of freight movements (i.e. the locations that are most likely to reach the break-even volume) and the decision of each particular vehicle that chooses to perform a direct trip or to use a specific UCC based on the total cost. The model allocates a specific freight flow to a specific UCC if the cost is lower than a direct trip or a passage though any other UCC.

The model considers three different pricing scenarios for parcels and pallets, three types of distance-based road fees and the possibility of having off-hours deliveries to the UCC(s). The compilation of results provides the optimal configurations of UCC(s) in terms of number, size and location that capture the highest amount of vehicle trips from 15 302 possible location patterns of UCC(s) (corresponding to a maximum of 5 UCCs from 26 candidate sites with 1 fixed site). The model also provides information for all scenarios about the number of freight movements, number of trips, vehicles*km, total duration of deliveries and total cost of deliveries.

Vehicle routing model

The data about the optimal location of the UCC(s) as well as the number of captured deliveries was used then as input to a vehicle routing model developed by Lebeau et al. (2015). It computed the last mile operations of the UCC considering the different constraints of urban distribution. First, the time windows of the different shops are considered so that the shops are delivered between 10am and 6pm. But when nigh distribution is considered in the scenario, the time windows are extended from 8am until 6pm. A second constraint is the capacity of the vehicles. We considered two types of vehicle: a van with a volume of 7,5m³ and a truck with a volume of 21,2m³. Finally, a third constraint considered the more limited range of battery electric vehicles compared to diesel vehicles.

External cost model

Based on the one hand on the kilometres driven by the vehicle to the UCC provided by the location-allocation model and on the other hand on the kilometres driven from the UCC provided by the vehicle routing model, the external cost model estimates for each scenario the following environmental impact: climate change, air pollution and noise emissions. In order to do this, the external cost model considers how the kilometres are driven. First, it differentiates the vehicles according to their size categories (vans, truck and trailers/semi-trailers). Heavier vehicles produce more global, local and noise emissions and contribute more to congestion. Then, it takes into account the vehicle technologies (diesel and electric). For diesel trucks, we considered an EURO V vehicle while battery electric vehicles were considered to use electricity produced from renewable energy sources. Finally, it distinguishes deliveries that are made at night and during the day. External costs of noise are indeed more important at night. The external cost model was constructed based on the report of the DG MOVE (2014).

UCC Financial model

Finally, the UCC financial model was used to test the financial viability of each scenario. The revenues of the UCC were established based on the number of freight movements captured by each UCC (coming from the location-allocation model) and the cost hypothesis used in each model. The following cost categories were considered: (1) infrastructure costs were estimated based on the UCC surface (calculated based on the UCC throughput, i.e. number of parcels and pallets) and the UCC location (with varying price per square meter); (2) vehicle costs were estimated based on the number of vehicles tours from the vehicle routing model and the cost data used by Lebeau et al. (2013); (3) equipment costs were estimated based on the UCC throughput; (4) human resources costs were estimated based on the number of tours (drivers) and on the UCC throughput (warehouse staff), (5) overhead costs. It is to be noted that the hypothesis used in the financial model suppose optimal operations of the UCCs.

