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Promising but challenging urban freight transport solutions: freight flow consolidation and off-hour deliveries

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List of Abbreviations

AHP	Analytic Hierarchy Process
AT	Additional transfer
BAU	Business as Usual
BC	Behaviour of carriers
BMA	Business model analysis
BRS	Behaviour of retailers and/or shippers
CAPEX	Capital Expenditures
CBA	Cost Benefit Analysis
CD	Common delivery
CEA	Cost Effectiveness Analysis
CEP	Courier, Express and Parcel
CH ₄	Methane
CNG	Compressed Natural Gas
CO	Carbon monoxide
CO ₂	Carbon dioxide
EEA	Economic Effects Analysis
ELP	Espace de Livraison de Proximité
EU	European Union
FQP	Freight Quality Partnerships
g	gram
GDSM	Group Decision Support Methods
GPS	Global Positioning System
HC	Hydrocarbons
HGV	Heavy Goods Vehicles
HoReCa	Hotels, Restaurants and Cafés
ITS	Intelligent Transport System
km	kilometre
KPI	Key Performance Indicators
LNG	Liquid Natural Gas
LSP	Logistics Service Provider
LTG	Large Traffic Generators
MAMCA	Multi Actor Multi Criteria Analysis
MCA	Multi Criteria Analysis
MCDA	Multi Criteria Decision Analysis
MD	Mobile Depot
mg	milligram
NO _x	Nitrogen oxides
OPEX	Operational Expenditures
PIA	Private Investment Analysis
PM	Particular matter

PM2.5	Fine particles (diameter of 2.5 micrometres or less)
PM10	Fine particles (diameter of 10 micrometres or less)
PPP	Public Private Partnerships
PSD	Platform Stedelijke Distributie
SCBA	Social Cost Benefit Analysis
SOx	Sulphur oxides
SUMP	Sustainable Urban Mobility Plan
UCC	Urban Consolidation Centre
UK	United Kingdom
USA	United States of America
vkm	Vehicle kilometre
VOC	Volatile organic compound

Abstract

Although inevitable, urban traffic causes air pollution, noise pollution and congestion. Up to 20% of urban traffic is related to freight transport and service trips and, proportionally, it contributes more to the negative side-effects of urban traffic than passenger related traffic. Throughout the past few decades, a range of solutions to reduce the negative impact of urban freight transport have been researched, tested and implemented. Two possible solutions are: freight flow consolidation and off-hour deliveries. They have two things in common. First, despite the fact that it is generally accepted that there are considerable benefits to both solutions they seem to remain permanently promising and have not been widely adopted yet. Second, they require support of both public and commercial stakeholders to be successful in the long term. The purpose of this thesis is to identify feasible, consensual and successful applications of urban freight flow consolidation and off-hour deliveries. To reach that goal a twofold approach is adopted: (i) reassessing the generally accepted logic behind freight flow consolidation and off-hour deliveries as well as their impact and (ii) evaluating both concepts and/or their applications from the perspective of all stakeholders.

One possible freight flow consolidation solution is to implement an Urban Consolidation Centre (UCC). A review of the available UCC impact assessment made me conclude that 87% of UCCs have a positive impact on the number of urban freight vehicle kilometres. However, this positive impact might have to partially be put down to the lack of high-quality urban freight data and the consequent too positive estimations. Despite the dominant attention for UCCs in the literature on urban freight flow consolidation, there are alternative approaches. This thesis identifies and categorizes them and cites existing, often small-scale examples. One possible alternative approach is to use a Mobile Depot for express deliveries and pick-ups. Evaluating this concept revealed that it decreases the amount of emitted pollutants and the number of diesel vehicle kilometres but doubles the operational costs for the express service provider. The thesis also demonstrates that there is no overall stakeholder support for a general shift of urban freight flows to off-hours in Belgium. There are, however, freight flows that are more suited than others to be shifted to off-hours. My research identifies these freight flows and characterizes them. Based on this research, one particularly suited freight flow would be supermarket deliveries. Evaluating a trial that took place in Brussels revealed that there are considerable time and fuel savings when deliveries to two supermarkets in Brussels are shifted to off-hours and that this solution would be able to receive overall stakeholder support when sufficient measures are taken to keep the noise nuisance for local residents to a minimum. Finally, the thesis contributes to the research field of urban freight transport by introducing the concept of stakeholder involvement in the evaluation of urban freight transport solutions by using Multi Actor Multi Criteria Analysis which is an evaluation tool that explicitly includes the goals and objectives of all stakeholders.

Keywords: Urban freight transport, Urban distribution, City logistics, Consolidation, Urban consolidation centre, Off-hour deliveries, Evaluation, Multi Actor Multi Criteria Analysis, Stakeholder involvements

Samenvatting

Het groot aantal gemotoriseerde voertuigen in steden heeft een aantal ongewenste neveneffecten zoals luchtvervuiling, geluidsoverlast en filevorming. Tien tot twintig procent van die voertuigen kunnen gelinkt worden aan het vervoer van goederen of aan het leveren van diensten en hun proportioneel aandeel in die ongewenste neveneffecten kan zelfs oplopen tot boven de 50%. De voorbije decennia is dan ook gezocht naar manieren om stedelijk goederenvervoer te verduurzamen en werden een aantal mogelijke oplossingen getest en toegepast. Twee van die oplossingen zijn: het meer en/of beter bundelen van goederenstromen en het verschuiven van goederenstromen naar de daluren. Beide concepten hebben gemeenschappelijk dat ze vandaag nog niet op grote schaal toegepast, ondanks het feit dat ze algemeen beschouwd worden als goede oplossingen en dat ze draagvlak moeten hebben bij zowel publieke als commerciële actoren om op lange termijn succesvol te zijn. Het doel van dit proefschrift is om haalbare en duurzame toepassingen van deze concepten te identificeren die aanvaardbaar zijn voor alle betrokken actoren. Om dat doel te bereiken heb ik een dubbele aanpak gevolgd: enerzijds heb ik de algemeen aanvaarde logica achter en impact van beide concepten herbekeken en anderzijds heb ik de concepten en hun toepassingen geëvalueerd vanuit het perspectief van de verschillende betrokken actoren.

Goederenstromen meer en/of beter bundelen kan enerzijds door de stromen via een stedelijk distributiecentrum de stad binnen te brengen. In dit proefschrift bestudeerde ik bestaande evaluaties van stedelijke distributiecentra. Daaruit bleek dat 87% van de stedelijke distributiecentra een daling van het aantal voertuigkilometers tot gevolg hadden. Ondanks de dominante aandacht voor distributiecentra in de literatuur rond het bundelen van stedelijke goederenstromen zijn er ook nog andere manieren om die stromen meer en/of beter te bundelen. In mijn proefschrift worden die manieren structureel opgelijst en geef ik een aantal reeds bestaande, vaak kleinschalige, voorbeelden. Eén van die alternatieven is het gebruik van een mobiel depot. Mijn evaluatie van het concept in de sector van de pakjesdiensten toont aan dat de uitstoot van schadelijke stoffen en het aantal gemotoriseerde kilometers daalt, maar dat de operationele kost voor de dienstverlener verdubbelt waardoor het draagvlak voor de oplossing in zijn geteste vorm laag is. Het proefschrift toont ook aan dat het draagvlak voor een algemene verschuiving van stedelijke goederenstromen naar de daluren in België laag is. Er zijn echter wel goederenstromen die meer geschikt zijn dan andere om naar de daluren te worden verschoven. In het proefschrift worden deze stromen geïdentificeerd. Een voorbeeld van zo'n stroom zijn de stromen tussen de distributiecentra van supermarkketens en hun supermarkten. Mijn evaluatie van een proefproject in die sector toont aan dat er aanzienlijke tijd- en brandstofbesparingen te boeken zijn als supermarkten 's morgens, 's avonds of 's nachts belevend worden in plaats van overdag en dat het mogelijk moet zijn draagvlak te vinden bij alle betrokken actoren op voorwaarde dat er voldoende maatregelen genomen worden om de geluidsoverlast voor omwonenden te beperken. Naast de focus op twee specifieke oplossingsconcepten draagt het proefschrift ook bij tot het onderzoek naar duurzamer stedelijk goederenvervoer door een evaluatiemethode toe te passen die de verschillende actoren en hun doelstellingen expliciet opneemt: de Multi Actor Multi Criteria Analyse.

1

Introduction

1.1 Urban freight transport

Cities have multiple functions. Not only do people reside in them; they are also workplaces and places for education, leisure, production, administrations, shopping and health care which turns them into dominant centres of production and consumption. More than 80% of global domestic product is created in cities (World Bank, 2013). Since most goods are not consumed where they were produced, big volumes of goods need to be transported to and from the urban market to keep this system going. Without frequent and reliable urban freight transport both urban production and consumption would come to a stop and the city would lose a part of its attractiveness and competitiveness (See for example Browne, 1999; Allen, Anderson, Browne & Jones, 2000; Rodrigue, Comtois & Slack, 2006; Lindholm & Behrends, 2012).

Many different terms are used to refer to the transport of goods within, into, through or out of a city or urban area. The most common are 'urban freight transport', 'urban goods transport' and 'urban distribution' (Lindholm, 2012). Each author defines the term he is using in a different way (Quak, 2008). What they have in common is that they all touch upon three important aspects: the transportation aspect, the geographic aspect and the commodity aspect. Concerning the transportation aspect, most of them refer to "movement" or "transport" (Ogden, 1992; Ambrosini & Routhier, 2004; Munuzuri, Larraneta, Onieva & Cortes, 2005; Dablanc, 2008; Lindholm, 2012). OECD (2003) does not mention the movement aspect at all while others specify the type of vehicle that is used for the deliveries (and collections). For Allen et al. (2000), urban distribution transport can only be carried out with motorised vehicles (goods vehicles and other). Hicks (1977) refers to "road vehicles specifically engaged in pick-up or delivery of goods" and emphasizes that also empty vehicles should be taken into account. Dablanc (2008) specifically mentions that also vans can carry out urban freight transport, but only when it is done by professionals. Geographically, most definitions locate movement or transport in the "urban area" without defining what an urban area is (e.g. Ogden, 1992; Allen et al., 2000; Lindholm, 2012). Some definitions are more specific and mention both the city and the suburban area (OECD, 2003) or refer to morphological and traffic conditions associated with an urban context (Munuzuri et al., 2005). All definitions state that freight transport can be called urban when freight is moved to, from or within the urban area. A few of them also consider freight traffic "crossing the urban territory without delivering goods" as urban freight traffic (Ogden, 1992; Ambrosini & Routhier, 2004; Dablanc, 2008; Lindholm, 2012). The definitions mutually differ most on the commodities aspect. The basic distinction made is that it concerns the transport of "things (as distinct from people)" (Ogden, 1992). OECD (2003) further specifies this into "consumer goods, not only by retail, but also by other sectors such as manufacturing. Ambrosini & Routhier (2004) consider

household purchasing trips as urban freight transport while Dablanc (2008) explicitly excludes them because the transport is not carried out by professionals. Just like the others who give more detail about the type of goods, she does consider home deliveries as urban freight transport, however. Also transport of things that cannot be consumed is mentioned, e.g. waste collection (whether or not clean), urban road maintenance, money collections and deliveries (Allen et al., 2000; OECD, 2003; Ambrosini & Routhier, 2004; Dablanc, 2008). Allen et al. (2000) formulate it more generic. For them, both core goods collection and deliveries, goods transfers between urban premises and ancillary goods deliveries to urban deliveries are urban freight traffic. Together with Lindholm (2012) who merged the existing definitions, they are the only authors that also mention service transport in their definition. Apart from “urban freight transport”, “urban distribution” and “urban goods transport”, the term “city logistics” is also used. There are a few important differences. First, “city logistics” does not only relate to the transport activities of companies in urban areas but also to their logistics (Taniguchi, Thompson, Yamada & van Duin, 2001). Second, the aspect of improvement, innovative solutions and efficiency gains (both economic and environmental) is included (OECD, 1996; Yanqiang, 2014). Some authors even define it as one specific solution, being a cross-company model of distribution which consolidates the loads of the different companies that are part of the scheme (Benjelloun, 2009). In this thesis, we will use the term urban freight transport and keep to the definition of Allen et al. (2000) because it considers all types of transport within, to, out of and through an urban area of which the aim is not merely to transport people. In their definition urban freight transport includes:

- “All types and sizes of goods vehicles and other motorised vehicles used for (core) goods collections and deliveries at premises in the urban area”
- “All types of goods vehicle movements to and from urban premises including goods transfers between premises, ancillary goods deliveries to urban premises, money collections and deliveries, waste collections and home deliveries made from urban premises to customers”
- “Service vehicle trips and other vehicle trips for commercial purposes which are essential to the functioning of urban premises”

The majority of urban freight movements are done by road. In the 28 countries of the European Union (EU), 71.6% of the inland tonne-kilometres are done by road (European Commission, 2014). The other 29.4% are done by rail, inland waterways and pipelines. Figures on modal split for urban freight transport on a European level do not exist, but it can be expected that road transport will be even more dominant since rail, inland waterways and pipelines are mainly suited for long distance transport (Marinov et al., 2013). The many urban freight surveys that were carried out for individual cities or urban areas give some insight in the type of vehicle that is used for urban freight transport. A review of 30 United Kingdom (UK) urban freight surveys reveals that in the UK vans (or light goods vehicles) are used for 41% of urban deliveries on average (Cherret et al., 2012). Rigid goods vehicles are also frequently used (38%) while articulated goods vehicle are used for 17% of the deliveries. The trend that vans are the dominant mode in urban freight transport is confirmed by a Brussels study indicating that at any time of day, more than half of freight vehicle in Brussels are vans (Lebeau & Macharis, 2014). A Dutch study that found that in Utrecht and Rotterdam, light goods vehicles are responsible for 33% and 40% of urban deliveries respectively (Schoemaker, Allen, Huschebeck & Monigl, 2006). However, the same Dutch study found that in Amsterdam, the dominant mode are heavy goods vehicles (41%) closely followed by passenger cars (38%). The British and Dutch studies strongly disagree on the proportion of passenger cars in urban freight transport. In the Netherlands, they are responsible for 33% of the deliveries on average while in the UK that is only 7% (Schoemaker et al., 2006; Cherret et al., 2012). The 7% average is only based on the 8 surveys that had “passenger cars” as a separate category in their survey. The other surveys did not consider passenger cars as a possible transport mode for urban freight transport or put them under the category “other” (Allen, Browne, Cherret & McLeod, 2008). Other urban freight studies confirm the dominance of vans. In Liège (Belgium), for example, 58% of the vehicles doing deliveries or pick-ups in the city-centre are vans (Debauche, 2006). For every heavy goods vehicle entering or leaving the Paris region (France), 1.4 light goods vehicle are entering or leaving as well. Within Paris, vans are even more dominant representing 80% of all delivery vehicles (Augerau, 2009). None of the urban freight surveys consider bicycles, motor cycles and/or mopeds as fully-fledged freight vehicles. Or they were not mentioned, or they were put in the category “other” together with, for example, taxis and/or mini busses. In the UK, less than 5% of urban deliveries are carried out by “other” vehicles on average (not taking into account the studies where passenger cars are also in the category “other”) (Allen et al., 2008). Based on the studied urban freight studies, we can assume that urban deliveries and pick-ups in Europe are usually carried out by heavy goods vehicles, light goods vehicles and passenger cars. Only a minority of these vehicles are alternatively powered (Schoemaker et al., 2006). The adoption of electric freight vehicles in urban distribution

operations, for example, is still very limited despite the many European trials and demonstrations during the past 20 years (Nesterova, Quak, Balm, Roche-Cerasi & Tretvik, 2013). The penetration rate of liquid biofuels and gaseous fuels in urban freight transport is not documented. However, in Europe, only 5% of the liquid fuels consumed for transport (passenger and freight) are biofuels (European Commission, 2014). And oil counts for 94% of all energy consumed in transport (European Commission, 2013).

