OPTIMAL LOCATION FOR AN URBAN DISTRIBUTION CENTRE

GLASGOW CASE STUDY

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ABSTRACT

The work carried out and presented in this report is inserted in the context of City Logistics, being a case study of the implementation of an Urban Distribution Centre serving Glasgow City Centre, from public entities point of view. The goal is to build a methodology that allows to cross present freight patterns in the city centre, , evaluated through a survey process to retailers, with the possibility of implementing an urban distribution centre that satisfies those patterns and simultaneously, allows the mitigation of logistics activity in the centre.

More than to simulate the functioning of an urban distribution centre, it is intended to evaluate whether it presents a valid solution to mitigate city logistics activity and how stakeholders' acceptability is a deal-breaker for the success of its implementation, in Glasgow City Centre. On that last note, is it also a goal of this work to analyse what public policies would best accompany the implementation of a UDC in order to draw retailers' into taking part in a UDC scheme.

The methodology will take advantage of the work already carried out by Munõz-Villamizar et al. 2014, alongside other characteristics needed to solve the identified problem. The intent of this formulation is to understand the best location for an urban distribution centre as well as the best delivery scheme that serves the city centre with maximum efficiency and sustainability. Also, retailers' preferences and already imposed legislation for road traffic are to be taken into account.

Keywords: City Logistics, Urban Distribution Centres, Public Policies, Optimization, Location Routing Problem, Glasgow

INTRODUCTION

Freight transportation is a vital element in the economic prosperity of any country. Every day, a wide variety of products has to be efficiently transported within the consumer markets, industry sectors and international trade networks, at the same time adverse impacts on congestion, environment and safety have to be addressed.

As soon as freight crosses the city borderline it is considered as urban freight, even if the transport flow has its origin outside the urban area or within other urban areas. Despite it being a relevant support of the economic life in these areas, it is often found that urban freight operations play a secondary role in city planning priorities, while much more attention is paid to freight transport at an interurban level.

However, urban freight flows occupy about one fourth of the street traffic of a typical city and require loading and unloading operations, storage/conditioning and packaging, demanding an even greater use of urban space, then suggesting the need to adjust the priority given to urban freight transport.

All these movements and dynamics are a result of logistics decisions, i.e. of the processes required to organize the movement of goods in an efficient manner within the goods production system. These decisions are based on the demands of the production and distribution sectors, while dependent on economic agents' behaviours. It is these interactions that give a complex structure to urban mobility of goods and turn the development of an efficient and sustainable urban freight system a challenging task.

This difficulty in managing the urban goods system, the lack of attention given to this component of the transport system plus the expansion of urban areas and accompanying growth of their population create, in the transport network, a set of issues associated with freight like congestion, CO^2 emissions and local pollution as well as societal issues. For the above reasons, cities' supply systems have to be reorganized. It is this interest in restructuring goods flows within urban areas that is commonly referred to as City Logistics.

Despite the vast set of solutions to mitigate city logistics problems, the main issue relates to the need to alleviate those while ensuring that the efficiency of deliveries is maintained. Therefore, the ultimate solutions should, at the same time, be able to ally efficiency with sustainability, crossing the interests of all stakeholders involved in the process. While private entities (such as transport companies) aim at maximising the efficiency of freight transport, with little regard for a sustainable operation, public entities aim at ensuring that the operation respects environmental standards and minimizes conflicts with the already built environment (whether it is traffic, conflicts between pedestrians and vehicles or illegal parking).

Transferability of city logistics mitigation strategies from city to city is hardly attainable. Here, the development of each strategy has to be done with consideration for current established freight dynamics (delivery patterns and existing legislation and stakeholders), the degree of involvement of public entities (past, current and future studies) as well as decision power, stakeholders' preferences and willingness to cooperate in reorganization plans for freight and stakeholders' viewpoint on different logistics activity mitigation strategies.

The need for that amount of information suggests that the study of mitigation solutions for urban logistics has then to be done at city level, in a case study type framework where, ultimately, the success of a freight strategy will depend on how smoothly it can integrate itself in the built environment.

CITY LOGISTICS

Definitions and Domains

City Logistics can be described as the process for totally optimising the logistics and transport activities by private companies with the support of advanced information systems in urban areas while considering traffic environment, its congestion, safety and energy savings within the framework of a market economy (Witkowski & Kiba-Janiak, 2014). According to (Muñuzuri, et al., 2005), City Logistics can also be described as a term used to designate the specific logistics concepts and practices involved in deliveries in congested urban areas and the "last mile" transport, with specific problems such as delays caused by congestion, lack of parking spaces, close interaction with other road users, etc. Dablanc, 2007 stated that City Logistics can be defined as the attempt to reorganize goods flows within urban areas in the interest of sustainability by restructuring cities' supply systems, justifying this need with the negative effects that come with urban goods transport due to the expansion of urban areas and growth of their populations.

This way, when considering City Logistics, not only as to be taken into account the means over which freight distribution can be arranged in urban areas but also the strategies that can be put into action in order to improve its overall efficiency while mitigating congestion and environmental externalities that come with this activity. Hence, City Logistics should ideally conciliate the efficient distribution of goods with the promotion of innovative schemes for the reduction of the operations' total cost, including economic, social and environmental costs, with the ultimate objective of reducing the clash between the interests of logistics companies and those of other stakeholder groups involved in urban mobility. It can then be stated that City Logistics deals, mainly, with three different domains: transportation network, supply-demand and traffic, where urban goods is common entity in all three domains (Quak & van Duin, 2007).

Stakeholders involved in City Logistics

As a mainly private activity, City Logistics tends towards focusing on the interests of both the final consumer and the logistic provider, action that creates externalities that normally have to be regulated by local authorities. This way, City Logistics represents a complex activity, involving the interests of more than one actor, connecting a group of stakeholders with very different interests. The social system created by different stakeholders acts under several forces which, often, not only reactively but proactively and with vigorous goal orientation, end up conflicting. To be simultaneously satisfied, this multiplicity of interests produces one of the biggest challenges in logistics activity in urban areas where analysis and selection of implementable measures has to consider such interests and find an optimal compromise between them.

Each stakeholder in City Logistics is then an agent in a multi-agent system where each of them has certain goals to achieve and certain rules to follow. The course of logistics activity in a certain urban depends on the interaction between Shippers (or Wholesalers), Freight Companies/Logistics Providers, Receivers, End-consumers and Public Entities/City Administrators. On the one hand, city administrators affect planning procedures by applying legislation to the establishment of delivery patterns. On the other hand, they are in charge of collecting mass data on traffic dynamics, which are a valuable source for more efficient and reliable planning of pick-up and delivery tours.

By assuming that the main goal of logistic providers is a constant growth in profit, a desire for reduction in transportation costs is implicit as well as an increase in the amount of sales, while keeping in mind that residents and shippers correspond to customers of their service, who expect it to be economic and reliable. Similarly, the prime objective of shippers can also be mentioned as a growth in profit, implying a reduction of the total cost of their operations. These costs consist of opportunity, manufacturing or purchasing and logistics costs (which encompass inventory, transportation and information processing costs) (Ehmke, 2012). As for residents, with the prime goal of providing them a good living environment, it is necessary to reduce the negative impact that comes with traffic, which mainly relates to vehicle emissions. In order to fully understand the dynamics of logistics in urban areas, it is then necessary to comprehend how these stakeholders interact, their degrees of understanding and their dependence upon each other.