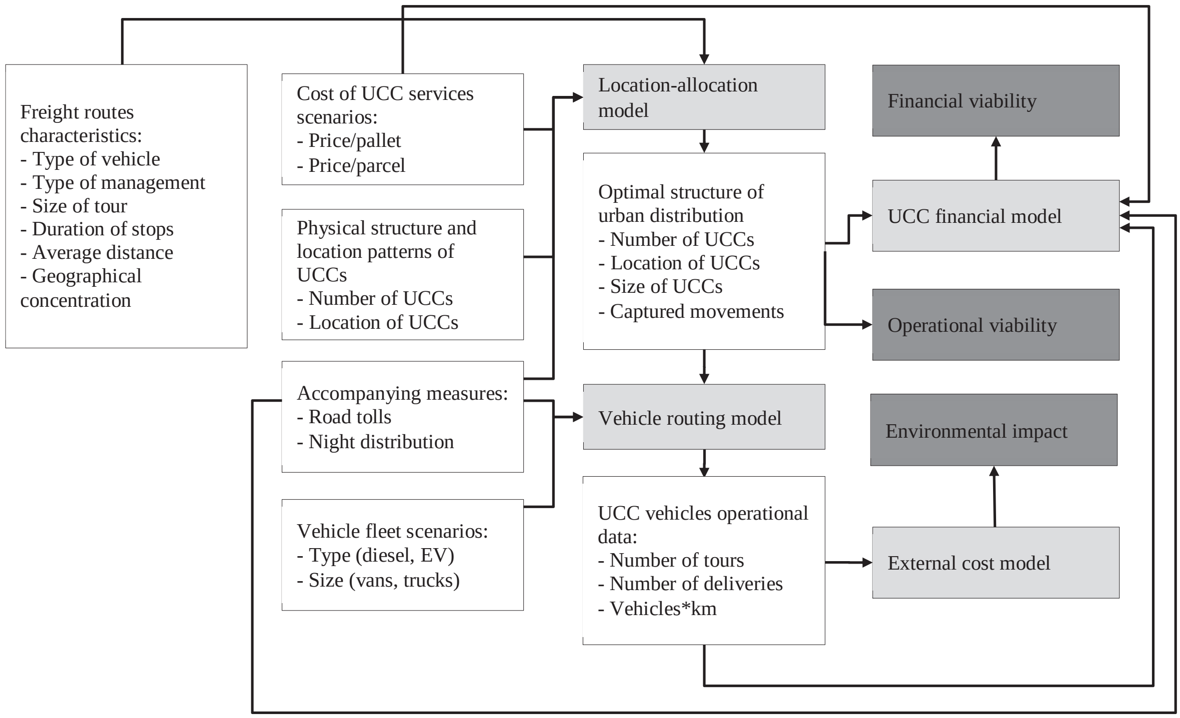

Fig. 1. Overall modeling structure

The quantitative models have allowed limiting the number of possible scenarios due the following considerations:

(1) The marginal impact of adding one additional UCC decreases with the number of UCCs. A 2nd UCC enables capturing 27,6% more vehicle-routes that the first one whereas a 5th UCC allows capturing 2,9% more vehicle-routes compared to four UCCs. We have therefore reduced the number of possible UCC(s) to 1, 2 and 4. Moreover, the precise location of a UCC has very little impact on the captured routes and movements as UCC locations in neighbouring zones tend to have the same performance. The scenarios shall therefore be presented in terms of UCC zones rather than precise locations.

(2) The results of the location-allocation is used to estimate the necessary surface for setting-up a UCC at each particular location with regards to the flows captured, allowing eliminating some scenarios with regards to their

operational viability (e.g. a scenario with one single UCC and distance based pricing for all vehicles would require dimensions exceeding the possible space)

(3) The low-cost scenario for pricing of the UCC services has consistently produced negative gross margins whereas the high cost scenario for the pricing of the UCC has not been able to capture a sufficient number of deliveries. Only the medium cost scenario shall be considered for the decision scenarios. In fact, public subsidies are possible in the start-up phase, but all scenarios must eventually reach financial sustainability.

(4) The setting-up of 4 UCCs is only possible with strong regulations and accompanying measures such as night distribution to the UCC as other alternatives do not capture sufficient freight flows.

(5) Under the hypothesis that each UCC serves the entire region and with regards to the distances to be travelled by UCC vehicles, vans are appropriate for the scenario with 4 UCCs only.

2.4.3. Choosing scenarios with the most realistic narrative

The quantitative models have allowed reducing significantly the number of scenarios, but still resulting in a large number of possibilities. In order to choose the final decision scenarios, we will choose among the possible scenarios those who have the strongest narrative. In fact as scenario is more than a random combination of elements: each scenario tells a story of how various elements might interact under certain conditions (Schoemaker, 1995). The scenarios that have been finally selected must provide storylines that are clearly distinguishable. With this in mind, the following scenarios have been selected:

(1) Scenario 1: one UCC situated at Schaerbeek Formation, freight road pricing for HGVs, regular trucks and medium price of UCC services. Night distribution is not allowed to the UCC. This scenario positions as an extrapolation of the political option that is currently chosen by regional authorities.