In the European Union, more than seven million jobs are related to freight transport by road, warehousing and support activities, and postal and courier activities (European Commission, 2013) which is 3% of all jobs in Europe (Eurostat, 2015). However, the prevalence of road transport and traditional fuel types in urban freight transport negatively influences the liveability in urban areas because of some negative side-effects this transport causes. Nearly all papers and research project reports dealing with urban freight transport touch upon these negative impacts (whether or not in detail) since the conflict between the economic necessity of urban freight transport and its negative side-effects is the foundation on which the existing research into this topic is built. In this sense, most research closely relates to the concept of sustainable development which was first described and defined by the World Commission on Environment and Development (1987) in the so-called Brundtland report. The commission defined sustainable development as “a development that meets the needs of the present without compromising the ability of future generations to meet their own needs”. Afterwards, this was translated in successfully balancing economic goals with social and environmental, also sometimes referred to as the triple bottom line of sustainability (People, Profit, Planet) (Soubbotina, 2004). This link explains why many authors categorize the negative impacts of urban freight transport according to these three P's (See for example Anderson, Allen & Browne, 2005; Browne, Piotrowska, Woodburn & Allen, 2007; Quak, 2008).

The observed negative impacts of urban freight transport include (based on van Binsbergen & Visser, 2001; OECD, 2003; Anderson et al., 2005; Schoemaker et al., 2006; Browne et al., 2007; Quak, 2008):

- Economic impacts:
 - Increased traffic congestion which leads to
 - Time losses and inefficiencies for the person or company doing the transport
 - Unreliable deliveries for the receiver
 - Use of resources
 - Cost of governmental regulation and planning of urban freight transport
- Social impacts:
 - Health impacts
 - Local air pollution
 - Traffic accidents
 - Noise nuisance
 - Contribution to traffic congestion
 - Damage to buildings and infrastructure
 - Vibration
 - Traffic accidents
 - Damage to the road surface because of the weight of goods vehicles
 - Other quality of life issues
 - Loss of greenfield sites and open spaces in urban areas as a result of transport infrastructure developments
 - Visual intrusion
 - Physical hindrance
 - Stench
 - Vibration
- Environmental impacts:
 - Emission of global pollutants contributing to global climate change (e.g. carbon dioxide (CO₂))
 - Emission of local pollutants (e.g. carbon monoxide (CO), nitrogen oxides (NO_x), particular matter (PM) and volatile organic compounds (VOCs))
 - Use of non-renewable resources
 - Fossil-fuel

- Aggregates
- Land
- Waste products such as tyres, oil and other materials
- The loss of wildlife habitats and associated threat to wild species

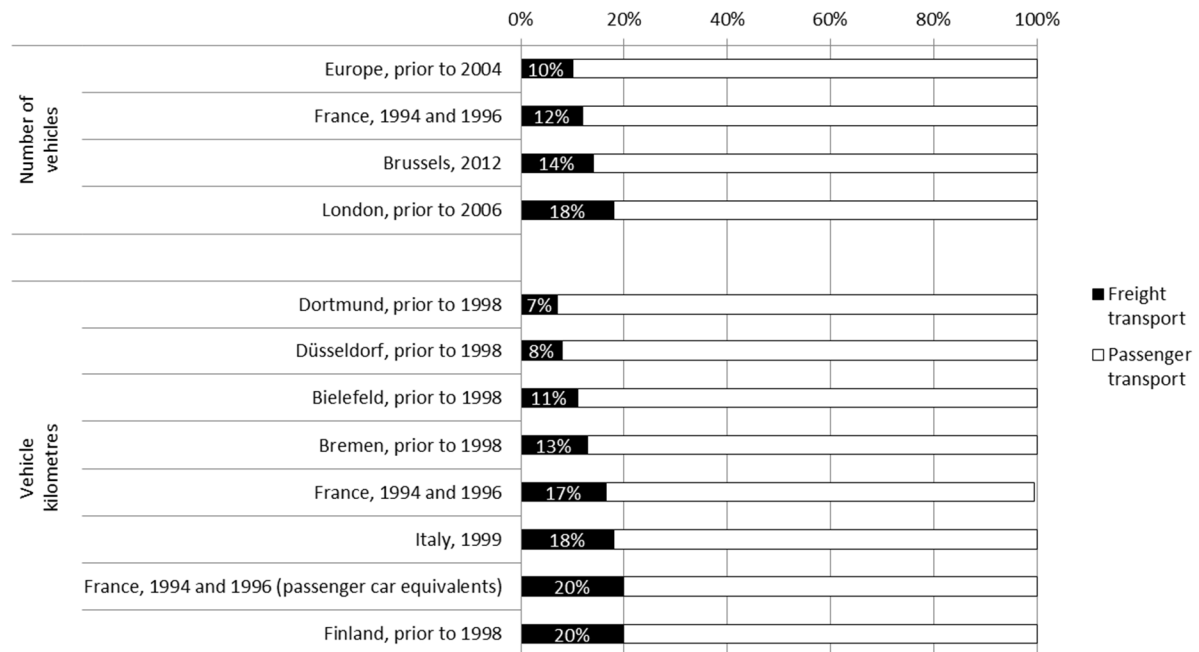
In general, most authors mention more or less the same negative impacts of urban freight transport. They do sometimes differ, however, in the category they attribute these impacts to. Van Binsbergen & Visser (2001), for example, categorize local air pollution and traffic safety as environmental impacts and only consider accessibility as a non-environmental impact. Also noise nuisance is not always put in the same category (sometimes under environmental impacts, sometimes under social impacts) (van Binsbergen & Visser, 2001; Browne, Allen, Sweet & Woodburn, 2005; Quak, 2008). Browne et al. (2005) also take into account the cost of governmental regulation and planning of urban freight transport as an economic impact.

A survey conducted among 43 European cities confirms that the negative impacts of urban freight transport are a real problem to local policy makers (Ruesch and Glücker, 2001). The cities were asked to score a list of urban freight problems on a scale of one to five from a very important to a less important problem. They were also given the possibility to add additional problems. The problems that made it to the top ten got an average score of 2.07 to 2.79. Six of the top ten problems can be linked to one of the negative impacts of urban freight transport listed earlier: noise emissions (average score of 2.14), conflicts with other road users during delivery operations (average score of 2.16), traffic congestion (average score of 2.30), environmental pollution (average score of 2.30), intimidation of (vulnerable) road users (average score of 2.49) and damage to road surface and infrastructure (average score of 2.79). The other four are related to the fact that the urban environment is not suited to receive so many freight vehicles (e.g. lack of suitable infrastructure for deliveries, access of freight vehicle to pedestrian zones of historic centres).

The negative impacts that are described above are not impacts that are unique to urban freight transport but impacts that go hand in hand with all types of (predominantly motorised) road transport. The limited amount of available data on how urban freight transport compares to urban passenger transport by road and to freight transport by road in general, reveals that it is relevant to also take measures in the field of urban freight transport to mitigate these negative impacts. EU statistics show that 31.8% of all energy consumption and 25.8% of all greenhouse gas emissions in the 28 member states can be attributed to transport (European Commission, 2014). Relevant for urban freight transport is that 75.0% of the greenhouse gas emissions caused by transport can be attributed to road transport (European Commission, 2014). The data collected by the EU on passenger and freight transport by road are expressed in tonne-kilometres and passenger-kilometres respectively while data expressed in vehicle-kilometres are needed to mutually compare both types of road transport (European Commission, 2014). These data are not available on EU level. REMOVE, the European transport model that was developed as part of the Clean Air for Europe program estimates that in 2015, 86.4 % of road vehicle kilometres can be attributed to passenger transport, 5.3% are driven by vans, 1.7% are driven by light duty trucks and 6.6% are driven by heavy duty trucks (Transport & Mobility Leuven, 2010). It should be taken into account here that all passenger cars are categorised under passenger transport while some of them are also carrying out freight transport and that all vans are categorised under freight transport while some of them are used for passenger transport only. When we focus on the urban level, again, the proportion of freight vehicle kilometres in total vehicle kilometres is not very well documented. This is very well illustrated by the fact that nearly all publications touching upon this topic refer to the same reference (Dablanc, 2007). The data of Dablanc are based on estimations published by Albergel, Ségalou, Routhier and de Rham (2006). Their estimations were based on traffic counts dating back from 1994 and 1996 and concluded that 9 to 15% of the vehicle trips in the urban areas are freight transport (through traffic not included), that 13 to 20% of the urban vehicle kilometres are freight kilometres (again through traffic not included) which increases from 15% to 25% when expressed in passenger car equivalents (Albergel et al., 2006). The trend in these data is confirmed for other countries. In Italy, 18% of urban vehicle kilometres can be attributed to freight vehicles (Schoemaker et al., 2006). The other available data are expressed in number of vehicles. In London, 18% of the vehicles on urban roads are freight vehicles (Schoemaker et al., 2006). For the whole of Europe, it was found that 10% of the vehicles on urban roads are freight vehicles (Zunder & Ibanez, 2004). In Brussels, traffic counts in 2012 revealed that 14% of the vehicles on urban roads are freight vehicles again taking into account that all passenger cars are considered to be used for passenger transport only and all vans for freight transport only (Lebeau & Macharis, 2014). Figure 1 provides an overview of the proportion of freight transport compared to all urban road transport. The proportion of freight

transport that takes place in an urban area again is not very well documented and quantified. It has been established, however, that fuel costs and therefore fuel consumption are higher in urban areas because of the short distance trips, the high stop frequency and the high congestion level (Zunder & Ibanez, 2004; Filippi, Nuzzolo, Comi, & Delle Site, 2010). Since many of the negative impacts of road transport are linked to fuel consumption, it can be expected that the negative impact urban freight transport causes is higher in percentage than the corresponding share of freight transport by road (in vehicle-km).

Figure 1. Overview of the proportion of freight transport compared to all urban road transport. Country or city are mentioned and the year in which the data were collected



Source: Own setup based on Albergel et al., 2006; COST 321, 1998; Lebeau & Macharis, 2014; Schoemaker et al., 2006; Zunder & Ibanez, 2004.

European trends for the future such as increasing urbanisation, increasing connectivity, a shift from single or multi-channelling towards integrated cross channelling, growth of e-commerce and home deliveries lead to expect a further increase of the demand for urban freight transport. Most papers and publications on urban freight transport cite one or more of these trends superficially to support their research question. A few, however, give a more thorough overview of future mega trends and their impact on urban freight transport. These trends and impacts include (based on Amarnath & Vidyasekar, s.d.; Browne et al., 2007; Cityfreight, 2002; European Commission, 2011; European Commission, 2015a; European Commission, 2015b; Herzog, Gota & Ahuja, 2013; Konstantinopoulou et al., 2010; Lindholm, 2012; MDS Transmodal Limited, 2012; Portal, 2003; Visser, Nemoto & Browne, 2014):

- Population trends:
 - Demographic: in the next years, the EU will witness zero population growth; the proportion of older adults will increase and they tend to move from suburbs to city-centres.
 - Urbanisation: By 2025, over 75% of Europe's population are forecast to live in urban areas and by 2050 the proportion is expected to increase to 84%.
 - Connectivity: By 2025, each person will have a minimum of five connected devices which will lead to a demand for faster deliveries anywhere and at any time.
- Policy trends:
 - Climate change, pollution risks and health risks will force governments (but also the private sector and the general public) to reduce emissions.
 - EU policy:
 - The EU has committed to cutting its emissions:
 - To 20% below 1990 levels for 2020

- To 40% below 1990 levels for 2030
 - To 80-95% below 1990 levels for 2050
- One of the goals registered in the 2011 White Paper on Transport is to achieve essentially CO₂-free city logistics in major urban centres by 2030.
- Significant EU funding has been provided for research and technological development which has helped to develop a wealth of innovative approaches. Also the new funding programmes incorporate calls that address urban freight transport.
- National policy: Usually, countries do not have a national policy framework to support cities in their urban freight plans.
- Local policy
 - Cities are taking measures and testing ideas on their own but in many cases they concentrate their few available resources on planning passenger transport. There is a trend, however, towards increasing attention for urban freight transport.
 - Cities tend to restrict permissions for out-of-town shopping centres and malls and are expected to continue this policy which will stimulate city-centre development.
 - The road freight transport sector is a very competitive sector which means that additional costs that are caused by policy measures will eventually be passed on to consumers and might disturb the market when not applied carefully.
- Commercial trends:
 - General
 - Continuously increasing consumer demands give rise to a constantly changing assortment of a wide variety of goods that has to be provided
 - Non-core activities within the supply chain are outsourced and supply chains become increasingly integrated which leads to many different cooperating private actors in freight transport.
 - E-commerce and home delivery
 - By 2025, 20% of retail will happen through online channels increasing the demand for parcel deliveries. Shipments will become smaller and more frequent.
 - This growth in e-commerce and home deliveries will change the urban freight flow patterns and therefore urban freight transport. The impact of these changes remains uncertain and depends on whether consumers will change their travel behaviour because of their increased online purchase behaviour and whether the trips of express couriers will be further rationalised because of the higher volumes.
 - In the case of home deliveries, there are large flows of returned product which will require major reverse logistics operations.
 - Retail
 - Traditionally, the retail business was dominated by smaller family-run or regionally targeted stores but this market is increasingly being taken over by retail groups. This trend leads to larger vehicles and efficiency gains caused by the increase of goods from retailer-controlled distribution centres.
 - The past years, many out-of-town shopping centres were built. There is a backward trend, however, towards smaller store formats due to the popularity of the urban lifestyle and the wish to shop locally.
 - Because of the growth of e-commerce and home deliveries, the retail model will evolve from a Single/Multiple Channel model to an Integrated Cross Channel model demanding for more delivery options
 - Trend towards longer opening hours and Sunday openings. Together with just-in-time systems, reductions in stock level and smaller store formats this will lead to even more frequent and smaller deliveries.
 - Hotels, Restaurants and Cafés (HoReCa)
 - The HoReCa sector has been growing strongly but future zero population growth will slow down this growth.