The state of logistics in a certain urban area is the result of the made stands and initiatives from both private and public entities, along with their interactions and coexistence of interests. Since private entities have their main goals on optimization of deliveries and reduction of costs, the assurance of social, economic and environmental standards regarding the field of city logistics falls under the attention of public entities who are then in charge of safeguarding those interests. It is this task that blends the field of city logistics with urban planning, implying the need to look at freight activity in cities from a larger perspective, one that does not stick to supply chain management but, instead, inserted in a more complex context, bringing together the diversity of aspects with need for consideration and making a study from public entities' point of view a challenging task.

Looking at the concept associated with City Logistics, local authority can then be seen as the player with the most important role in the city logistics system. They are the ones striving to ensure high living standards in the city in the social, economic and environmental fields. They should therefore be the initiators, motivators and coordinators of logistics solutions in order to improve the movement of people and goods within the city (Witkowski & Kiba-Janiak, 2014).

The following table presents the main goals of local governments for social, economic and environmental high-quality insurance, categorized in their fields of intervention regarding City Logistics.

Table 1 – Local authorities decision categorization in the field of city logistics

	Goals of local governments in the field of City Logistics		
	Social (Quality of Life)	*Economics*	*Environment*
Goods flow (including waste)	Citizens' safety; citizens' education about waste segregation	Cost reduction	Reduction of CO2, NOx emissions, noise reduction, waste segregation
People flow	Citizens' education in order to improve their movement within the city by collective transport	Cost reduction of collective transport	Changing citizens' transportation behaviour into the use of collective transport instead of a car
Information flow	Current information about congestion, Closed roads in the city, etc.	Long term cost reduction of data gathering and analysis	Current information about CO2 emissions

However, the little influence of local governments on the basic drivers of freight flows can be seen as the main problem these entities deal with regarding their intervention on the field of City Logistics, while local communities have to bear many of the externalities related to this activity. It happens that local authority' policies have, in general, limited effect on local impacts since supply chains are a difficult target for local policy efforts and due to the fact that these policies do not affect the underlying demand for freight movements. Because of the interdependencies within a chain, policies to address a problem created by one part of the chain affect other links.Also, local authorities are vulnerable to the fragmentation of local governance, especially in large metropolitan areas where freight problems are more severe and, at the same time, where these areas are under the jurisdiction of multiple government units (sometimes from multiple cities) such as public transit operators, port authorities and planning agencies.

For most cities, the current freight policies seem to struggle to measure up to the important changes constantly taking place in the production, distribution and consumption sectors. Space dedicated to logistic activities is disappearing from cities, and few municipalities are promoting the development of new modern logistic areas (Ville, et al., 2013). It happens that the large majority of cities have not yet found proper solutions to potentiate the optimization of the urban movement of goods, since it seems that all entities involved are expecting initiatives to come from the other side.

City Logistics Current State

It has to be taken into account that the concept of City Logistics emerges from the need to solve the growing problem of freight transport densification in urban areas. Due, on its majority, to the expansion of these areas and the growth of their populations, urban goods transport has a significant contribution to negative effects like congestion, CO^2 emissions and local pollution (including noise). Also, globalization has increased freight flows due to the growing distribution of production across multiple locations around the world, rather than remaining local. This, combined with customers' increasing demand for a wide variety of products and retailers' inclination to stock less inventory, leads to the need for more frequent deliveries for replenishment of inventory. Moreover, the decentralization of logistics facilities, resulting on storage and distribution centres being moved to the periphery in response to high land costs within the city, produces the need for freight to be moved into the city to reach its end consumers. Also, road capacity within cities is limited, as are the number of parking spaces and loading facilities where each of these resources have, on top of its limitations, to compete with passenger flows. Finally, with the growing popularity of e-commerce, substantial amounts of freight movements can be allocated to direct trips to individual homes rather than in bulk to store locations (Transportation Research Board, 2013).

Therefore, City Logistics plays an increasingly important role in many of these cities where, despite increasing difficulties associated with the movement of goods and people, efforts towards urban logistics remain insufficient. There then is a constant need to restructure cities' supply systems in the interest of sustainability, reorganizing goods flows in urban areas.

Nonetheless, the freight sector is a major source of jobs and freight transport represents an essential link between goods supply and demand. Therefore, it is worth reminding that solutions envisioning the mitigation of freight transport in urban areas have to respect and prioritize its efficiency as much as solving the impacts of its activity in cities.

It then becomes important to recognize the multiplicity of urban freight relatable problems, which fall in a diversity of categories, described in the table above. It is this variety that adds complexity to the problem-solving strategies that can be implemented by local authorities in urban areas and creates the need to fully identify the visible problems in each city.

Table 2 – Problems associated with freight transport in urban areas

Problem Domain				
Efficiency	***Relational***	***Road Safety***	***Environment***	***Urban Structure***
Poorly loaded vehicles leading to excessive trips and thus, congestion	Lack of influence of local authorities on freight flows	Passenger/freight conflicts – accidents involving freight vehicles	Growing demand for reverse logistics flows (waste and recycling)	Capacity of urban freight systems (leading to congestion)
	Improper/unauthorized loading			Distribution sprawl leading to space consumption
	Complexity of supply chains makes policy implementation difficult		CO2 emissions from freight vehicles	Contribution of intense freight activity for devitalisation of city centres
Lack of know-how on sustainable freight movements organization	Fragmentation of local governance: freight activity under the jurisdiction of multiple government units			Degradation of levels of service due to high volumes of freight traffic
	Lack of awareness of the impacts of urban freight transport from private entities – focus on efficiency and profit		Traffic noise	Lack of space dedicated to logistic activities inside city centres (Decentralization of logistics facilities)
Scarce and outdated freight activity mitigation policies	Dichotomy between the efficiency of freight transport and the sustainability of urban areas			Road capacity limitations within cities
			Use of high-emission vehicles for freight distribution	Limited loading facilities and parking spaces within cities

The identification of freight mitigation strategies is an essential step when attempting to build an effective and efficient strategy for mitigating logistics activity in urban areas and highly variable from city to city, limiting the ability to develop a fully transferable strategy, applicable to every urban area. However, a background consultation and analysis of best practices has to be undertaken in order to understand to what extent the current practices under the City Logistics' domain can be applicable to solve the conflicts identified in a certain city.

After analysing some of the classifications on measures for city logistics activity mitigation proposed on the reviewed literature (Russo & Comi, 2010), (BESTUFS, 2006), (Russo & Rindone, 2007) or (City Ports, 2005) it was decided to formulate a new classification that could allow to differentiate policies into the ones that express physical and direct changes to the transport network (to facilitate the circulation of vehicles, reduce its impacts and control its intensity inside urban areas), the ones that relate to technology innovation (in order to improve the efficiency of deliveries and to provide the transport system with more environmentally friendly transport solutions) and the ones that, through regulation, can shape delivery approaches into more sustainable solutions (implying the need to rethink delivery strategies).

This proposed classification was made to highlight the involvement of public entities in the range of available freight activity mitigation policies for urban areas, evincing the need for their presence in the development of a broader strategy, especially involving network related solutions and enforcement solutions. Network related solutions are, in general, initiated by public entities, envisioning not the direct mitigation of freight activity, but the facilitation of more efficient delivery schemes (thus with positive impacts on the transport network), by providing infrastructure for freight activity. Differently, with enforcement policies, logistics companies are required to shape their delivery schemes to the imposed legislation, with direct impacts on sustainability indicators like traffic, air pollution, noise and conflict levels.