(2) Scenario 2: Two UCCs (one at Schaerbeek Formation and one at the north of Brussels), night distribution to the UCCs and no freight road pricing, trucks and medium price of UCC services. This scenario is an option to which the freight carriers are expected to be most favourable, as it does not introduce any additional costs and still offers the possibility of using a consolidation centre if more cost-effective. Moreover, the night distribution to the UCC allows decreasing even more the cost of transport to the UCC. Since no additional pressure is put on the carriers to use the UCC services, two UCCs are expected to suffice to cover the demand. In order to test the effect of the introduction of the electric-vehicles, two sub-scenarios are defined: scenario 2a using the diesel trucks and scenario 2b using electric trucks

(3) Scenario 3: Four UCCs, night distribution allowed to the UCCs, freight road pricing based for all vehicles based on their environmental performance, vans and medium price of UCC services. This scenario presents the extreme point of possible futures and the most radical change in urban distribution as it combines heavy regulation, large number of UCCs and night distribution. It is the scenario with the best results in terms of environmental performance but with the heaviest constraints for the carriers. In order to test the effect of the introduction of the electric-vehicles, two sub-scenarios are defined: scenario 3a using the regular vans and scenario 3b using electric vans.

Fig. 2 shows the optimal UCC locations for the three scenarios. These locations will be used to evaluate the scenarios – however, the precise location of a UCC has very little impact on the evaluation.

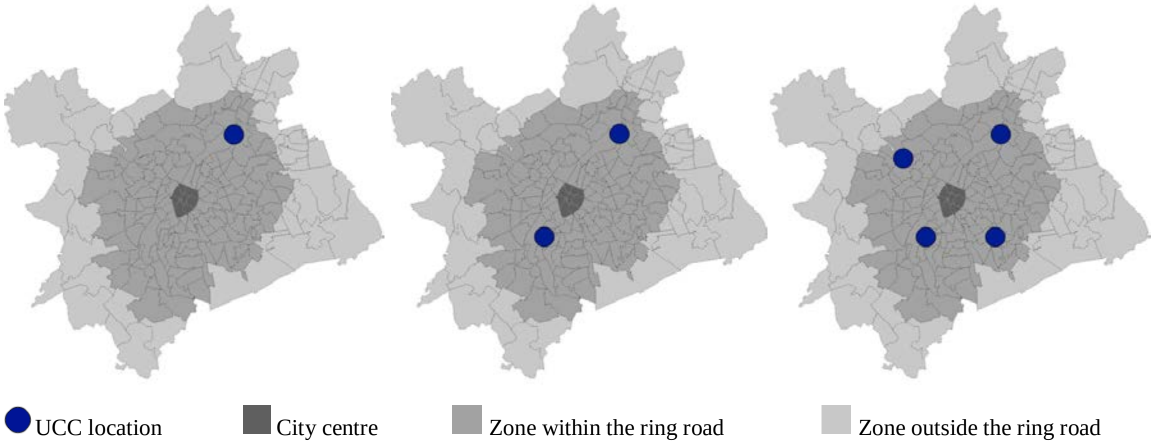

Fig. 2. Optimal locations of the UCCs for the Scenario 1, 2 and 3 respectively

3. Results

Based on the tools we developed, we quantified the impact of the scenarios on the urban freight flows in Brussels as depicted in Table 1. The evaluation of the selected scenarios details: (1) the impact on transport costs for the carriers (the cost variation is expressed for all carriers regardless of the fact that they use the UCC(s)); (2) the impact on congestion from all carriers in the region (to include the different impact on congestion of different vehicle categories, the indicator did not consider vehicles arriving at the depot before 6am and expressed the vehicles*km in terms of "personal vehicle equivalent" which implies a multiplication by 1,5 for vans, 2 for trucks and 2,5 for trailers and semi-trailers as considered by Routhier et al. (2001)); (3) the impact on external costs of local and global emissions from all carriers in the region; (4) the impact on external costs of noise emissions from all carriers in the region; and (5) the gross margin of the UCC(s) which is expressed for all the UCC(s) in each specific scenario.

Table 1. Evaluation of decision scenarios with regards to business as usual

	Scenario 1	Scenario 2a	Scenario 2b	Scenario 3a	Scenario 3b
Cost of transport	+6,3%	-1,3%	-1,3%	13,4%	13,4%
Congestion	-2,2%	-4,1%	-4,1%	-7,2%	-7,1%
Emissions	-3,0%	-2,9%	-3,7%	-5,8%	-8,1%
Noise	-2,2%	5,6%	4,7%	3,9%	2,0%
Gross margin UCC(s)	8,3%	15,3%	3,2%	11,9%	7,8%

Cost of transport is being reduced in scenario 2a and 2b when no toll is introduced. This benefit is coming from the optimisation of the goods flows achieved by the services of the UCCs. However, in scenario 1, costs increase because of the introduction of the toll on heavy goods vehicles. Costs increase further in scenario 3a and 3b when the toll is extended to the light commercial vehicles.