- Despite the presence of some large multi-national chains, the industry remains dominated by small family-run restaurants, bars and hotels.
- Orders are usually rather small and deliveries are often required on a just-in-time basis.
- Construction
 - Growing number of construction developments leads to increasing demand for delivery operations serving construction sites.
 - Construction sites are located throughout the city, also in already congested areas or sensitive locations (e.g. pedestrian areas or heritage locations). This leads to additional hindrance, especially when large trucks are needed to do the deliveries.
- Waste
 - Increase in the collection of recyclable waste leads to more freight vehicle trips.
- Transport trends:
 - Road will remain the dominant mode of urban freight transport but smaller and more fuel-efficient or alternatively powered vehicles will be used.
 - Infrastructure development investments will focus on high speed rail projects.
 - Information technology advancements will also penetrate the logistics and transport sector.
 - There is a trend towards horizontal collaboration between logistics service providers. Distribution will be shared and become more consolidated.

The observation that urban freight transport is responsible for a considerable part of the negative impacts linked to urban transport in general and the outlook that the number of urban freight trips will further increase has led to an increase in the research on this topic since the late 1990s (Browne et al., 2007). Two types of research can be distinguished. First, there is the research aiming to improve basic knowledge: what caused it to develop the way it did and what can be expected for the future? Most publications, however, deal with identifying promising solutions and finding a way to successfully implement them. These publications address three main aspects: (i) involving all stakeholders, (ii) urban freight measures and (iii) ex-ante and ex-post evaluation. These three topics will also be combined in this thesis.

1.2 Stakeholder involvement

Stakeholders are any group of people, organised or not organised, who share an interest or stake in a particular issue or system (See for example: Freeman, 1984; Banville, Landry, Martel, & Boulaire, 1998; Munda, 2004; Macharis, Turcksin & Lebeau, 2012). In urban freight transport, two types of stakeholders can be distinguished: (i) public stakeholders who are not directly involved in the freight transport movements in their city and (ii) commercial stakeholders who are not primarily driven to create or enjoy an attractive urban environment (Melo, 2004; MDS Transmodal Limited, 2012). The interests of public stakeholders can be categorised according to the triple-bottom line of sustainability: environmental, social and economic interests (Quak, 2008). The stakes of the different public stakeholders can be mutually conflicting. Compared to city dwellers, for example, tourists and visitors will care less about air quality and pollutant emissions (MDS Transmodal Limited, 2012). Commercial stakeholders are all involved in supply chains of which the first or last part is taking place in an urban environment (Allen et al., 2000). Their aim is to provide the best possible service to their customers at the lowest possible cost (Quak, 2008; Behrends, 2011). Usually, these actors are private companies organising their own operations as efficiently as possible to cut costs. From the perspective of a city, however, the urban transport part of that logistics service can be very inefficient (Dablanc, 2009; Quak, 2014). That is not the case for full-truckload transport between a retailer's distribution centre and one of the retailer's outlets. It is the case, however, for many own-account transport operations where average loading rates are much lower (Dablanc, 2009). It shows that also the stakes of the different types of commercial actors can mutually differ.

The fact that there are many different stakeholders involved in urban freight transport is commonly mentioned in papers and research project reports on urban freight transport. Ogden (1992) who was one of the first to write a comprehensive analysis of urban freight transport identified three main stakeholders with an active role in urban freight transport: receivers, carriers and forwarders. Most of the other authors addressing the topic of urban freight stakeholders also distinguish among these three, although some of them do not consider forwarders (also called senders) and receivers to be separate stakeholders (Taylor, 2005; Witlox, 2006; Quak, 2008; Behrends; 2011) or do not include receivers (Taniguchi & Tamagawa, 2005). The importance of policy-makers, decision-makers and local

authorities as urban freight transport stakeholders is also commonly recognised (Munuzuri et al., 2005; Taniguchi & Tamagawa, 2005; Taylor, 2005; Witlox, 2006; Quak, 2008; Behrends, 2011; Russo & Comi, 2011; Stathopoulos, Valeri & Marcucci, 2011; Lindholm, 2012; MDS Transmodal Limited, 2012; Ballantyne, Lindholm & Whiteing, 2013; Lindholm & Browne, 2013; Ystmark Bjerkan, Bjorgen Sund & Elvsas Nordtomme, 2014). Policy makers take the role of defending the stakes of all urban stakeholders that are affected by urban freight transport. Some authors suggest considering 'society' or 'citizens' as a fifth stakeholder (Taniguchi & Tamagawa, 2005; Taylor, 2005; Witlox, 2006; Quak, 2008). Ballantyne et al. (2013) argued that citizens and visitors have an interest in the system of urban freight transport but do not have a direct influence on the system. From that perspective, the authors differentiated between actors and stakeholders and also considered public transport operators, trade associations, commercial organisations and land owners/property owners as passive stakeholders. Some authors also include infrastructure providers and operators (Taniguchi & Tamagawa, 2005; MDS Transmodal Limited, 2012). The most extensive overview of the different stakeholders and their main interests in the context of urban freight transport can be found in MDS Transmodal Limited (2012). They distinguish:

- Supply chain stakeholders
 - Shippers
 - Transport operators (own account and third party providers)
 - Receivers (major retailers, shop owners, etc.)
- Resource supply stakeholders
 - Infrastructure providers
 - Infrastructure operators
 - Landowners
- Public authorities
 - Local government
 - National government
- Other stakeholders
 - Other economic actors located in the urban area
 - Residents
 - Visitors/tourists

On a first level, listing urban freight transport stakeholders and their interests is used to set the scene and to support the idea that it is difficult to organise urban freight transport in a way that it meets the interests of all these stakeholders. The observation that, today, urban freight transport is organised in a way that fails to serve the interests of public stakeholders is then used to discuss one or more measures that are expected to do better in reconciling the interests of all stakeholders (See for example: Holguín-Veras et al., 2005; van Rooijen & Quak, 2010;). It is impossible and not necessary, however, to find measures (or combinations of measures) that do not have any disadvantage to any stakeholder (Ystmark Bjerkan et al., 2014). It suffices that each stakeholder perceives the advantages of a measure to be greater than its disadvantages to "reach common ground" which requires reflective collaboration between the different stakeholders (Ystmark Bjerkan et al., 2014). The idea that it is important that public and commercial stakeholders co-operate was already mentioned in 2003 by OECD, be it mainly co-operation between commercial stakeholders to increase service levels or decrease costs through consolidation. This type of co-operation was brought in practice through several physical consolidation schemes (See for example: Urban Consolidation Centres (UCCs) of Bremen, Regensburg, Evora, Freiburg and Basel; Rosini, Panebianco & Zanarini, 2005; Trendsetter, 2006; Panero, Shin & Lopez, 2011) and is also gaining in interest for other urban freight measures (Gonzalez-Feliu & Morana, 2011). Other physical consolidation schemes are operated through a partnership between government and one or more private sector companies for the funding of the scheme (Public Private Partnership or PPP) (Browne, Nemoto, Visser & Whiteing, 2004; Lindholm, 2012; van Duin 2012;)) (See for example: UCCs of Bristol, Siena, Stockholm, Bath and Norwich; Panero et al., 2011; C-Liege, s.d.). To Browne et al. (2003), however, a PPP in urban freight transport should be more than an agreement on funding; it should also include consultation and dialogue between public and commercial stakeholders. Crainic, Ricciardi and Storchi (2004) state that consolidation schemes require some form of public-private understanding, collaboration and innovative partnerships to be able to survive in the long run. Holguín-Veras, Wang, Browne, Darville Hodge & Wojtowicz (2014) consider it to be one of the main lessons learned from their off-hour delivery project in New York: when public agencies put effort into building relations with commercial urban freight stakeholders the chances of success

of public policy will increase. And at least for UCCs, there is a trend towards stronger involvement by public organisations (van Duin, 2012). This public involvement should not be restricted to governments but also include active citizen support and new forms of communication between citizens and professionals (Booth & Richardson, 2001; Bannister, 2002). For urban transport in general, the idea that you need integrated transport planning processes to come to a more sustainable urban transport system has gained increased recognition and importance at the European level in what are called Sustainable Urban Mobility Plans (SUMP) (Bühmann, Wefering & Rupprecht, 2011; European Commission, 2011). However, in the guidelines for implementing a SUMP and the examples that are provided in these guidelines, the balance is heavily skewed towards passenger transport. A few years ago, the approach to also organise structured consultation between urban freight stakeholders was not widespread (Dablanc, 2008). Today, this type of consultation has been put into practice in some cities and countries: Freight Quality Partnerships (FQPs) in the UK and Sweden, variants to the FQP concept in Canada, the United States of America (USA) and Australia, Platform Stedelijke Distributie (PSD or the Consultation Platform for Urban Distribution) and its successors in the Netherlands, Good Practice Charters in France and the use of the Design and Monitoring website in dedicated workshops in Berlin (Germany), the Lombardy Region (Italy) and Newcastle upon Tyne (UK) (Van Kampen & Vis, 1998; Allen, Browne, Piotrowska & Woodburn, 2010; Lindholm & Browne, 2013; Lindholm, 2014; Zunder, Aditjandra, Schoemaker, Vaghi Laparidou & Österle, 2014). Today, there is no commonly accepted approach for integrated urban freight transport planning and also the research into the topic has only just started (Lindholm & Browne, 2013).

1.3 Urban freight measures

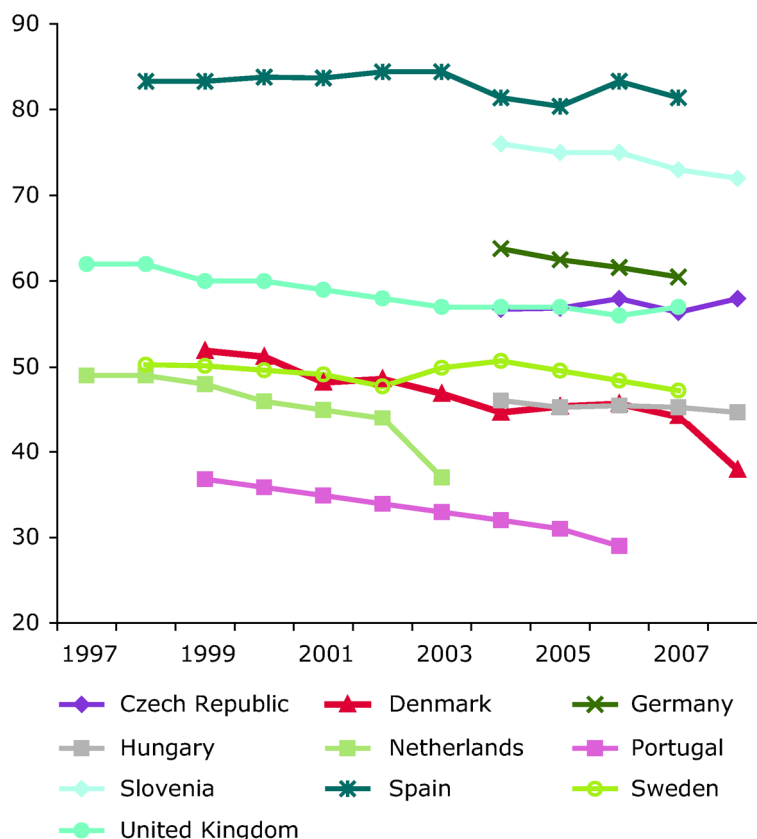
During the last 20 years, a range of initiatives to reduce the negative impacts caused by urban freight transport has been researched, tested and implemented. Overviews of existing measures and solutions and their results have been made within the framework of several national and European research projects (Allen, Thorne & Browne, 2007; Bohne & Ruesch, 2013; Browne et al., 2007; C-Liege, s.d.; COST 321, 1998; INRETS, 2010; Roche-Cerasi, 2012; Rosini et al., 2005; Wagdahl, 2013; Wangsness & Johansen, 2014). The different measures can be classified by common characteristics that are also common indicators for failure, success, stumbling blocks or attention points (Quak, 2008). Different authors use different characteristics to classify urban freight measures. A first characteristic that is used is the spatial scale on which the measure is implemented which can vary from an entire urban area to a specific street or loading and unloading zone (Roche-Cerasi, 2012). Urban freight measures are also categorised according to whether they are implemented by public or private actors (Browne et al., 2007; MDS Transmodal Limited, 2012). For Quak (2008) whether improvements are done within the existing context or by changing that context is what primarily characterizes an urban freight solution. When improvements are made within the context he also distinguishes between policy initiatives and company driven initiatives. For improvements that intervene by changing the context he uses the field of intervention to distinguish between physical infrastructure initiatives and transport reorganising initiatives. Other authors also distinguish by the field of intervention. In the case of Russo and Comi (2011), for example, this leads to four categories: material infrastructures, non-material infrastructures, equipment and governance. Finally, Macharis (2013) uses the actions needed to make the transport more sustainable to categorise urban freight measures: awareness, act and shift, avoidance and anticipation.