Table 3 – Overview of policies applicable to urban freight transport mitigation

Overview of policies applicable to urban freight transport mitigation		
Network	**Technology**	**Enforcement**
Usage of bus lanes by freight vehicles (or other specific routes)	Low-emission vehicles (or electric)	Establishment of maximum parking times
Dedicated zones for loading and unloading operations	Traffic information systems	Incentives for policy adoption
Heavy vehicles' dedicated sub-network	Route Optimisation systems	Time windows for deliveries
Logistics facilities close to/inside urban areas	Electronic Toll Collection (ETC)	Low Emission Zones (LEZ)
	Logistic information system (in-company or between companies)	Vehicle regulations (according to sizes or emissions)
Route bans for freight vehicles	Freight Capacity Exchange Systems	Road pricing

(Oliveira, et al., 2012) highlighted that the increased congestion due to the growing circulation of goods in urban areas relates to the current production and distribution model, based on low inventories and just-in-time deliveries, as well as explosive growth of e-commerce, which generates significant volumes of home deliveries. Because governments treat urban freight distribution as a mainly private activity, public authorities promote few policies on this matter, variously involving regulation of parking, road access and time windows for loading and unloading, among others. It thus becomes important to single-handedly explore the solutions that are within the reach of local authorities and understand the extent to which they can be conciliated with the simultaneously wanted efficiency of deliveries and local competitiveness of the freight sector.

Table 4 – Classification of urban freight solutions for application by local authorities

Land Use Management	Public Infrastructure	Access Conditions	Vehicles	Traffic Management
Load zone provision	Urban distribution centres	Access according to weight and volume	Emission standards (through Low Emission Zones)	Differentiated parking charges
		Access to pedestrian zones		
Parking space planning	Outskirts logistic centres	Road pricing	Fuel taxes	Street classification
		Night deliveries		Carrier classification
Load/unload interfaces	Use of the tram/underground system	Rotation in load zones	Subsidies for low-emission trucks	Freight zone classification
		Loading time		
Hub areas	Use of rail/ship terminals	Access time windows	Minimal load-factors	Subsidizing intermodal transport

Nearly all the above policies have generated both successful and failed implementation cases due to diversified factors that cannot be standardized per reason, location or funding. Every urban area presents itself as a single case study and as to be approached as so.

One of the policies that has been explored for the past years, attempting to make a still very conceptual comeback for solving city logistics' problems are urban distribution centres. As a concept that attempts the relocation of logistics platforms to the inside (or periphery) of the urban area with the goal of improving load factors in freight vehicles and performing deliveries with smaller and more environmentally friendly vehicles, this is a solution that, when rightly explored, can come to solve many of the problems associated with city logistics.

Simultaneously, it represents an interesting solution since it has to conciliate the efforts of both private and public entities, working together to present a solution that is both sustainable and effective: private entities make the compromise of adjusting their delivery schemes while public authority facilitates regulation for freight movements associated with the distribution centre, implying the need for accompanying measures and incentives coming from local authority for successful (as thus profitable) implementation of the centre. More than that, it demands a commitment from all the involved stakeholders, where retailers have to be on board with having their goods come through the logistics platform prior to delivery to their establishments.

Urban Distribution Centres

An Urban Distribution Centre is a logistics facility located inside or relatively close to the urban area, intended to serve a city centre, an entire town or a specific site such as a shopping centre, airport, hospital or major construction site, where the goods destined to these locations are dropped off at the centre. Subsequently, centre operators sort and may or may not consolidate the goods (hence the difference between urban consolidation and distribution centres), making deliveries to the final destinations, often using environmentally-friendly vehicles (electric or gas-powered) (Browne, et al., 2011).

This concept involves the separation of logistics activities inside and outside the city where consolidation is not always the best solution from the perspective of the city since supply chain operators optimize their deliveries at the flow of origin while, for the sake of the city as a whole, the optimization considering the destination should come first.

By improving the load factors of goods vehicles for last mile transport, urban distribution centres reduce the total distance travelled by freight vehicles inside urban areas, thus reducing greenhouse gas emissions and local air quality pollutants. Other social and environmental advantages can include noise reductions through the use of quitter vehicles, reduction of conflicts between freight vehicles and other road users and increased pedestrian safety (Browne, et al., 2011).

Generally speaking, an urban distribution centre can reduce the delivery time in congested areas as well as total fuel consumption and the number of vehicles for urban distribution operations and optimize retailers' stocks. However, and as referred by (van Duin, et al., 2010), retailers and carriers compliance is a crucial factor for a logistics initiative of this nature, since their participation will maximize its benefits and decrease many of the involved costs. BESTUFS (2008) pointed out that a synergistic network of urban distribution of goods is a key factor for the implementation of a successful urban distribution centre.

The logistics companies dropping off their load at the UDC benefit from not needing to enter a congested urban area, saving time and money. Similarly, those receiving goods from the UDC can benefit in terms of delivery reliability. In addition to potential consolidation and final delivery, a range of other value-added logistics and retail services can also be provided at the centre including off-site stockholding, consignment unpacking, preparation of products for display and price labelling, benefiting receivers by reducing their on-site space requirements, saving time on on-sit tasks and thus enhancing productivity and sales in core activities (Browne, et al., 2011).

According to (Browne, et al., 2005), the number of users is a crucial factor in all success and failure cases, very much dependent on how the organisation of the UDC is setup. The fact that a UDC is privately organised can possibly explain success as does the provision of public subsidies. The selection of the right type of distribution vehicle should meet the unique requirements for the situation and therefore be determined for every scheme individually. The location of the UDC is also a determinant factor for success as are well-chosen accompanying measures.

It happens that organisational and contractual problems seem to arise as major supply chain barriers, as does the desire for companies to maintain competitive advantage rather than sharing expertise and systems. Also, problems related to loss of control sensed by shippers are highlighted (Lindholm, 2012). As a result, more "commercial" schemes have started to be thought and developed, paying more attention to potential supply chain benefits, as a result of greater effort being devoted to integrating the centres into the supply chain. Nevertheless, the impacts are generally only identified towards the end of the supply chain, with little attention being paid to what happens further upstream.

Ultimately, there is a considerable lack of awareness of the potential opportunities of a UDC if they were to be established in the right manner and in the right situations, which appears to result from the pre-conceived idea that this system means additional costs and little else. In addition, there is the commonly misconception that there is only one model for a UDC, which is untrue. UDCs need to be customised to the requirements of the locality and the clients they serve. By going beyond traffic regulation measures, this is a policy that involves more than compliance with public authority, involving all stakeholders in a broader sense by taking its individual goals into a strategy that ideally accommodates efficiency and sustainability, demanding the challenging task of guaranteeing the successful integration of an extra step in the supply chain.

MODELLING FOR CITY LOGISTICS

The Need to Model for Policy Implementation

Passenger transport has been investigated quite thoroughly inside urban areas but a gap in knowledge is perceived in what concerns freight transport in those same areas (van Duin, et al., 2012). Before the 1990s, modelling of urban goods movements was typically based on both transport and facility costs but a later shift towards policy-oriented modelling took place (van Duin, et al., 2012). This type of modelling tries to understand urban truck movement under the influence of various government policies and adds the policy instruments to the city logistics models, introducing a component of respect for social impact and allowing the study of the dynamic behaviour of actors, reacting on policies, to observe and analyse the effects on sustainability and economic/social impacts (van Duin, et al., 2012).