The second indicator shows that congestion is reduced with the introduction of additional UCCs. The increasing number of UCCs offers a better geographical coverage on the city and captures therefore more flows. We can highlight the minimal influence of battery electric vehicles on congestion: the scenario with battery electric vehicles (3b) reduces less congestion than the scenario with diesel vehicles (3a). Their limited range imposes additional constraints which lead to, sometimes, more delivery turns and thus more vehicle kilometres. Still, that difference is very low since no difference can be observed between scenario 2a (with diesel vehicle) and scenario 2b (without battery electric vehicle).

The benefits of battery electric vehicles appear better in the impact of the scenarios on emissions. Table 1 shows that they improve significantly the environmental performance of their similar diesel scenarios. The reduction of vehicle kilometres due to an optimisation of freight flows by the UCC contributes also to a better environmental performance. Interestingly, that is not the case between the scenario 1 and scenario 2a. The toll in scenario 1 was indeed incentivising more heavy goods vehicles to use the UCC than in the scenario 2 where no toll is considered. As a result, the UCCs in scenario 2 capture a larger share of light commercial vehicles than heavy goods vehicles compared to the scenario 1 which explain a lower environmental efficiency of scenario 2 despite a better result on the criteria congestion.

The impact of the scenarios on external costs of noise shows more negative results. The night distribution allowed to the UCC impacts significantly noise levels in the city. The reduction of noise because of less freight vehicles in the traffic (through a rationalisation of freight flows) cannot compensate the impact of a few freight vehicles driving at night. The marginal impact of a freight vehicle is indeed much higher during the night and when the density of the traffic is low than during the day and when the density of the traffic is high. Still, we can note the positive influence the battery electric vehicles can bring to reduce noise levels in the city.

Regarding the gross margin, we can see that while using the same type of vehicles (diesel trucks), the scenario 2a presents a higher profitability than the scenario 1: the addition of a second UCC allows shortening the total distances and times travelled by UCC vehicles, thus reducing the related operational costs. The scenario 3a (4UCCs and diesel vans) results however in lower profitability. In fact, although vans have lower kilometric and hourly costs than trucks, their small capacity results in lower efficiency in terms of volume transported per euro of operating cost.

We can observe also the influence of battery electric vehicles on the gross margin by comparing scenarios 2b with 2a and comparing scenarios 3a with 3b. Battery electric vehicles produce in each scenario a lower margin compared to their similar scenarios with diesel vehicles (2a and 3a). In fact, battery electric vehicles can improve the profitability of a fleet if it is used in combination with conventional vehicles as observed by Lebeau et al. (2015). The negative impact of electric vehicles on the gross margin is lower for the scenario 3b than for the scenario 2b for two reasons: (1) scenario 3b uses smaller electric vehicles that are more competitive than larger electric vehicles (as demonstrated by Lebeau et al., 2013); (2) electric vehicles are not affected by the distance-based freight pricing in the scenario 3b since in this case, freight-pricing is based on the environmental performance of the vehicles and not their weight.

4. Conclusion

This paper uses a combination of qualitative and quantitative approach in order to construct scenarios for the urban city distribution in the Brussels-Capital Region using UCCs. The large number of options regarding the possible scenario components calls for a use of a formal methodology in order to be able to select a limited number of scenario themes. These themes are then detailed though a series of quantitative models in order to reach a limited number of decision scenarios. This paper shows that the combination of these two approaches can be an interesting option for enhancing decision-making under uncertainty and that scenario planning methodology which is usually applied in corporate setting can in fact bring interesting results in the fields of public decision making in urban freight transport.

It is however important to leave different possible alternatives open in order to evaluate the support of the stakeholders. They are indeed recognised to be critical to guarantee the success of projects in urban freight transport. As previously discussed in this paper, the non-monetary benefits and the power relations between supply chain actors have a major impact on the acceptance of UCC schemes. Future research is therefore needed to further evaluate the scenarios based on a consultation of the local stakeholders. This will lead to the identification of the scenario with the highest acceptance among the stakeholders.

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