This dissertation will further explore two urban freight transport solutions: consolidation and off-hour deliveries. They do not fit the same category in any of the above classification. Still, they have two things in common which is why I exactly chose these two urban freight transport measures. First, despite the fact that both measures are very popular and have been receiving a lot of research attention, they remain permanently promising. It is generally accepted that there are benefits to consolidating urban freight and shifting urban deliveries to off-hours but despite numerous trials and implementations, the measures have not been widely adopted yet. Second, they both require support of both public and commercial stakeholders to be successful in the long term. In this section, consolidation and off-hour deliveries will be introduced and defined and the gaps in the research into both topics will be identified.

1.3.1 Consolidation³

According to *Cambridge Dictionaries Online*, consolidating means “combining several things so that they become more effective”. In transport, consolidation refers to “the process of putting items together in order to send or transport them”. The aim of consolidating several small shipments is to reduce the distribution costs by increasing the loading rate of a vehicle since the fixed costs for transport can then be spread across more shipments (Verdonck, Caris, Ramaekers & Janssens, 2013). The low loading rates in freight transport by road and the high proportion of vehicles that drives empty reveal that there is certainly room for more consolidation. Figure 2, for example, reveals that in several countries the average loading rate of laden freight vehicles is below 50% (EEA, 2010). In the whole of Europe in 2010, 24% of the vehicles drove empty (Eurostat, 2011). The same data also revealed that empty running is twice as prevalent in national (shorter distance) transport than in international transport which shows that there is even more room for consolidation there (Eurostat, 2011). Urban freight transport in particular is also characterised by low loading rates, especially when the loading rate is expressed in terms of weight (Schoemaker et al., 2006; MDS Transmodal Limited, 2012). It is not always clear whether fill rates are measured in volume or weight, but the operating pattern of seven British companies operating in the cities of Birmingham, Basingstoke and Norwich, for example, revealed fill rates ranging from 43% to 79% taking into account, however, that some of these companies delivered two or more cities using the same truck leading to lower loading rates when the second or third city was entered. The results of other studies bundled by Schoemaker et al. (2006) are not conclusive on whether loading rates are lower for large freight vehicles or for small freight vehicles. Figures on commercial transport with vehicles with loading capacity up to 3.5 tonnes in Germany reveal that 27.3% of these vehicles drive empty (Schoemaker et al., 2006).

Figure 2. Load factor utilization for freight transport by road expressed in terms of percentage



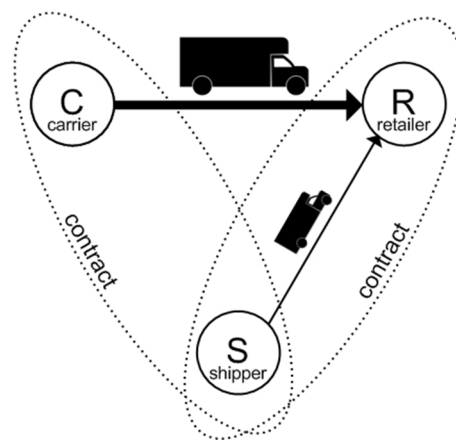
Source: EEA, 2010. For Spain, only public freight service vehicles are included in the data which explains the high load factors. Its deviant upwards trend until 2003 is due to the fact that the Spanish data are not expressed by tonne-kms but by weight.

³ Partly based on Verlinde, S., Macharis, C., Witlox, F. (2012). How to consolidate urban flows of goods without setting up an urban consolidation centre. *Procedia – Social and Behavioral Sciences*, 39, 687-701.

These inefficiencies are caused by the typical mode of operation within urban freight transport. Urban deliveries in retailing, for example, are carried out because people buy consumer goods at downtown retail stores. In response to that, retailers order new items from their suppliers to replenish their stock. At that point, supplier and retailer agree on the amount of goods to be delivered, the price (including transport) and the acceptable lead time. The supplier strives to provide the best possible service to his client and tries to fulfil their agreement to the best of his abilities by making sure the requested goods are delivered on time. Some suppliers carry out their deliveries on own-account and are therefore able to enter into direct consultation with the retailer on a mutually favourable delivery date and/or time within the agreed lead time. For the most part, however, suppliers make use of a professional carrier to pick up the goods and to take them to the shopkeeper's premises. In that case supplier and carrier enter into an agreement of their own which states, among other things, how much time the carrier is granted to deliver the goods.

This mode of operation is characterized by the lack of contractual obligations between retailer and carrier, also illustrated in Figure 3. As a result, retailer and carrier are only little inclined to consult with each other on the most appropriate delivery date or time. This lack of direct consultation leads to particular inefficiencies which, for their part, cause a considerable amount of unnecessary freight kilometres (Stichting Leve De Stad, 2005). First of all, there is the inefficient ordering behaviour of retailers. As carriers usually work by order of shippers and suppliers, the retailer is never directly faced with the consequential transport bill. This is reflected in his ordering behaviour since he often places his orders scattered in time, depending on when he has got time for it or when he thinks it fits to sales. Consequently, for the most part, suppliers receive small orders from their retailers instead of one bundled order. Secondly, suppliers and carriers are convinced that a short lead time is vital to a good customer service which means they do not save up deliveries but carry them out as fast as possible. Consequently, the flood of small orders results in many small deliveries. This approach also dominates our streets: many small delivery trucks and vans delivering small packages often several times a week at the same premises.

Figure 3. The common mode of operation within urban logistics characterized by the lack of contractual obligations between retailer and carrier



Source: Own setup

Irrespective of the size of individual deliveries, carriers aspire to use their freight vehicles as efficient as possible by sending off their vehicles fully loaded and aiming at as little empty or half empty kilometres as possible. Consequently, many urban delivery trips are round trips with several delivery addresses which are planned as efficiently as possible. As most carriers operate on a regional or even national level, not all addresses are located in one city. It means that freight vehicles usually enter the first city on the round trip fully loaded, but are only partially loaded when entering the second or third city. At the urban level, these empty or half empty kilometres are inefficient thus causing unnecessary hindrance and pollution. That is why, from a destination perspective, the adverse effects of urban deliveries would be reduced if flows of goods headed for the city were consolidated more efficiently. Higher loading rates within cities and fewer freight vehicle kilometres are, in the first place, objectives of transport companies and logistics service providers. If they can achieve these goals by changing their way of working, they do because of the fuel and wage savings linked to them. That is why, on a company level, consolidation oriented measures are taken every day. They are, however, not very well documented in research into urban freight transport and, so far at least, did not lead to optimal consolidation from a city perspective.

For more than twenty years now, initiating a UCC has been a popular consolidation oriented measure in urban freight transport (Karrer & Ruesch, 2007). Because goods destined for a certain urban area or location are transhipped onto (often smaller) UCC vehicles and transported into the city in a consolidated way UCCs can combine high-quality deliveries with mitigating the negative effects of motorized goods vehicles entering cities. However, previous research on UCCs clearly shows that many of these freight platforms are granted only a short lifespan (Browne et al., 2005; van Duin, 2009). The cost of the additional transshipment often prevents them of being cost-effective. Therefore they depend on governments willing to subsidize them because of their assumed positive impact on congestion, emissions and shopping climate. Urban retailers also do not always see the added value and therefore often opt out as soon they are expected to pay for the service (Zunder & Ibanez, 2004; Marcucci & Danielis, 2008). Often, transport companies are also not willing to pay for a UCC service unless a regulatory framework (set by the local authorities) or the receiver forces them to (Browne et al., 2005). In addition to UCCs, there are also other measures and solutions that would lead to urban freight consolidation. The first European research project that listed feasible urban freight measures, for example, came up with a total of 56 measures of which 13 were, at least to some extent, consolidation oriented (COST 321, 1999). Examples are "road pricing in cities", "transport co-ordination and co-operation of retailers" and "development of lock chambers common to a group of receivers". Throughout the years, the attention for UCCs increased and other consolidation concepts were more or less put aside (See for example: www.civitas.eu; www.bestufs.eu). With the difficulties in finding a viable business model for UCCs, the question can be raised whether there are valuable alternatives to consolidate urban freight flows.

1.3.2 Off-hour deliveries⁴

Merriam-Webster online dictionary defines an off-hour as a "period of time other than a rush hour" or "other than regular business hours". In that sense off-hour deliveries could be defined as deliveries taking place at a time when there is no or little traffic congestion or as deliveries taking place outside regular business hours. In most literature on the topic off-hour deliveries are deliveries that take place during the evening, night or early morning. The starting time of the off-hour period ranges from 6pm until 10pm and it stops between 6am and 10am (See for example: Browne, Allen, Anderson & Woodburn, 2006; Holguín-Veras, 2006; Douglas, 2011). Allen et al. (2008) reviewed 30 United Kingdom urban freight studies and concluded that, on average, 4% and up to 14 % of deliveries in British cities were conducted during the evening, night or early morning (between 7pm and 6am). This trend is confirmed by Schoemaker et al. (2006) for other European cities. The body of literature on off-hour deliveries identifies two main reasons for this low share. First, in many cities, off-hour deliveries are prohibited because it is assumed that the act of loading and/or unloading freight vehicles causes noise levels that cannot be tolerated at these hours (Douglas, 2011). Second, receiver attitudes are typically negative (Holguín-Veras et al., 2005). Carriers, wholesalers and suppliers conducting their own logistics indicate that although off-hour deliveries would be cheaper, receivers do not want them. Receivers prefer to receive goods during operating hours because they fear the extra costs of evening or night work for staffed deliveries or security for unassisted deliveries. Also for off-hour deliveries, the lack of contractual obligations between the receiver and carrier also is partly responsible for the low proportion of off-hour deliveries in cities (Stichting Leve De Stad, 2005). The receiver is the final addressee for the delivery, but if he is not the sender of the goods, he usually does not choose nor pay the carrier. Receivers and carriers therefore typically do not consult with one another on the most appropriate delivery date or time.

Since the beginning, it was believed that shifting deliveries to the off-hours would positively affect peak-hour congestion (Browne et al., 2006; Holguín-Veras et al., 2005). Iyer et al. (2011) modelled the traffic impact of various off-hour delivery programs and demonstrated that as larger tax incentives were offered, congestion decreased throughout the regional highway network. Their research does not necessarily imply that introducing additional off-hour deliveries would decrease actual road congestion because the demand for urban freight and passenger transport is very high. However, this research supports that off-hour deliveries can alleviate some of the pressure. This idea was brought into practice during the Olympics of 2000 in Sydney where deliveries were prohibited after 8am, during the Olympics of 2004 in Athens when a night deliveries regulation was imposed and during the Olympics of 2012 in London, off-hour deliveries were allowed and even encouraged (Transport for London, 2012; Dablanc, 2013). The

⁴ Partly based on Verlinde, S., Macharis, C., Witlox, F. (2014). Which types of freight flows can be shifted to the off-hours? A review and case study of Flanders (Belgium) using a new freight flow classification framework. Manuscript submitted to *Transport Reviews*.

results of multiple off-hour delivery trials indicate that other societal benefits can be expected. Most importantly, off-hour deliveries enable carriers to avoid traffic congestion, which reduces their fuel consumption and saves them time which is why many carriers are in demand for more off-hour deliveries (See for example Dassen, Colon, Kuipers & Koekebakker, 2008; FTA, 2009; Holguín-Veras et al., 2011). Although some studies question the overall environmental benefits of rescheduling deliveries (Sathaye, Harley & Madanat, 2010), most researchers recognise positive environmental effects of a shift to more off-hour deliveries. There is no consensus, however, about the impact on traffic safety. On the one hand, the degree of heterogeneity in the traffic mix determines the risk of traffic accidents with fatalities or injuries (Tiwari, 2000). Shifting more trucks to the off-hours would decrease interactions between vulnerable road users and trucks and therefore have a positive impact on traffic safety. On the other hand, driver sleepiness is increasingly recognised as an important factor contributing to the burden of traffic related morbidity and mortality (Nabi et al., 2006).

The literature on off-hour deliveries recognizes two main stumbling blocks. The research that was carried out in the United States of America (mainly New York) mainly focusses on the economic feasibility of off-hour deliveries, particularly on how to influence the traditionally negative attitude of receivers towards off-hour deliveries (Holguín-Veras, Marquis & Brom, 2012). In Europe, noise nuisance is considered to be the main stumbling block for a shift to more off-hour deliveries. Following the Dutch PIEK project several pilot programs were launched that focused on the noise levels that are produced when deliveries are done at night and how to avoid noise nuisance for local residents (Dassen et al., 2008; Niches, 2006a; Niches 2006b; Vlaamse Overheid, MOW, Haven- en Waterbeleid, 2011; Douglas, 2011). The conclusion of most of these tests was that noise nuisance can be circumvented if specially adapted rolling stock is used and if there is enough consultation between the different stakeholders (both public and commercial). The many bans on off-hour deliveries, however, demonstrate that local authorities still tend to consider off-hour deliveries as something that has to be avoided.