The difficulty in handling the course of freight distribution in urban areas can relate to the fact that the field of City Logistics policy-making is still in an immature stage. This immaturity is directly connected with the methodologies used in policy-making since most of the modelling associated with this field falls back upon differential equations and statistical modelling (Anand, et al., 2012).

Model Choice

Recent modelling efforts come to understand the importance of including other stakeholders in that process. According to (Anand, et al., 2012), a model by (Holguín-Veras, 2000) suggests a framework for "integrative market simulation" that considers producer, carrier, customer and government for urban freight analysis. (Crainic, et al., 2004) presents a model for efficient planning of urban freight distribution while reducing its impact on environment. Models by (Visser, et al., 1997), (Kanaroglou, et al., 2008) and (Muñuzuri, et al., 2010) emphasise the reduction of environmental externalities caused by urban freight transportation. A model by (Young et al. 1983) focuses on efficient planning of infrastructure for efficiently dividing traffic between rail and road. Similarly, (Crainic et al., 2004) discusses the location problem for city distribution centres.Ultimately, the goal of modelling for urban distribution centres lies in defining a framework for properly optimizing, in a sustainable way (by assuming economically-viable, eco-friendly and socially-accepted solutions) the implementation of the platform serving a certain urban area.

Though the performance of distribution centres can be analysed on different criteria, no model seems to allow quantifying, a priori, the effect of locating the centre at a given position. In this particular case study, adopting a model that allows this specific approach becomes interesting as a first step into evaluating the potential implementation of an urban distribution centre in Glasgow.

Being difficult to quantify acceptability from all the involved stakeholders, an approach of this nature could be able to estimate the easiness with which the centre could merge with the already built environment and its existing dynamics (freight in particular) estimating, indirectly, the viability of its integration among a consolidated urban area. Also, taking into account the existing knowledge of some of Glasgow City Centre dynamics and preferences regarding deliveries, the integration and respect for this component in the model would allow to quantity the difficulty in having a UDC as a viable solution to solve urban logistics problems in the city centre.

To that intent, the selected approach – Mathematical Programming Modelling and Resolution of the Location-Routing Problem in Urban Logistics – suggested by (Muñoz-Villamizar, et al., 2014) considers the problem of locating urban distribution centres and proposes an exact method, based on integer linear programming, for strategic (locating the UDC), tactical (defining the UDC's size) and operational (delivery routes of vehicles assigned to the UDC) decision-making. It then aims to solve, in an integer manner, location, sizing and operation (vehicle routing) problems in the logistics platform.

GLASGOW CITY CENTRE

Transport Activity

Glasgow City Centre is bounded by High Street to the east, the River Clyde to the south and the M8 motorway to the west and north. The main shopping grounds feature Argyle Street, Sauchiehall Street and Buchanan Street, with more upmarket retail activity in that last one. The denoted intense retail activity places Glasgow as UK's second largest and most economically important retail sector after London Central, self-explaining the wide interest in the study of city logistics for this area.

The city centre is constantly changing and evolving as land-use developments are taken forward and economic activity generates turnover in existing land-uses. This changes the needs for transport, as the demand to travel to different parts of the city, disregarding purpose, may increase or decrease accordingly. Understanding the likely impacts of the major land-use development proposals is therefore critical to developing a transport strategy.

Glasgow City Centre currently faces a number of transport related problems which current strategies seek to address. Keeping in mind this study's dedicated interest in freight activity in urban areas, only freight relatable issues (Sustrans, 2014) are referred below:

- Air Quality Issues: poor air quality from high traffic flows make streets like Hope Street, Renfield Street and Union Street unattractive to pedestrians;
- One-way System: there is a complicated and confusing network of one-way streets that make getting around and across the city centre difficult, especially for those unfamiliar with the area;
- Serving & Deliveries: the city centre has a high dependency on deliveries to operate but, in some areas, difficulties assessing premises by goods vehicles can cause problems and lead to illegal parking and thus, congestion and pedestrian issues;
- Peak Period Demand: many key streets into and out of the city centre experience high levels of traffic during the morning and evening rush hours, as well as some key through routes in the city centre;
- Loading activities: which, generating a lot of illegal parking, disrupt the flow of traffic, causing congestion.

The recent awareness for freight related issues and the importance of mitigating them is denoted in SPT's intention of developing freight strategies for the timeframe of 2014 to 2017. In these 3 years, SPT is aiming to undertake a multi-modal freight study to gather appropriate regional and local data to improve transport planning for freight, identify local and regional barriers to more efficient freight movements and establish realistic opportunities to reduce these barriers.

The city centre has, over a considerable period, maintained a consistently high quality, range and choice of retailing, largely important to tourism and the wider Glasgow economy, supporting approximately 15,000 jobs. Substantial retail investment over the last fifteen years (approximately 140,000 square metres) has played a large part in sustaining Glasgow's position as UK's second largest retail centre. The vitality of the city centre's retail activity is enhanced by the concentration of large-scale retail investment into a defined area, known as Principal Retail Area (PRA) focused on an almost 'Z' pattern formed by Sauchiehall Street, Buchanan Street and Argyle Street and definitely dominated by Buchanan Street. This area was defined in accordance with public transport accessibility and parking supply, concentration of retail outlets and quality of shopping environment. This provides consumers with easy and convenient access to a wide range of retail outlets and generates high levels of foot-fall and volumes of retail trade.

Retail is then the major representative of Glasgow commercial activity and accounts for a large, if not main, part of freight movements inside the city centre. Due to the magnitude of this activity, it becomes interesting to have the study of city logistics revolve around this market where policies implemented within this context will account for effective mitigation of many of the impacts arising from goods distribution in the city centre.

Logistics Patterns

Congestion, access restrictions, illegal parking and poor signing have been nationally identified as key problems facing companies and their drivers in delivering goods. Glasgow operates a wide variation in timescale restrictions for freight loading. On the radial route into the city centre, a peak hour time restriction is operated, while in the city centre itself restrictions apply during the working day.

Also, as main retail street in Glasgow, Buchanan Street is classified as a pedestrian street where deliveries can only take place from 6 to 10am, having the street to be clear of traffic by that time. Cars are banned from Sauchiehall Street, Argyle Street and Buchanan Street where deliveries made to those streets have to respect the defined time windows.

Access restrictions seem to be the most noted conflict between retailers and logistic providers. This is seen by far as the most common methods to discourage city centre deliveries at peak time, thus reducing congestion. On the other hand, smaller companies tend to attract deliveries direct from the supplier to the shop (Steer Davies Gleave, 2010).

RETAILERS CONSULTATION

Initial Approach

In order to study the viability of implementation of an urban distribution centre for retailers in Glasgow, the need for extensive information on inner dynamics of retail activity in the centre as well as retailers pre-disposition for embracing a scheme of this nature (highly dependent on their view of the logistics state) was crucial at this point of study of this potential solution. The contact opportunity with Glasgow's freight related dynamics allowed the identification of three entities whose authority is relevant when dealing with both traffic and commercial issues: SPT (Strathclyde Partnership for Transport), Glasgow City Council and Glasgow Chamber of Commerce.

After gathering information among these entities' available online data, a study report requested by SPT in 2010, elaborated by Steer Davies Gleave, on stakeholders' consultation on the possibility of implementing a freight consolidation centre serving Glasgow was found online mainly stating that back in 2010, retailers' view of an urban distribution centre serving Glasgow suggested that the idea was not appealing enough as well as not needed due to considerable satisfaction with their current deliveries schemes.