1.4 Evaluation⁵

Together with the rise of various urban freight measures, multiple evaluation methodologies emerged. The evaluation of urban freight measures can have two purposes. First, an ex-ante evaluation can be used to assess the expected impact of one or more measures or solutions which helps public as well as private actors in deciding whether a measure should be supported or implemented (Filippi et al., 2010). Second, ex-post evaluations are useful to know whether a measure or solution really achieves what it was implemented for and can be called a good solution. The results of earlier ex-post evaluations can then serve as input for ex-ante evaluations. Evaluations require a thorough and systematic approach (See for example: Thompson and Hassal, 2005; van Duin, Quak & Munuzuri, 2007). Today, evaluating best practices is a generally accepted approach (Allen & Browne, 2012). However, the used methodologies mutually differ (Patier & Browne, 2010). Most common is that the effect of the change is measured by comparing the before and after values of a number of selected indicators. It has to be said though that no clear approach can be found in what indicators and what measurement units are used in the evaluation of urban freight measures (Patier & Browne, 2010). Some authors have tried to come up with a list of indicators and measurement units with the aim to be able to mutually compare the impact of the different real-life implementations, be it a generic method for all types of urban freight measures or a dedicated methodology for one type of measure (See for example: Browne et al., 2005; Patier & Browne, 2010; Balm, Browne, Leonardi & Quak, 2014). Apart from these before-after assessments, other methods that are typically used to evaluate transport related projects are also used in the field of urban freight transport both for ex-ante and ex-post evaluations. Cost benefit analysis (CBA) which is a tool that determines if a new transport project is a sound economic investment, for example, was often applied to evaluate UCCs (van Duin et al., 2007). A variation to the CBA is the social cost benefit analysis (SCBA) which does not only take into account the economic costs and benefits but also the monetized costs and benefits to society (See for example: Gonzalez-Feliu, 2014). A third method that is used is multi criteria analysis (MCA) which is a decision making support tool that evaluates and mutually compares different alternatives on different criteria (See for example: Kapros, Panou & Tsamboulas, 2006; Suksri, Raicu & Long Yue, 2012). Fourth, there is the business model analysis (BMA) which describes the value that an organisation offers to its customers and links that to activities, resources and partners needed to create, market and deliver that value (Osterwalder & Pigneur,

⁵ Partly based on Verlinde, S., Lebeau, P., Macharis, C., Witlox, F. (2015). Does implementing an urban consolidation centre really decrease the number of urban freight vehicle kilometres: a systematic quantitative review of 93 impact assessments. Manuscript submitted to *Transportation Research Part E: Logistics and Transportation Review*.

2010). This method was part of the evaluation framework developed as part of the European research project STRAIGHTSOL (Balm et al., 2014). All these evaluation methods require input and when no before-after measurements are done, social and environmental impacts are usually estimated using all types of impact models (Filippi et al., 2010).

Recently, Ystmark Bjerkan et al., 2014 pointed out that pilot programs and trials must be evaluated from the perspective of all stakeholders. This is in line with the idea expressed in Section 1.2 that successful urban freight transport solutions have to reconcile the interests of all stakeholders. The evaluation methods that are currently used in urban freight transport were not designed and developed from that perspective (Macharis 2005, 2007). Indicators that are used in the widespread before-after-assessments do cover, to some extent, the objectives of the various stakeholders. However, they are not addressed in a balanced way. When comparing the evaluations of American and European off-hour delivery trials, for example, we see that in Europe, apart from the noise aspect, there is a focus on societal and environmental impacts whereas in the USA, there is a focus on the economic feasibility and how to mutually share possible benefits. A SCBA also carries within that aspect of evaluating economic, societal and environmental impacts but still is developed top-down. It is the evaluator who decides which aspects are evaluated and which are not. In other fields of research, methodologies were developed that explicitly include the goals and objectives of all stakeholders when evaluating a set of alternatives. Macharis (2000) developed the Multi Actor Multi Criteria Analysis (MAMCA). This methodology is an extension of the traditional Multi-Criteria Decision Analysis (MCDA) (Fandel and Spronk, 1985; Guitoni and Martel, 1998). MAMCA allows the evaluation of different alternatives (policy measures, business concepts, scenarios, technologies, etc.) by explicitly accounting for the objectives of the stakeholders who are involved in the decision-making process. MAMCA develops a separate value tree for each stakeholder instead of only one value tree for all stakeholders (MCDA). The methodology was developed by Macharis (Macharis 2000, 2005 and 2007) and has been used for many applications, particularly transport-related decision-making problems (for an overview, see Macharis, De Witte and Ampe, 2009).

1.5 Purpose and research questions

1.5.1 Overall purpose and main research questions

The overall purpose of this dissertation is:

To identify feasible, consensual and successful applications of two urban freight transport solution approaches of which is generally accepted that they lead to more sustainable urban freight distribution (i.e. freight flow consolidation and off-hour deliveries).

A twofold approach is adopted: (i) reassessing the generally accepted logic behind consolidation and shifting to off-hour deliveries as well as their impact and (ii) evaluating both concepts and/or their applications from the perspective of all stakeholders.

This purpose is translated into three general research questions which are explained and formulated below.

Despite the fact that carriers aspire to use their freight vehicle as efficient as possible, average loading rates of freight vehicles entering cities are low (Schoemaker et al., 2006). Since most deliveries are done by road using diesel vehicles, these inefficiencies give rise to unnecessary negative impacts which could be avoided if flows of goods headed for the city were consolidated more efficiently. Initiating an urban consolidation centre (UCC) has been a popular consolidation oriented urban freight measure the past two decades. However, in the long run, many UCCs do not survive (Browne et al., 2005, van Duin, 2009). These observations gave rise to the following research question:

RQ1: How to consolidate urban freight flows in a way that it contributes to long-term sustainable urban goods distribution?

Today, most urban deliveries are carried out by day (Schoemaker et al., 2006; Allen et al., 2008). It is generally believed that a shift to off-hour deliveries would positively affect peak-hour congestion and that also other societal and environmental benefits can be expected (Holguín-Veras et al., 2005; Browne et al., 2006). However, two main stumbling blocks are identified: the traditionally negative attitude of receivers towards off-hour deliveries (Holguín-Veras et al., 2012) and the noise nuisance caused by loading, unloading and manoeuvring freight vehicles when local

residents are asleep (Dassen et al., 2008; Douglas, 2011). These observations gave rise to the following research question:

RQ2: How to shift urban deliveries to off-hours in a way that it contributes to long-term sustainable urban goods distribution?

Evaluating best practices is a generally accepted approach in urban freight transport (Allen & Browne, 2012). Various evaluation methods are used for that (see for example: Patier & Browne, 2010; Balm et al., 2014; van Duin et al., 2007). To assure that the evaluation is relevant and representative, pilot programs and trials should be evaluated from the perspective of all stakeholders (Ystmark Bjerkan et al., 2014). However, the evaluation methods that are currently used in urban freight transport were not designed and developed from that perspective (Macharis, 2005, 2007). These observations gave rise to the following research question:

RQ3: How to include stakeholders in the evaluation of urban freight concepts and applications?

In the next section, it is explained how these general research questions are broken into sub research questions in the various chapters of this dissertation.

1.5.2 Dissertation structure and research objectives per chapter

The dissertation consists of two main parts, one dealing with urban freight consolidation, the other dealing with urban off-hour deliveries. For each part, there are three chapters. The first chapters of both parts (**Chapter 2** and **Chapter 4**) discuss the aspects of the current state that motivated the remaining part of this research. **Chapter 3** and **Chapter 6** focus on the future potential of urban freight consolidation and urban off-hour deliveries. The final chapters (**Chapter 5** and **Chapter 7**) evaluate two innovative measures or solutions that were developed in the spirit of the results of Chapters 3 and 6. The dissertation structure is illustrated in Figure 4. Chapters 2, 3 and 6 (indicated in a lighter blue in Figure 4) aim to reassess the generally accepted logic behind consolidation and off-hour deliveries as well as their impact whereas Chapters 4, 5 and 7 (indicated in a darker blue in Figure 4) evaluate the concept and/or innovative applications from the perspective of all stakeholders using MAMCA. Below, the motive and research objectives are explained per chapter.

Chapter 2 starts from the observation that there are reasons to question whether implementing a UCC really leads to a decrease in urban freight vehicle kilometres. First, we know that, more and more, UCCs aim to attract urban receivers as their clients (and not only logistics service providers (LSPs) or shippers) (van Rooijen & Quak, 2010). As a result, it could be that when additional receivers turn to a UCC, the LSPs previously servicing them might still have to enter the urban area where the receivers are located to service their other clients also located there. Second, in some cases, a UCC is an answer to more severe policy restrictions on the type of freight vehicle that is allowed to enter the area (See for example: ADEME, 2004; Campbell et al., 2010; Panero et al., 2011). LSPs that do not comply or wish to comply with the access regulations can drop their freight at the UCC. The vehicles used for the consolidated deliveries range from tricycles and vans to large rigid vehicles (Allen, Browne, Woodburn & Leonardi, 2012). There is a growing interest, however, to use alternatively powered vehicles (Allen et al., 2012). These vehicles are usually smaller than the ones used before the UCC was implemented which might lead to more kilometres for the same transported volume. It can therefore be questioned whether the environmental benefits attributed to UCCs are mainly caused by a decrease in number of kilometres or an increase in the use of alternatively powered vehicles.

The main research objectives of Chapter 2 are to:

- **Evaluate the impact of implementing a UCC on the number of urban freight vehicle kilometres**
- **Evaluate the impact of implementing a UCC on loading rate, emissions, fuel consumption and number of freight vehicle journeys**
- **Examine whether there is a statistically significant relation between certain UCC or assessment characteristics on the one hand and a positive or negative impact assessment on the other**

The research in Chapter 2 is based on an international systematic quantitative review of 93 UCC impact assessments found in a wide range of scientific publications on the topic as well as in research project reports and on dedicated websites. Distinction is made between ex-ante and ex-post assessments and Fisher's exact test and Box-and-Whisker

plots are used to look for statistically significant relations between the outcomes of the impact assessment and UCC or impact assessment characteristics.

Figure 4: Dissertation structure

Chapter 1: Introduction Background & Research Questions		
Part I: Consolidation	Measure	Part II: Shift to off-hour deliveries
Chapter 2: UCC impact on urban freight vehicle kilometres Research objectives are to: <ul style="list-style-type: none"> Evaluate the impact of implementing a UCC Examine whether there is relation between UCC or assessment characteristics and a positive or negative impact assessment 	Current State	Chapter 5: Night-time delivery as a potential option in Belgian urban distribution Research objective: are to <ul style="list-style-type: none"> Identify which stakeholders are affected by a shift to urban off-hour deliveries Evaluate stakeholder support for possible future off-hour delivery scenarios in Belgium
Chapter 3: How to consolidate urban flows of goods without setting up a UCC? Research objectives are to: <ul style="list-style-type: none"> Identify feasible consolidation concepts aiming to make better use of the load capacity of urban freight vehicles Develop a suitable classification system for consolidation-oriented tools, measures and initiatives 	Future Potential	Chapter 6: Which types of freight flows can be shifted to the off-hours? Research objective are to <ul style="list-style-type: none"> Develop a new framework to systematically describe and classify types of freight flows Identify urban freight flows that are more suited to be shifted to off-hours
Chapter 4: Does a mobile depot make urban deliveries faster, more sustainable and more economically viable Research objectives are to: <ul style="list-style-type: none"> Assess the impact of the MD trial of TNT Express in Brussels Evaluate stakeholder support for possible future MD scenarios in Brussels 	Innovative Implementation	Chapter 7: Who is in favour of off-hour deliveries to Brussels supermarkets? Research objective are to: <ul style="list-style-type: none"> Assess the impact of an off-hour delivery trial with supermarkets in Brussels Evaluate stakeholder support for possible future off-hour scenarios in Brussels
Chapter 8: Conclusions General Conclusions, Recommendations and Further Research		

Source: Own setup.

Despite the fact that most tested and implemented UCCs are not economically viable implementing one remains the most common consolidation oriented urban freight solution. However, there are also other measures and initiatives that can be taken to better consolidate urban freight flows (e.g. cooperation between LSPs or truck ownership licenses for urban distribution). **Chapter 3** focusses on alternative consolidation oriented urban freight transport solutions by reviewing existing classifications of urban freight measures for this type of solutions and by scanning urban freight transport practice for already implemented examples.

The main research objectives of Chapter 3 are to:

- **Review how the position of urban freight consolidation evolved within the research domain of urban freight transport.**
- **Develop a suitable classification system for consolidation-oriented tools, measures and initiatives**

One example of a consolidation-oriented urban freight solution is a Mobile Depot which is a trailer fitted with a loading dock, warehousing facilities and an office. The solution was developed by TNT Express as a mobile inner city base from where last-mile deliveries and first-mile pick-ups are done with electrically supported cyclocargos. In **Chapter 4** the impact of implementing a Mobile Depot is assessed. On the one hand, a before-after comparison is made of a three month trial with a Mobile Depot in Brussels. On the other hand, MAMCA is used to evaluate stakeholder support for possible future Mobile Depot scenarios in Brussels.

The main research objectives of Chapter 4 were to:

- **Assess the impact of the Mobile Depot trial of TNT Express in Brussels**
- **Evaluate stakeholder support for possible future Mobile Depot scenarios in Brussels**

In **Chapter 5** the switch is made from urban freight consolidation to urban off-hour deliveries. In Belgium, like in most European cities, urban deliveries are usually carried out by day. By means of MAMCA, this chapter evaluates stakeholder support in Belgian cities for a shift to off-hour deliveries. Stakeholders and their objectives were identified and possible future scenarios were developed. Afterwards, stakeholders were asked for their attitude towards off-hour deliveries by means of semi-structured interviews.

The main research objectives of Chapter 5 are to:

- **Identify which stakeholders are affected by a shift to urban off-hour deliveries and what their objectives and criteria are**
- **Evaluate stakeholder support for possible future off-hour delivery scenarios in Belgium**

The findings in Chapter 5 confirm that there are multiple stumbling blocks for a shift to more off-hour deliveries in cities (e.g. noise nuisance, fear of unattended deliveries because of the safety of the goods, cost for the receiver, etc.). However, despite the fact that most urban deliveries are carried out by day, some are already carried out during off-hours. In **Chapter 6**, these existing urban off-hour freight flows were used to gain insight in which types of flows are more suited to be shifted to off-hours. Therefore, a freight flow classification framework was developed based on existing urban freight transport frameworks and models. To identify which freight flows are suited to be shifted to off-hours the research on urban off-hour deliveries was reviewed from this perspective and backed up by the outcome of 41 interviews with general or logistics managers of companies that are part of different types of supply chains (partly) active during off-hours.