At this point, it became interesting to explore retailers' current views on this matter in order to find out if, five years later, potential changes to freight dynamics and satisfaction with delivery schemes could support the reconsideration of an urban distribution centre. Moreover, retailers' general rejection of such scheme would be, as highlighted on literature review, a definite deal breaker for its viability and thus, stakeholder consultation is a vital step for a study of this nature.

Taking that last thought into account, it was decided that the best way to obtain information on delivery patterns and to probe retailers' pre-disposition for embracing a distribution centre serving their shops, would be to develop surveys to be completed by shop managers from the main retail streets in the city centre. Besides retailers' consultation, surveys' necessity was also due to the lack of available information on freight patterns in the city centre.

Sample Choice

The set of stores qualifying as survey responders was too large of a universe to be surveyed by a single individual entity where an attempt to do so would only result in a statistically irrelevant sample and would be far from succeeding in being descriptive of the population in study. By imposing some restrictive parameters to Glasgow retailers' universe, it was possible to reduce the scope of the survey to retailers that, simultaneously:

- Currently integrate The Style Mile (a project dedicated to improving retail activity in the city centre);
- Do not manage goods requiring special storage and transport conditions (advisable on a UDC trial phase);
- Have their shops located in the Prime Retail Area and adjacent relevant streets (the focus on a smaller area is advisable on a UDC trial phase);
- Own high street shops (because shopping centres would typically have their own dedicated delivery scheme).

Obtaining a universe of **108** retailers.

Survey Structure

The survey was then composed by six chapters:

1. **Business/establishment characteristics**: business hours, type of business and ownership (or not) of warehouse space;
2. **General characteristics of deliveries**: number of suppliers, load factors of delivery vehicles and distance from vehicles' departure point;
3. **Specific characteristics of deliveries**: number of weekly deliveries, comparisons between a specific week (during Christmas) and a typical week, type of vehicles performing deliveries, time windows for delivery availability and satisfaction with deliveries scheme;
4. **Characteristics of the delivered goods:** size and amount per size of delivered goods, comparison between a specific week (during Christmas) and a typical week and online shopping services and volume of goods allocated to that service;
5. **Characteristics of loading and unloading operations:** identification of problems in loading/unloading operations;
6. **Urban distribution centres:** circumstances under which the integration in a UDC scheme would be accepted and priorities in the provision on that service.

Ultimately, this survey would allow the modeller to analyse the outcome of an urban distribution centre's feasibility through collection of information like: storage space requirements (according to volumes), number of daily required vehicles to fit the delivery needs of retailers, preferable location of the UDC, preferable accompanying measures and incentives for participation and willingness to participate.

Survey Results

After survey completion, only **38** responses were obtained while **83** retailers were approached. This lower than expected value is thought to be mainly due to the impossibility of shop managers of completing the survey without Head Office's authorization. However, the obtained answers are still valid for speculation about possible scenarios for a UDC scheme implementation.

Survey analysis allowed to notice that many shops already had their deliveries coordinated, especially for larger stores and the majority of vehicles already made deliveries to multiple establishments. This fact supports the idea that consolidation and coordination of deliveries are already implicit in Glasgow City Centre. A big majority of shops (82%) already had storage areas for their shops, corroborating the idea that most of the stores already process their stock in an auto-replenishment, just-in-time way. Thus, the possible advantage of transforming storage area into extra retail space brought by UDC schemes is not that appealing for retailers in Glasgow.

When approaching retailers on the conditions under which they would join a distribution centre, general opinion was that they would join a UDC if deliveries to their shops did not suffer any alterations and it did not involve any extra operation costs to their business. From the survey, and based on a set of simplifications, average values for demand volumes were also obtained for computation in the model to be developed.

VIABILITY OF AN URBAN DISTRIBUTION CENTRE

Model Presentation and Analysis

The optimization model, based on the formulation by (Muñoz-Villamizar, et al., 2014) was implemented in Xpress where the majority of the mathematical formulation was kept as the original in spite of a few changes needed to adapt the model to the situation to be modelled, which will be interspersed with the model description.

Main Sets

$$UDC = Urban\ Distribution\ Centres\ \{Albatrans, Eurogate, \dots, i\}$$

$$Node = Retailers\ \{Topshop, Wallis, \dots, j\}$$

$$Veh = Vehicles\ \{Veh1, Veh2, \dots, k\}$$

Decision Variables

$$A_i = \begin{cases} 1, & if\ a\ UDC\ is\ located\ in\ i \\ 0, & otherwise \end{cases}$$

$$X_{ijk} = \begin{cases} 1, & if\ vehicle\ k\ goes\ from\ UDC\ located\ in\ i\ to\ retailer\ j \\ 0, & otherwise \end{cases}$$

$$X_{jik} = \begin{cases} 1, & if\ vehicle\ k\ goes\ from\ retailer\ j\ to\ UDC\ located\ in\ i \\ 0, & otherwise \end{cases}$$

$$X_{jhk} = \begin{cases} 1, & if\ vehicle\ k\ goes\ from\ retailer\ j\ to\ retailer\ h \\ 0, & otherwise \end{cases}$$

Model Parameters

$$C_{ij} = cost\ matrix\ of\ travelling\ from\ UDC\ located\ in\ i\ to\ retailer\ j$$

$$C_{ji} = cost\ matrix\ of\ travelling\ from\ retailer\ j\ to\ UDC\ located\ in\ i$$

$$C_{jh} = cost\ matrix\ of\ travelling\ from\ retailer\ j\ to\ retailer\ h$$

$$C_i = Fixed\ cost\ of\ UDC\ i$$

$$Max_{UDc} = number\ of\ UDCs\ to\ open$$

$$D_j = demand\ of\ retailer\ i$$

$$CAP_k = capacity\ of\ vehicle\ k$$

Objective Function

$$Min\ Z = \sum_i \sum_j \sum_k C_{ij} \cdot X_{ijk} + \sum_i \sum_j \sum_k C_{ji} \cdot X_{jik} + \sum_i \sum_j \sum_k C_{jh} \cdot X_{jhk}$$

Constraints

Maximum number of UDCs: $\sum A_i \leq Max_{UDC}$

Vehicles routes can only be defined from an open UDC: $Veh \cdot A_i \geq \sum_i \sum_k X_{ijk} \quad \forall i$

Minimum number of routes/vehicles to meet total demand: $\sum_i \sum_j \sum_k X_{ijk} \geq \frac{\sum_j D_j}{CAP_k}$

Ensures that if a shop is visited from a UDC, the vehicle must go to another shop, starting from the same visited shop and in the same vehicle: $\sum_i X_{ijk} \leq \sum_h X_{jhk} \quad \forall j, \forall k$

Establishes that if a shop is visited it should go to another shop or return to the UDC in the same vehicle performing the route: $\sum_i X_{ijk} + \sum_h X_{hjk} = \sum_i X_{jik} + \sum_f X_{jfk} \quad \forall j, \forall k$

Ensures that all shops are visited exactly once, either from a shop or from the UDC: $\sum_i \sum_k X_{ihk} + \sum_j \sum_k X_{jhk} = 1 \quad \forall h$

Ensures that after a vehicle visits a shop it goes to another shop or returns back to the UDC: $\sum_h \sum_k X_{ihk} + \sum_i \sum_k X_{jik} = 1 \quad \forall j$