The main research objectives of Chapter 6 are to:

- **Develop a new framework to systematically describe and classify types of freight flows**
- **Identify urban freight flows that are more suited to be shifted to off-hours**

Chapter 7 builds on findings from the previous chapter indicating that when sender-receiver operations in a big company are integrated, transport is organised privately and most trips are origin-destination trips and no milk-runs freight flows are suited to be shifted to off-hours. This is the case for the flows between retailers' distribution centres and their supermarkets. In Chapter 7 the impact of a shift of supermarket deliveries to off-hours was assessed. On the one hand, a before-after comparison was made of four week trial in Brussels. On the other hand, MAMCA was used to evaluate stakeholder support for possible future off-hour scenarios in Brussels.

The main research objectives of Chapter 7 are to:

- **Assess the impact of an off-hour delivery trial with supermarkets in Brussels**
- **Evaluate stakeholder support for possible future off-hour scenarios in Brussels**

This PhD research was conducted under the supervision of my promotors Prof. Dr. Cathy Macharis (associated to Vrije Universiteit Brussel) and Prof. Dr. Frank Witlox (associated to Ghent University). The six manuscripts that constitute the main part of this dissertation (Chapter 2 to Chapter 7) are identical to the original texts that either are already published or have been submitted as articles in double-blind peer reviewed international academic journals or in conference proceedings with an international referee system. Below, the reference of each chapter is mentioned as well as the contributions of co-authors.

Chapter 2: Verlinde, S., Lebeau, P., Macharis, C., Witlox, F. (2015). Does implementing an urban consolidation centre really decrease the number of urban freight vehicle kilometres: a systematic quantitative review of 93 impact assessments. Manuscript submitted to *Transportation Research Part E: Logistics and Transportation Review*.

Philippe Lebeau gave feedback on the development of the database. Cathy Macharis, Frank Witlox and Philippe Lebeau revised the manuscript.

Chapter 3: Verlinde, S., Macharis, C., Witlox, F. (2012). How to consolidate urban flows of goods without setting up an urban consolidation centre. *Procedia – Social and Behavioral Sciences*, 39, 687-701.

Cathy Macharis and Frank Witlox revised the manuscript.

Chapter 4: Verlinde, S., Macharis, C., Milan, L., Kin, B. (2014). Does a mobile depot make urban deliveries faster, more sustainable and more economically viable: results of a pilot test in Brussels. *Transportation Research Procedia*, 4, 361-373.

Lauriane Milan put the information I collected in the software used to do the MCDAs (D-Sight) that are part of MAMCA. Cathy Macharis and Bram Kin assisted in interpreting the MAMCA results and revised the manuscript.

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Annelies Heemeryck and Ellen Van Hoeck did the MCDA for the MAMCA based on the information I collected from the 18 interviews. Together we developed the list of stakeholders and a first list of criteria. The list of criteria was adapted based on the interviews. Cathy Macharis assisted in interpreting the MAMCA results. Wanda Debauche, Cathy Macharis and Frank Witlox revised the paper.

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2

Does implementing an urban consolidation centre really decrease the number of urban freight vehicle kilometres? A systematic quantitative review of 93 urban consolidation centre impact assessments⁶

2.1 Introduction

An Urban Consolidation Centre (UCC) is a logistics facility within or close to the urban area where goods can be consolidated for subsequent delivery into the target area be that a specific site, a city centre or an entire town (Browne, Allen, Sweet & Woodburn, 2005; Allen, Browne, Woodburn, & Leonardi, 2012). The key purpose of a UCC is the avoidance of the need for underutilized goods vehicles to make deliveries in the target area (Allen et al. 2012). Suppliers, carriers and large retailers already seek to consolidate their loads as much as possible as it is cost-efficient for them (Van Rooijen & Quak, 2010). But although trucks might depart from the supplier's distribution centre fully loaded, once the first delivery is carried out their load loading rates drop. A supplier's client-businesses are usually located in different cities, so most freight vehicles entering a particular city are not used to their full capacity (Verlinde, Macharis & Witlox, 2012).

⁶ Verlinde, S., Lebeau, P., Macharis, C., Witlox, F. (2015). Does implementing an urban consolidation centre really decrease the number of urban freight vehicle kilometres? A systematic quantitative review of 93 urban consolidation centre impact assessments. Manuscript submitted to *Transportation Research Part E: Logistics and Transportation Review*.

During the past 35 years, UCCs have been researched, tested and implemented (and many of them closed down again) (Quak, 2008; Allen et al. 2012). It is generally accepted that UCCs lead to higher loading rates and fewer urban freight vehicle kilometres (See for example: Browne et al., 2005; Quak, 2008; Campbell, MacPhail, Cornelis & Al-Azzawi, 2010; Wisetjindawat & Showa-ku, 2010; Allen et al., 2012). These societal benefits (possibly together with the fact that local policy makers prefer complete measures with good visibility) explain why many UCCs receive government support (Panero, Shin, & Lopez, 2011; Verlinde et al., 2012). Some observations, however, lead to question whether the use of a UCC actually will contribute to a decrease in urban freight vehicle kilometres. There are a number of good reasons to doubt this assertion. First, we know that, more and more, UCCs aim to attract urban receivers as their clients (and not only logistics service providers (LSPs) or shippers) (Van Rooijen & Quak, 2010). As a result, it could be that when additional receivers turn to a UCC, the LSPs previously servicing them might still have to enter the urban area where the receivers are located to service their other clients also located there. Second, in some cases, a UCC is an answer to more severe policy restrictions on the type of freight vehicle that is allowed to enter the area (See for example: ADEME, 2004; Campbell et al., 2010; Panero et al., 2011). LSPs that do not comply or wish to comply with the access regulations can drop their freight at the UCC. The vehicles used for the consolidated deliveries range from tricycles and vans to large rigid vehicles (Allen et al., 2012). There is a growing interest, however, to use alternatively powered vehicles (Allen et al., 2012). These vehicles are usually smaller than the ones used before the UCC was implemented which might lead to more kilometres for the same transported volume. It can therefore be questioned whether the environmental benefits attributed to UCCs are mainly caused by a decrease in number of kilometres or an increase in the use of alternatively powered vehicles.

The aim of this paper is to evaluate the impact of implementing a UCC on the number of urban freight vehicle kilometres and, by extension, on loading rate, emissions, fuel consumption and number of freight vehicle journeys. On the one hand, we want to expose whether this impact can be considered positive or negative. On the other hand, we want to identify UCC and assessment characteristics that influence that impact. The paper is based on an international systematic quantitative review of UCC impact assessments found in a wide range of scientific publications on the topic as well as in research project reports and on dedicated websites. We will make the distinction between ex-ante and ex-post assessments and will use Fisher's exact test and Box-and-Whisker plots to look for statistically significant relationships between the outcome of the impact assessment and UCC characteristics or impact assessment characteristics. The next section (Section 2.2) defines and explains the UCC concept and its differentiating attributes. In Section 2.3, the research method is motivated and explained in detail. Section 2.4 discusses the results of the systematic quantitative review. These results are discussed in detail in Section 2.5. Finally, Section 2.6 concludes and provides opportunities for further research on this topic.

2.2 Urban Consolidation Centres

Nearly all definitions of a UCC start by referring to a physical place of transshipment where goods destined for a certain urban area or location are consolidated (Browne et al., 2005; Karrer & Ruesch, 2007; Quak, 2008; Russo & Comi, 2010; Wisetjindawat & Showa-ku, 2010; Allen et al., 2012). Still, the many research papers, trials and implementations show that this starting point can eventually lead to many different designs (Browne et al., 2005). Hence, the different UCC characteristics can then be used to distinguish and categorize UCCs (Visser, van Binsbergen & Nemoto, 1999; Browne et al., 2005; Karrer & Ruesch, 2007; Wisetjindawat & Showa-ku, 2010; Panero et al., 2011; Triantafyllou, Cherret & Browne, 2014). Below, the most frequently used UCC characteristics are listed and explained: i.e. operational model, customers, degree of government support, provided service and vehicle type.

A first important attribute that differentiates UCCs is the adopted operational model. UCCs tend to be public or privately owned according to the sector from which the initiative emerged (Panero et al., 2011). More blended formulas such as public private partnerships (PPPs) also exist (van Duin, 2009). These PPPs are joint ventures engaging local governments, chambers of commerce and forwarding firms (Browne et al., 2005). The private UCCs can be owned by one single company or by a private joint venture (usually led by the carrier industry) (Panero et al., 2011). UCCs owned by one single company can be used for the last-mile deliveries of one single company or several companies and they can be operated by the company itself or by an appointed or subcontracted LSP (Karrer & Ruesch, 2007, Panero et al., 2011). Publicly owned UCCs are usually operated by a private company winning a public tender but in some cases they are also publicly operated (Browne et al., 2005; Panero et al., 2011).

Next to ownership and operational organisation, UCCs also differ in who their (paying) customers are. Some initiatives aim at carriers who then do not have to come into the city anymore and can avoid busy traffic and strict regulations (Browne et al., 2005; van Rooijen & Quak, 2010). Other initiatives aim at the receivers and convince them to change their delivery address to the UCC in return for increased flexibility or frequency of delivery (Browne et al., 2005; van Rooijen & Quak, 2010). In London, Stockholm, Paris and L'Hospitalet de Llobregat UCCs where the shippers are the customers were tested or implemented (Browne et al., 2005; Trendsetter, 2006; Leonardi, Browne & Allen, 2012; Churchill, 2014; Johansen et al., 2014).

Another differentiating attribute is the degree of government support which can be financial or regulatory. Among the tested and implemented UCCs, there is a great variation regarding the type and degree of government support (Panero et al., 2011). The justification for government interventions differs from solving environmental externalities to addressing traffic congestion or other inefficiencies such as the lack of space for loading/unloading and/or for parking (van Rooijen & Quak, 2010; Panero et al., 2011). The general consensus is that in the medium / long term UCCs must be financially successful in their own right and that subsidies are not a viable solution (Browne et al., 2005). It appears, however, that financial support from the public sector is of critical importance to initiate a UCC that is not related to a major new property or commercial development (Browne et al., 2005; Wisetjindawat & Showa-ku, 2010). During the development of a UCC scheme, there are three possible timings for financial government support (Wisetjindawat & Showa-ku, 2010). It can be provided to fund a feasibility study and/or the UCC design. In a later stage, authorities can fund/co-fund/subsidise the setup of the UCC and the procurement of related equipment. Finally, once the UCC is operational, the government can provide subsidies to the UCC operators until the UCC breaks even (Wisetjindawat & Showa-ku, 2010). The funding can come from European, national, or local government bodies (Browne et al., 2005). Apart from financial support, governments can also provide regulatory support. The most extreme measure, in the case of publicly owned UCCs, is to make the use of the UCC mandatory (Panero et al., 2011). Apart from that, there is a whole range of possible measures such as stricter access regulations and stronger enforcement, tightened delivery windows, exemptions to the existing rules for UCC vehicles, etc. (Wisetjindawat & Showa-ku, 2010).

UCCs also differ in the services they provide. First, there is the spatial coverage which can range from a single site to an entire town or city (or even several cities in the case of smaller cities) (Browne et al., 2005; Wisetjindawat & Showa-ku, 2010). Second, there is the product range handled by the UCC which can differ depending on the type of receivers that are serviced through the UCC (e.g. retail or construction materials) and on the transport and storage conditions needed for certain types of goods (e.g. ambient, chilled or frozen in the case of food) (Browne et al., 2005). Third, many UCC have been designed to offer a range of additional services other than consolidated deliveries, such as storage and management of stock, inventory and returns (Browne et al., 2005; Panero et al., 2011). Finally, some UCCs have extended opening hours compared to the shops they deliver and are available up to 24 hours a day (Rees & Gahan, 2011).

An increasingly shared characteristic of more recent UCCs is that they use alternatively powered vehicles for the last-mile deliveries which often is encouraged by the funding or subsidising authority in their aim to solve environmental externalities (Panero et al., 2011; Allen et al., 2012). When linked to inland waterways and/or the rail network, a transshipment point can also support the shift of long distance transport from road to rail or waterways (Karrer & Ruesch, 2007). Finally, the location of the UCC in relation to the service area and to main roads and the throughput of the UCC are mentioned as important UCC characteristics (Browne et al., 2005).

2.3 Method

2.3.1 Evaluating the impact of UCCs

Decision makers can benefit from earlier experiences when deciding on what urban distribution measure to apply or support in their city. Besides an insight in the characteristics of the implemented measure and the urban area it requires a thorough and systematic evaluation of real-life examples (See for example: Thompson and Hassal, 2005; van Duin, Quak & Munuzuri, 2007). Today, evaluating best practices is a generally accepted approach (Allen & Browne 2012). The used methodologies for evaluation, however, mutually differ and the observed units and measurements are frequently found to be different from one implementation to another (Patier & Browne, 2010). Specifically for UCCs, Browne et al. (2005) concluded from their review of 67 UCC schemes that not all of them had

been evaluated and that the existing UCC evaluations tended to be fairly ad hoc and limited in scope. Throughout the years, multiple evaluation methodologies have been developed, some of them specifically for UCCs, other for urban logistics measures in general. Some evaluation methods focus on the financial viability of UCC schemes (See for example: Tsamboulas & Kapros, 2003), other are more general. Patier and Browne (2010), for example, developed an evaluation methodology for urban logistics measures based on the wide range of criteria used in the evaluation of 15 real-life projects. Browne et al. (2005) developed a detailed methodology to evaluate UCCs based on their review of 67 UCC schemes. During the last decade, there also have been multiple European funded research projects that developed methodologies to evaluate urban logistics measures (see for example: www.bestufs.eu; www.bestfact.eu; www.strightsol.eu; www.smartfusion.eu). Despite the existing guidelines and evaluation frameworks, also for the more recent evaluations of UCCs different methods are applied and different indicators are used (Kin, Verlinde, van Lier & Macharis, 2015). Leonardi, Browne and Allen (2012), for example, measured the local impact of a UCC trial with a before-after assessment, whereas Roca-Riu and Estrada (2012) have focused more on the economic effects.

2.3.2 Systematic quantitative review of UCC impact assessments

To evaluate the impact of implementing a UCC on the number of freight kilometres, freight trips, emissions, fuel consumption and loading rate, a systematic quantitative approach was used to review the publicly available UCC impact assessments. This methodology was extensively used in health care but can be applied to a wide range of study designs and research questions (Petticrew, 2001). A systematic review differs from a traditional narrative review in its strive to allocate all relevant publications and to base conclusions on those publications which are most methodologically sound (Petticrew, 2001). For this paper, the stepwise approach as described by Pickering & Byrne (2014) was followed.

Electronic databases were searched to identify original research papers published in English language journals or conference proceedings related to UCC impact assessment. These databases included: ScienceDirect, Web of Science, Google Scholar and Google. Databases were searched between July and December 2014. Keywords used for the search included: 'urban consolidation centre', 'urban distribution centre', 'city distribution centre' and 'freight consolidation centre'. These keywords were combined with 'evaluation', 'impact', 'assessment', 'kilometres' and 'pilot'. Additional papers were identified from the reference list of those research papers found through the database search. The papers reporting on an assessment of the impact of implementing a UCC (be it ex-ante or ex-post) on distance travelled, number of vehicle journeys, energy consumption and/or emission of pollutants were selected. This search method led to a slender selection of eight papers (Browne, Allen & Leonardi, 2011; Browne, Allen, Nemoto, Patier, & Visser, 2012; de Assis Correia, de Oliveira & Guerra, 2012; Leonardi, Browne, & Allen, 2012; Patier, & Browne, 2010; van Duin, Quak & Muñuzuri, 2010; van Duin, van Kolck, Anand, Tavasszy, & Taniguchi, 2012; van Rooijen & Quak, 2010). There is a twofold explanation for this rather slim research search outcome. First, many research papers describe the 'potential', 'theoretic' or 'expected' benefits of implementing a UCC but for only relatively few of them the transport or environmental impact is quantified (Allen et al., 2012). Second, multiple quantitative UCC impact assessments were never reported on in research papers. They do exist, however. The Google search came up with a series of non-academic publications such as research project reports, dedicated websites and conference presentations. These publications also provided references to other relevant publications that were then consulted. It should be noted here that for some UCCs, it was impossible to get access to the original research report or impact assessment because they were not publicly available or not published in English (but e.g. in Swedish (nnerstadengbg.se/innerstaden-goteborg/projekt/stadsleveransen/) or Danish (<http://citylogistik-kbh.dk/>)). Sometimes the results got published in a journal by means of a paper, in other cases, the reports providing an overview of the existing UCC schemes were a big help. In our sample there might be a predominance of schemes that received some kind of European funding as the EC tends to require a thorough publicly available impact assessment in return for their support. For the same reason, it can also be expected that the share of schemes involving environmentally friendly vehicles is overrated in our sample. In the beginning, when UCCs were implemented, the goal was to have less freight vehicles in our cities (in the hope to decrease the negative effects caused by these vehicles). It was only in a later stage that the opportunity occurred to operate environmentally friendlier vehicles for the last-mile between the UCC and the urban receiver. Often, these vehicles were subject to public funding requiring an impact assessment.

2.3.3 Data extraction

From each reference, the following items of information were recorded in a database: (i) year of publication, (ii) type of publication (research project report, published research paper, dedicated webpage, presentation, master thesis), (iii) title, and (iv) where the reference can be found. Using the reference to make the distinction between the different impact assessments appeared to be inadequate as some of them describe the measured or calculated impact of multiple UCC schemes and because some of these UCC schemes emerge in multiple references. That is why we came up with a new database in which the following items of information were recorded for each UCC impact assessment mentioned in our set of references (the longlist with the subcategories can be found in Annex A): (i) Name UCC scheme, (ii) Year of impact assessment, (iii) Type of impact assessment (ex-ante or ex-post), (iv) Reference used, (v) Number of UCCs, (vi) Timing, (vii) Location, (viii) Delivery vehicles used in Business As Usual (BAU), (ix) Delivery vehicle used for UCC, (x) Institutional and operational characteristics, (xi) UCC customers; (xii) UCC scale, (xiii) UCC receivers, (xiv) Enforcement, (xv) Impact assessment methodology, (xvi) Impact and (xvii) Additional remarks.

Information related to the impact of implementing a UCC was extracted from each publication and assigned to relevant categories and subcategories. In light of our research questions, the most important category is the impact on distances travelled. Assessing this impact does not always happen in the same way. The subcategories for this category record whether the impact relates to total urban traffic, total urban freight traffic or the traffic that can be linked to the consolidated volume. If possible, the impact was recorded in terms of percentage. If not, the impact was recalculated to a monthly impact. It is possible that this recalculation somewhat distorts the picture as some impacts were measured for a period of two years and others only for the first month the UCC was in operation.

Despite the fact that one of the main motivations to start a UCC usually is the expected positive impact on the number of freight kilometres, not all impact assessments evaluate this. That is why a number of other impacts that are, to some extent at least, indicative for the impact on distance travelled were also recorded. First, the impact on the number of freight vehicle trips needed to deliver the consolidated volume. Again, as for all impacts, if possible the impact was recorded in terms of percentage. If not, the impact was expressed in the number of freight vehicle journeys that were avoided or added (in a certain period of time). Second, the impact on load rate was recorded based on the assumption that higher loading rates lead to fewer vehicles (when the same type of vehicles is used) and to fewer kilometres. Finally, also the impact on emissions and energy consumption was recorded. For this indicator, however, the type of vehicle used plays an even bigger role in whether or not it is indicative for the impact on distance travelled (e.g. diesel vehicles in BAU and electric vehicles for the UCC). Again, if it was not possible to express the impact on emissions and energy consumption in terms of percentage, they were expressed in monthly emissions or consumption.

The methods used to assess the impact of implementing a UCC were recorded. First it was recorded whether or not the methodology was explained or not. If so, it was recorded whether or not the assessment was (partly) based on (i) real-time measurements/observations, (ii) estimations, (iii) calculations using impact factors and/or (iv) modelling. These subcategories were not decided on in advance, they were developed during the data extraction based on the observed methods and the level of detail in the reviewed publications.

To determine the influence of certain UCC characteristics on the assessed impacts, a whole range of characteristics was recorded. First, some general information such as the location of the UCC, the year of start-up and the year of close-down was recorded. Second, the institutional and operational characteristics are used to distinct the different types of consolidation schemes. The subcategories here are an adaption of the classification schemes developed by Browne et al. (2005) and by Panero et al. (2011): (i) Single private ownership and operation, (ii) Private joint ventures, (iii) Public-private partnerships and (iv) Publicly owned UCCs. Third, it was recorded who were the (paying) customers of the UCC. There are three types of customers: (i) Receivers, (ii) Shippers and (iii) Logistic Service Providers. Next, the type of receiver serviced by the UCC was recorded. Distinction was made between: (i) Hotels, Restaurants, Bars and Takeaways, (ii) Construction sites, (iii) Retail, (iv) Households, (v) Public institutions and (vi) Other businesses. Fifth, the vehicle types servicing the UCC were also recorded, together with the vehicle types used in BAU. Subcategories were (i) Truck, (ii) Van, (iii) Car, (iv) Bike, (v) Train or (vi) Barge. Next, we recorded the fuel type of the vehicles servicing the UCC and the vehicles used in BAU using the following subcategories: (i) Traditional fuels (petrol or diesel), (ii) Compressed natural gas (CNG), (iii) LNG, (iv) LGH, (v) Biogas, (vi) Electric,

(vii) Hybrid, (viii) 'Low emission vehicle'. It was also recorded how many vehicles the UCC operated at the time of the impact assessment. Important for the impact is to know whether the use of the UCC was voluntary or obliged by the local authorities. Therefore, the eighth recorded UCC characteristic was mandatory or voluntary participation. The ninth characteristic is the type of governmental support measure for the UCC at the time of the assessment: (i) EU project support, (ii) Local government subsidies, (iii) Time windows, (iv) Weight restrictions, (v) Pedestrian area / Low traffic zone, (vi) Toll area, (vii) Minimum loading rate for non-UCC commercial vehicles, (viii) Obligated global positioning system (GPS) in non-UCC commercial vehicles to allow tracking, (ix) Low environmental zone and/or (x) Requirement for trucks to use a one-way route system. Finally, the degree of adoption and the weekly transshipment volume were recorded when mentioned in the publication. For degree of adoption, we distinguished three subcategories: (i) Number of delivery addresses, (ii) Number of delivering LSPs and (iii) Number of clients. For weekly transshipment volume, there were five subcategories: (i) Number of heavy goods vehicles (HGVs) visiting the UCC, (ii) Number of cages, (iii) Amount of tonnes, (iv) Number of items and (v) Number of Pallets. Most of the subcategories of the category UCC characteristics were identified and defined during the data extraction from the publications: when mentioned in a certain publication, a new subcategory was added and the previous entries were checked on accuracy.

Finally, some information about the impact assessment itself was recorded. First, the status of the UCC scheme at the time of the impact assessment was recorded. Based on Allen et al. (2012) the impact assessments were allocated to one of two categories: (i) ex-ante assessments and (ii) ex-post assessments. The ex-ante assessments never progressed beyond a research project or feasibility study. For the ex-post assessments two subcategories were distinguished: (i) trials and (ii) permanent implementations. 'Trials' are impact assessments of UCC schemes that did not proceed beyond a trial whereas 'Permanent implementations' did. Second, the year the impact assessment related to was recorded. If the assessment related to more than one calendar year, the earliest year was recorded.

Once the data extraction was finished, the database was scanned for same impact assessments that were described in multiple publications. These impact assessments were merged into one when they related to the same UCC and mentioned the same UCC characteristics and the same assessment period. When merging the impacts was difficult because the reported impacts were not the same we identified a 'dominant' reference preferring the primary sources (e.g. project report above later reviews of different projects). When two impact assessments relate to the same UCC but mention a different assessment period and, at the same time, differ on at least one of the recorded UCC characteristics, the impact assessments were listed as two separate assessments.

As it is the first time that this type of systematic review was carried out in this field of research and because there is no generally adopted evaluation methodology for UCCs yet, we did not exclude any impact assessments based on quality standards.

2.3.4 Statistical analysis

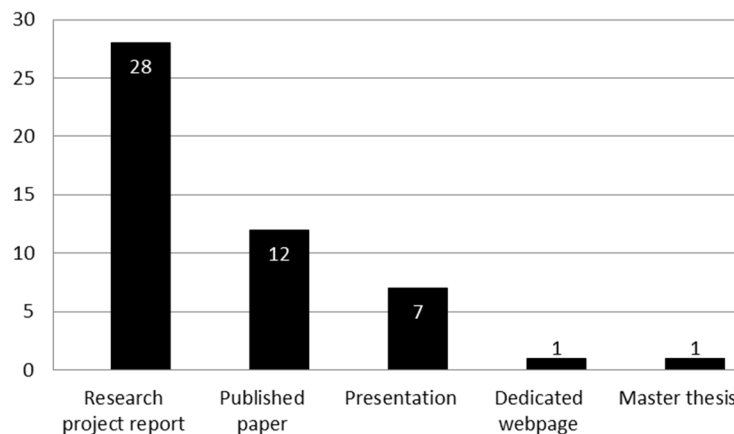
To quantitatively analyse the database, two statistical methods were used. First, Box-and-Whisker plots (box plots) were used to graphically depict the variation in our samples. The box plots were only used for indicators that are expressed in terms of percentage because a comparison of absolute impacts does not make sense as the scale and adoption rate of each UCC is different. In this paper, the end of the lower whisker represents the lower quartile minus 1.5 times the interquartile range whereas the higher whisker represents the upper quartile plus 1.5 times the interquartile range. Any data not included between the whiskers are displayed as an outlier with a cross sign. The second statistical method that was used is Fisher's exact test which is a statistical significance test used in the analysis of contingency tables. We used the test to calculate two-tail P values of the contingency tables which can be defined as the probability of getting the observed result or a more extreme result assuming that the UCC characteristic or assessment characteristic which is evaluated does not influence the result of the impact assessment. When the P value is less than 0.05, we reject the null hypothesis and conclude that the UCC characteristic or assessment characteristic does influence the result of the impact assessment.

2.4 Results

2.4.1 Impact assessment characteristics

Our database consists of 93 unique UCC impact assessments. A total of 49 publications mentioning one or more UCC impact assessments were identified (See Annex B). Nearly 60% of the references (28 out of 49) are research project reports. Less than 25% (12 out of 49) are peer reviewed research papers. The next most common reference type is a conference or webinar presentation. Finally, also one dedicated webpage and one master thesis was reviewed (See Figure 5). In total, the publications reported on 144 impact assessments. The different scenarios of the modelled ex-ante impact assessments were considered as separate assessments as the UCC characteristics differ in each scenario. Once double, triple or even more occurring impact assessments were merged, we ended up with 93 unique impact assessments to be reviewed.

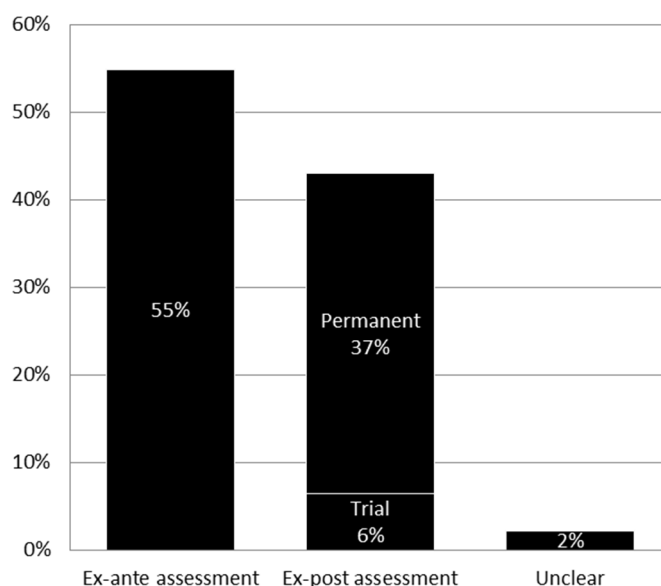
Figure 5. Distribution of the different types of references that were reviewed



Source: Own setup. Number of references out of a total of 49 is displayed in or above the bars.