Forces all vehicle routes to begin and end in the same UDC: $\sum_j X_{ijk} = \sum_h X_{hik} \quad \forall i, \forall k$

Capacity constraint: $\sum_i \sum_j X_{ijk} \cdot D_j + \sum_j \sum_h X_{hjk} \cdot D_j \leq CAP_k \quad \forall k$

Limits at most one route per vehicle: $\sum_i \sum_j X_{ijk} \leq 1 \quad \forall k$

Ensures that only vehicles that depart from the UDC can circulate within the city **(added to the original formulation)** $\sum_i \sum_j X_{ijk} \geq X_{hjk} \quad \forall k$

When performing test runs of the model, it was noted that sub tours within the solution were appearing. According to Muñoz-Villamizar, the constraint below would eliminate sub tours within the solution. However, the author himself did not explore the constraint past its presentation and a proper way to transpose that equation to Xpress was not found and it was thus impossible to eliminate sub tours with the aid of that constraint.

$$u_j - u_h + N \cdot X_{jhk} \leq N - 1 \qquad \forall j, \forall h, \forall k$$

To enable the elimination of sub tours in a different way, in spite of an acknowledged existence of associated errors, the model was programmed to detect the existence of sub tours in each route, easing the trouble of identifying them and, afterwards, the whole route containing the sub tour would be subject to a new model run for only the featured retailers in the route, chosen UDC location and single vehicle.

Delivery Points

When approaching the problem as an LRP, the amount of information to be processed by Xpress when considering 108 retailers was too much to obtain reasonable optimization values within feasible running times for the model, not even being able to reach a close to best bound solution within 24 hours.

In order to correct that and alleviate the input information, the solution was to create delivery points (DP). Those delivery points would correspond to vehicle stops and, for shops within a range of 140 m, deliveries would be made on foot from their assigned DP. To optimize the location of those DPs within the network of retailers to serve, the approach was to consider it as a **p-median problem**, a problem of locating P delivery points (in this case) in relation to a set of retailers such that the sum of the shortest weighted distance between retailers and delivery points was minimized.

When running the formulation on Xpress, a total of 21 delivery points were obtained, that being the number of nodes to be considered in the optimization model.

Cost Matrix

According to (Muñoz-Villamizar, et al., 2014), the costs to be considered in the model should be divided per type of movement: from a node to a potential UDC, from a potential UDC to a node and from a node to another node. Therefore, three cost matrixes have to be defined, for the costs of those three types of movements within the city.

To convert distances into costs, an average cost of 1.59 €/L was considered for fuel in Glasgow (The Automobile Association, 2015) and average fuel consumption values per type of vehicle were estimated based on (EMSD, 2015) tabled values. Similarly, vehicle emissions values were based on (DfT, 2015).

Scenario creation and results

The creation of a group of scenarios attempts to understand what would currently suit Glasgow best in the implementation of an urban distribution centre. Since the main goal was to explore a solution that prioritized the sustainable distribution of freight in Glasgow city centre, the developed scenarios attempt at evaluating the location that presents the best trade-off between proximity to the city centre (and thus less pollutant delivery schemes from shorter tours) and investment costs (which, for potential locations further from the city centre are inferior). Alongside that first goal of scenario creation, it is also an objective to extract information that allows comparison with the current delivery schemes and thus the impact of a UDC in the improvement of sustainability of delivery schemes.

All scenarios work on a total shift from heavy goods vehicles to lighter solutions, whether they are small trucks, light goods vehicles of electric vehicles. Since the optimization model will use data reporting to one day of deliveries, every other data components will be shaped to fit that same timeframe.

Scenario 1 worked with a UDC inside the city centre (which implied extra infrastructure and vehicle costs since, according to (Steer Davies Gleave, 2010), they were not optimized to assume a UDC scheme), with 21 m^3 vehicles (small trucks), scenario 2 worked with the same vehicle fleet but with a UDC in the periphery of the city centre (which assumed that the existing infrastructure and diesel vehicle fleet were enough to adapt the facility to a UDC). Scenario 3 worked with a UDC inside the city centre but with a majority of light goods vehicles (14 m^3 capacity) and only a few small trucks. Similarly, scenario 4 worked with the same vehicle fleet but with a UDC in the periphery of the city centre. The scenarios considering facilities in the periphery of the city centre were considered to already have the adequate and vehicle fleet and infrastructure to accommodate a UDC, according to (Steer Davies Gleave, 2010).

When considering the same scenarios running with electric vehicles, type 1 electric vehicles (EV) substitute LGVs and type 2 electric vehicles substitute small trucks, capacity-wise.

Table 5 – Summary of scenario results

		Chosen UDC	Travelling Costs	Emissions Costs	Vehicle Costs/Day	Infrastructure Costs/Day	Total Daily Costs
Scenario 1	7 Small trucks	Albatrans	3.73 €	0.31 €	**167.87 €**	857.08 €	1 028.68 €
	7 Type 2 EV		- €	- €	340.33 €	857.08 €	1 197.41 €
Scenario 2	6 Small trucks	TNT	69.97 €	5.90 €	- €	- €	69.97 €
	6 Type 2 EV		- €	- €	340.33 €	- €	340.33 €
Scenario 3	6 Small trucks + 3LGVs	Albatrans	**3.40 €**	**0.29 €**	169.20 €	857.08 €	1 029.68 €
	6 Type 1 EV + 3 Type 2 EV		- €	- €	306.11 €	857.08 €	1 163.19 €
Scenario 4	5 Small trucks + 3LGVs	TNT	68.87 €	5.80 €	- €	- €	**68.87 €**
	5 Type 1 EV + 3 Type 2 EV		- €	- €	**274.00 €**	- €	**274.00 €**

Scenario 3 represents the lowest travelling costs, justified by having a facility inside the city centre as UDC location. Through the same logic, it is also the one with least emissions costs, resulting from less driven kilometres and the use of light goods vehicles (less pollutant than small trucks). In terms of vehicle costs per day, when using diesel vehicles, Scenario 1 is the one with less investment costs since the dimensioned fleet for that scenario is composed by less vehicles (in comparison to Scenario 3, since the other two do not contemplate the acquisition of diesel vehicles). When considering the same scenarios running with electric vehicles, Scenario 4 has the lower investment costs in a vehicle fleet since it considers Type 1 Electric Vehicles, which have an extra associated incentive of 69 000 € from the Energy Saving Trust in Scotland (Smith Electronic Vehicles, 2015) for electric fleet acquisition and contemplate more of those type of vehicles than Scenario 3.

Regarding infrastructure costs, having the UDC located in TNT (Scenarios 2 and 4) will always represent less costs since no renting of warehouse space is considered necessary. Having Albatrans serving as UDC for the other two scenarios, the daily infrastructure costs will be constant. In terms of total daily costs, Scenario 4 is the most economic scenario for both diesel and electric vehicles consideration.

Assuming Buchanan Street's time window for deliveries (6am to 10 am – 4 hours) for the whole city centre, it will assumed that each vehicle should not have a permanency inside it longer than 4 hours. To evaluate compliance with that rule, driven distances inside the city centre were calculated based on the sum of distances from nodes to other nodes (which always occur inside the city centre) and the parcel of distance inside the city centre from the UDC to a node and back.

Road chiefs in Glasgow City Council plan to roll out a scheme in March 2016 establishing a maximum speed of 32 Km/h (20mph) as a low emission zone (LEZ) definition policy. With that limit in mind, an average travel speed of **30 km/h** was considered for vehicles driving inside the city centre, allowing to obtain the total time of driving inside it per vehicle. Moreover, for each delivery point, the sum of distances between all retailers associated to each DP was calculated and a **15 minute** period was considered necessary for loading and unloading operations for each retailer and a speed of **3 km/h** was assumed for deliveries on foot, performed by two people per vehicle.

Table 6 – Total time inside the city centre (hours)

Scenario	Vehicle 1	Vehicle 2	Vehicle 3	Vehicle 4	Vehicle 5	Vehicle 6	Vehicle 7	Vehicle 8	Vehicle 9
Scenario 1	1.93	1.27	1.77	1.77	**4.07**	0.99	2.53	-	-
Scenario 2	1.65	2.30	2.64	1.65	3.15	2.01	-	-	-
Scenario 3	2.27	0.97	2.33	1.86	0.97	0.84	2.10	2.14	1.03
Scenario 4	1.07	1.64	2.38	1.76	0.65	1.68	2.60	2.29	-

Another aspect to evaluate is the significance of emissions reduction for each scenario, being one the most important decision factors. In order to estimate that reduction in comparison to the current scenario (without UDC), the survey answers for the number and type of vehicles performing deliveries to each establishment were taken into account. From the survey, a rough estimate of the average number of vehicles circulating in the city centre, per delivery and prior UDC implementation was obtained for the whole population under survey (108 retailers).

Table 7 – Estimation of the number of vehicles in the city centre per delivery (prior to UDC implementation)

	LGV	Small Truck	HGV
Average number of vehicles per delivery for all surveyed retailers	15.9	15.5	3.9
Average number of vehicles per delivery per retailer	0.4	0.4	0.1
Total number of vehicles per delivery for the population	46.3	45.2	11.4
Total number of vehicles (considering coordination of deliveries	30.6	29.8	7.5

To estimate the emissions for the current situation in Glasgow City Centre, the tabled values for emissions were applied in this case.

Table 8 – Estimation of the number of vehicles in the city centre per delivery (prior to UDC implementation)

Scenarios	Total emissions (g CO2)	Total emissions (g CO2/Km)	Emissions reduction (g CO2/Km)
Current Scenario	-	29610.0	-
Scenario 1	6290.7	3620.7	25989.3
Scenario 2	12005.1	3103.4	26506.6
Scenario 3	5734.1	3320.5	26289.5
Scenario 4	10028.8	2803.3	26806.7

At this point, Scenario 1 is the one with higher total costs, the only one that does not comply with legislation regarding time windows for one of its routes and the one with less reduction of emissions per kilometre. Moreover, when compared to Scenario 3, that runs with the same UDC, this last one represents a better option in fleet dimensioning for emissions and daily costs. Therefore, Scenario 1 does not qualify as best scenario.

When comparing Scenario 2 with Scenario 4, where both have TNT as UDC location, Scenario 4 represents less total daily costs and emissions, meaning that Scenario 4 will always be a best choice when compared to Scenario 2.

Scenario 3 represents smaller values of total emissions than Scenario 4. However, the vehicle fleet dimensioned for Scenario 4 represents a bigger amount of emissions reduction (g CO^2/Km) where a higher value of total emissions for this scenario is explained by the extra kilometres that vehicles coming from TNT have to drive from the moment they enter the city centre to the moment of arrival to the retail area, which will always be associated with a distribution centre located in the periphery.

Coming down to choosing between Scenario 1 and Scenario 4 practically means choosing to locate the UDC inside the city centre or on its periphery. At this point, acknowledging past considerations on best practices for UDC implementation from literature review and Steer Davies Gleave study, the decision criteria will lay on those considerations for a UDC in trial phase.

On that note, according to Steer Davies Gleave study, the cost of property for an urban distribution centre represents about 50% of the total investment costs of setting up the whole operation. In all cases, the idea of building a purpose built facility to deliver a city centre service is seen, by logistics providers, unpractical, not cost effective and not the best use of resources. As for staffing and transportation costs (which represent the other half of investment costs), it was believed, by logistics providers in Glasgow, that those costs would not be that high if based on the adaption of their existing operation. Also, as seen on literature review of existing urban distribution centres studies in other European cities, the number of users is a crucial factor in all success and failure cases.

Scenario 4 is thus the one that best fits the above considerations: it would be based on a facility that has already the proper infrastructure to accommodate a distribution centre and TNT has the biggest market share of deliveries in Glasgow City Centre (60% among surveyed retailers by Steer Davies Gleave), being on the right track to guarantee a certain number of retailers joining the scheme. Moreover, the success of Albatrans (in Scenario 3) has an urban distribution centre would be highly dependent on the ability to adapt its infrastructure to a UDC scheme, especially in terms of warehousing space.

Finally, back in 2010, in the SPT study, it was felt that electric vehicles, while desirable, would be an expensive investment unless fully funded by public subsidy and any funding resource would be, in the short term, best placed to modify existing vehicles to become more efficient with a long term goal of providing an electric vehicle service.

CONCLUSIONS AND FUTURE WORKS

One of the most challenging tasks of this work was the attainment of concrete data to model the solution to be explored. Here, the obtained results fell somehow far from what was expected in terms of data relevance: the number of collected responses was not entirely representative of the population under study and the provided answers contained a certain degree of unawareness from shop keepers regarding urban distribution centres and their own delivery schemes, where direct approach to Head Offices would have solved this last gap in knowledge.

Because of the limitations in data attainment and computational constraints it was felt that the work did not live up to its full potential in terms of scenario creation and consequent conclusions. Instead, the output represents more of an indicative procedure on how the viability of implementation of an urban distribution centre serving Glasgow City Centre should be studied, providing the guidelines for a work to be carried with extensive collection of data on freight dynamics and stakeholders view on the implementation of the concept. Here, a full assessment of the willingness of retailers to take part in an urban distribution centre and the disposition of logistics providers to adapt their facilities to the concept, with full awareness of the involved costs and changes in the city's deliveries schemes is thought to be crucial.

It then is still very important to determine the most appropriate scale of a freight mitigation strategy as is defining a 'where to start' point of a detailed study on this field, which is highly dependent on the complete establishment of the retail versus supply/ demand pressures for the prime retail area, aligning current delivery and waiting constraints with the appetite Glasgow City Council may have for tightening or lengthening any restrictions as a 'stick' measure.

A comprehensive audit of all delivery and stock movements is therefore essential to fully understand the delivery profile for the whole retail area rather than applying an average approach from the data made available through retailers' consultation process. Moreover, a selection process should be completed in order to establish the most adequate logistics partner to serve as a UDC, offering much more credibility and weight for establishing such a service.

Also, patterns of freight movements within the chosen area must be closely monitored. When suitable data is already available, new surveys should be conducted to determine the volumes, mix and scheduling of deliveries and collections. Retail outlets generate significant volumes of return product and packaging waste that if often collected by separate vehicles, which was not a consideration made in this study.

It is also questionable the level of public funding that may be required to set up such a service. The need for subsidizing appears to be focused during the setup period as the distribution centre establishes itself in the market. However, the possibility of having the whole trial service with the full support of the public bodies is thought to be necessary for the success of the UDC. The necessity comes from the need to cover adaption costs for existing warehousing space plus a trial period cost saving in order to be able to provide attractive rates to potential customers to increase customer retention.

For a distribution centre to be effective and sustainable, it would need numerous retailers. This, as would not be possible to deliver all products within the normal access restrictions, would need a relaxation of any parking or delivery restrictions for vehicles associated with the UDC. In Glasgow, it was especially obvious that the willingness of retailers to join an urban distribution centre was very dependent on time-related issues. Retailers in Glasgow city centre have their deliveries occur according to their economic capability for having out-of-hours employees receiving the deliveries or, on the other hand, having them delivered before store-opening, on a very strict and specific time frame. In fact, when surveying retailers, the majority said that the deal breaker for joining a distribution centre would be the alteration of their delivery schemes. Therefore, if wanting to implement a UDC serving Glasgow's retail centre, retailers' individual preferences regarding deliveries (period for delivery, number of deliveries a week, delivery costs) would have to be very carefully evaluated. Briefly, the implementation of an urban distribution centre should play on three main fronts:

- The attraction of a significant amount of retailers, manageable through the respect for their preferences regarding deliveries as well as the introduction of a certain degree of compliance, attainable through the limitation of access conditions, both physical and time-related;
- The interest of public bodies, mainly SPT and Glasgow City Council, to recognize an urban distribution centre as a valid solution for freight activity mitigation (this acknowledgment is essential mainly due to the need for public funding for a successful building up of the operation);
- The study of logistics providers stands towards the UDC concept, guaranteeing that none see it as an attempt of monopolizing the market since it is these entities that are able to gain trust with existing clients and who can then engage with the decision makers to promote the change required at the same time they have the knowledge of how an urban distribution centre could benefit the demands of their clients.

In the end, is it the willingness of this group of stakeholders in welcoming the UDC concept that will determine the success of its implementation. Unfortunately, the degree of understanding of that stigma in this study only scratches the surface. The study of freight dynamics is still very incomplete and thus the output of modelling for UDC implementation presents a merely indicative suggestion of the best path for UDC implementation in Glasgow.

The need to quantify all involved costs in the built up of this operation is still to be done as is the collection of more concrete data for comparison of scenarios with and without the urban distribution centre. The usage of delivery points, though interesting to explore less intrusive delivery solutions (based on on-foot or bicycle deliveries) is not optimized nor viable to offer retailers the stands they demand for delivery times. Also, the estimation made for infrastructure and vehicle costs is merely indicative and does not reflect real associated costs to the setting up of a UDC.

In what concerns the ideal location of an urban distribution centre, this work corroborates the conclusions made by Steer Davies Gleave in 2010, stating that the ideal location should be associated with an accredited logistics provider who could deliver the right infrastructure without significant investment. Also, the purchasing of electric vehicles should not be done at an early stage of the UDC implementation but it would be important to develop the scheme with that medium-term goal in mind for the design of the operation.

Regarding the optimization model, eventual carrying of future work should be able to surpass some of the computational constraints denoted is this study, mainly related to the elimination of sub tours and a best approximation to more optimized solutions for a bigger quantity of data.

Further work is then essential to fully appreciate the benefits of creating a retail focused distribution centre. If deciding to do so in order to develop a real attempt at UDC implementation, stakeholders should be approached at an early stage of the process, guaranteeing that their levels of interest are fully assessed.

REFERENCES

[1] Anand, N., Quak, H., van Duin, J. & Tavasszy, L., 2012. City Logistics Modeling Efforts: Trends and Gaps - A Review. *Procedia - Social and Behavioral Sciences,* Volume 39, pp. 101-115.

[2] BESTUFS, 2006. *Deliverable D 1.1 BESTUFS Policy and Research Recommendations I. Urban Consolidation Centres, Last Mile Solutions,* s.l.: s.n.

[3] Browne, M., Allen, J. & Leonardi, J., 2011. Evaluating the use of an urban consolidation centre and electric vehicles in central London. *IATSS Research,* Volume 35, pp. 1-6.

[4] Browne, M., Sweet, M., Woodburn, A. & Allen, J., 2005. Urban Freight Consolidation Centres Final Report. *Transport Sudies Group, University of Westminster.*

[5] CSCMP, 2014. *CSCMP Supply Chain Management.* [Online]
Available at: https://cscmp.org/about-us/supply-chain-management-definitions

[6] DfT, 2015. *Van Fuel Data.* [Online]
Available at: http://vanfueldata.dft.gov.uk/vehicles.aspx
[Accessed September 2015].

[7] EMSD, 2015. *Transport - Energy Utilization Index.* [Online]
Available at: http://ecib.emsd.gov.hk/en/indicator_trp.htm

[8] Lindholm, M., 2012. How Local Authority Decision Makers Address Freight Transport in the Urban Area. *Procedia - Social and Behavioral Sciences,* Volume 39, pp. 134-145.

[9] Muñoz-Villamizar, A., Montoya-Torres, J. & Herazo-Padilla, N., 2014. Mathematical Programming Modeling. *Ingeniería y Universidad.,* Volume 18 nr 2, pp. 271-289.

[10] Muñuzuri, J., Larrañeta, J., Onieva, L. & Cortés, P., 2005. Solutions applicable by local administrations for urban logistics improvement. *Cities,* Volume 22, pp. 15-28.

[11] Oliveira, L. K. d. et al., 2012. Adoption Assessment by Carriers and Retailers to Use an Urban Consolidation Center - A Case Study in Brazil. *Procedia - Social and Behavioral Sciences,* Volume 39, pp. 783-795.

[12] Quak, H. J. & van Duin, J. H. R., 2007. *City logistics: a chaos between research and policy making? A review.* Southampton, UK, s.n., pp. 135-146.

[13] Russo, F. & Comi, A., 2010. A classification of city logistics measures and connected impacts Francesco. *Procedia - Social and Behavioral Sciences,* pp. 6355-6365.

[14] Smith Electronic Vehicles, 2015. *Smith Vehicles - Incentives.* [Online]
Available at: http://www.smithelectric.com/smith-vehicles/incentives/united-kingdom/

[15] Steer Davies Gleave, 2010. *Freight Consolidation Centre. Stakeholder Consultation,* s.l.: s.n.

[16] Sustrans, 2014. *Glasgow City Centre Transport Strategy 2014-2024,* s.l.: s.n.

[17] The Automobile Association, 2015. *Fuel price report - UK & Overseas price.* [Online]
Available at: http://www.theaa.com/motoring_advice/fuel/
[Accessed September 2015].

[18] Transportation Research Board, 2013. *City Logistics Research: a Transatlantic Perspective.* s.l.:s.n.

[19] van Duin, J., Quak, H. & Muñuzuri, J., 2010. New challenges for urban consolidation centres: A case study in The Hague. *Procedia - Social and Behavioral Sciences,* Volume 2, pp. 6177-6188.

[20] van Duin, J. et al., 2012. Towards an Agent-Based Modelling Approach for the Evaluation of Dynamic Usage of Urban Distribution Centres. *Procedia - Social and Behavioral Sciences,* Volume 39, pp. 333-348.

[21] Ville, S., González-Feliu, J. & Dablanc, L., 2013. The limits of public policy intervention in urban logistics: The case of Vicenza (Italy) and lessons for other European cities. *European Planning Studies,* pp. 1528-1541.

[22] Witkowski, J. & Kiba-Janiak, M., 2014. The Role of Local Governments in the Development of City Logistics. *Procedia - Social and Behavioral Sciences,* Volume 125, pp. 373-385.