Just over half (55%) of the impact assessments are ex-ante assessments. Of the ex-post assessments, 15% are assessments of trials whereas 85% are assessments of permanent implementations (See Figure 6). For 2% of the assessments, it is unclear whether the evaluated UCC schemes were feasibility studies, trials or real implementations. The oldest ex-ante and ex-post assessment relate to 1974 and 1993 respectively, the most recent for both categories to 2014. Most ex-post assessments relate to 2005 with a total of 7 out of 29 for which the year of assessment was mentioned in the publication. The evaluated UCC schemes are located on four different continents: Europe, North America, South America and Asia. The vast majority of the schemes, however, were located in Europe (46 out of 50 when double counts for ex-ante assessments that were part of the same modelling with different parameters and ex-post assessments that assessed the same UCC scheme but in a different year are left out).

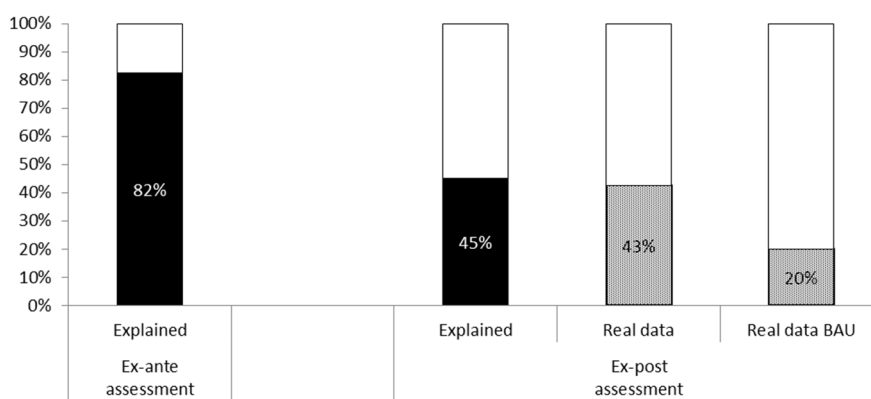
Figure 6. Distribution share of ex-ante and ex-post assessments that were reviewed



Source: Own setup. In case of ex-post assessments, the distinction is made between permanent implementations and trials. Percentages are displayed in the bars. In total 93 impact assessments were reviewed.

We chose not to exclude any impact assessments based on quality standards because there is no generally adopted evaluation methodology for UCCs which determines some kind of minimum quality standard. There is, however, a difference in quality between the different impact assessments. First of all, the methodology is not always explained. The explanation rate for the ex-ante assessments is quite high: 82%. This was to be expected since often a model is used to calculate impact. This rate drops considerably for the ex-post assessments. For only 45%, the assessment methodology is explained (See Figure 7). This might even be an overestimation since the threshold was set to at least one sentence giving some information about the methodology. For only a few ex-post assessments the method was explained in detail. For the ex-post assessments, it is also important to know whether the assessments were done using real data (surveys, counts, measurements, etc.) or only assumptions and estimations. Forty-three percent of the ex-post assessments are based on real data that were collected once the UCC was implemented. For a fifth of the ex-post assessments data were available to assess the situation before the UCC was implemented (See Figure 7).

Figure 7. Share of ex-ante and ex-post impact assessments that explained the assessment method



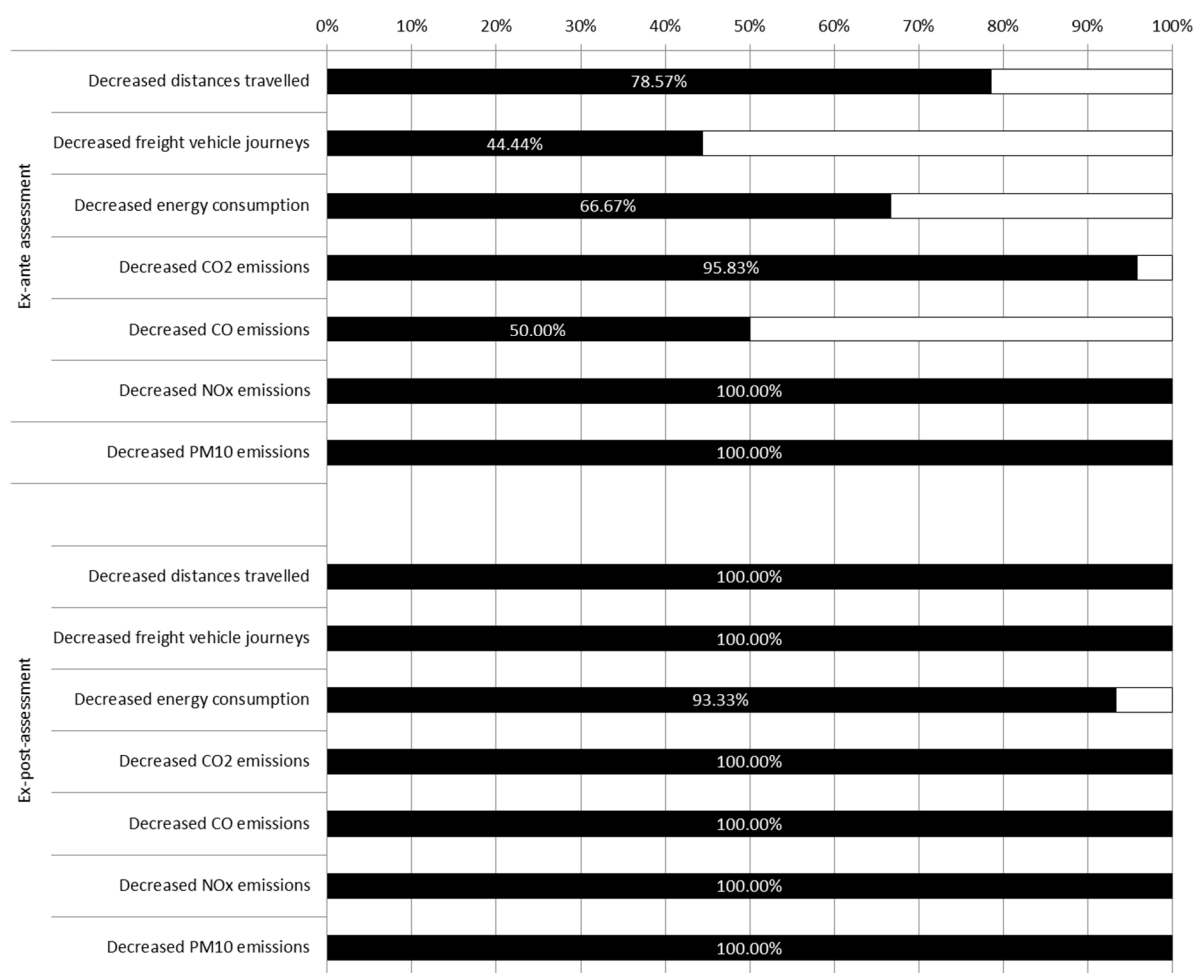
Source: Own setup. For the ex-post assessments the share of assessments that used real data to evaluate the UCC implementation and the before situation are added. Percentages are displayed in the bars.

2.4.2 Measured impacts

We have identified 74 impact assessments explicitly stating that the impact on the number of urban freight vehicle kilometres was evaluated (80%). The other 19 impact assessments only evaluated the impact on number of vehicle journeys, on energy consumption, on loading rate and/or on emission of pollutants (20%). Out of the 74 that did

evaluate impact on number of urban freight vehicle kilometres, four did not quantify that impact. The 70 that did quantify the impact did not always do that in the same way. In 8% of the cases, the impact on total traffic was measured, in 20% of the cases, the impact on total freight traffic was assessed and in 78% of the cases the impact on freight traffic for the consolidated volume was assessed. Overall, 87% of the assessments measured a decrease in number of kilometres travelled whereas 13% measured an increase or a status quo. When differentiating between ex-ante and ex-post assessments we see that 79% of the ex-ante assessments measured a decrease and 100% of the ex-post assessments. This is shown in Figure 8 which depicts for a set of indicators the proportion of ex-ante and ex-post assessments that measured an improvement caused by introducing a UCC. Not all indicators that were registered in our database are displayed in Figure 8, only the ones that were quantified in at least 10% of the 93 impact assessments. The indicator 'increased loading rate', for example, was not included because it was only mentioned by 7 impact assessments. Figure 8 shows a consistent view for the ex-post assessments: in all impact assessment a decrease was measured for all indicators, except for energy consumption. For the ex-ante assessments, the outcome is more diffuse. All or nearly all impact assessments measured a decrease in air pollution (NOx, CO and PM10) whereas only half of them measured a decrease in greenhouse gas emissions (CO2). Two third of the impact assessments measured a decreased energy consumption and less than half (44%) measured a decrease in the number of freight vehicle journeys.

Figure 8. Share of ex-ante and ex-post impact assessments that measured a positive UCC impact

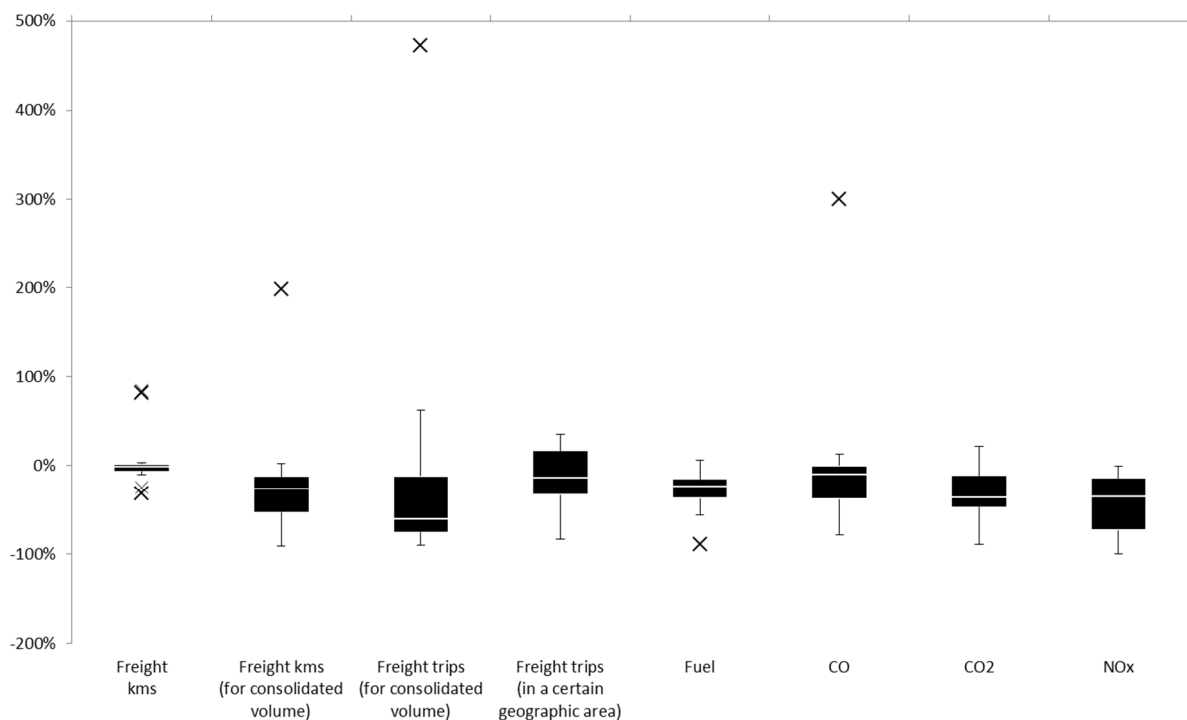


Source: Own setup. Distinction is made between different indicators. Percentages are displayed in the horizontal bars.

The quantified impacts are sometimes expressed in terms of percentage and sometimes expressed in absolute values. It is impossible to compare the absolute values as the scale of the different UCC implementations strongly differs. The distribution of the impacts that were expressed in terms of percentage is shown in a Box-and-Whisker Plot (see Figure 9). First, Figure 9 shows that the box plot for the impact on total freight kilometres in a certain geographic area (usually a city or a part of a city) is comparatively small. Excluding any outliers, the lower fence is -10% and the

upper fence +3% with a median value of -1% suggesting a rather low impact on the number of urban freight kilometres on the scale of the whole of the city. When the impact on freight kilometres is assessed for the consolidated volume only, the assessed impact is much bigger with a median value of -27% and upper and lower fences of +3% and -91% (also excluding any outliers). For the other indicators, the median value suggests a significant turn for the better of 10% or more. We also observe a wide spread both above and below the median value for all indicators apart from impact on total freight kilometres indicating that the different impact assessments mutually differ in the assessed impacts. This is extreme for the distribution for number of freight trips for the consolidated volumes. On the one hand, the median value of -61% suggests a significant decrease of the number of freight trips. On the other hand, the graph also shows a big spread between the upper fence (+63%) and the lower fence (-90%). The distribution of the assessed values for number of freight trips in a geographic area confirms the unclear impact of UCCs on number of freight trips. It is the only indicator for which the upper quartile value (or the lower quartile value in case of loading rate) suggests a decline instead of an improvement. Figure 9 show a few extreme outliers with very high increase in the number of freight kilometres, freight trips and CO emissions. It concerns the results of a modelled simulation based on real data in the food retail sector where loading rates already are high and volumes are large. Shifting these volumes to vans in a UCC would increase the number of trips and kilometres dramatically (Boerkamps & van Binsbergen, 1999). The extreme outliers in Figure 10 can be explained in the same way.

Figure 9. Box-and-Whisker plots of the distribution of the impacts that were expressed in terms of percentage



Source: Own setup. Distinction is made between different indicators. The end of the lower whisker represents the lower quartile minus 1.5 times the interquartile range whereas the higher whisker represents the upper quartile plus 1.5 times the interquartile range. Any data not included between the whiskers are displayed as an outlier with a cross sign.

2.4.3 Relationship between UCC characteristics or assessment characteristics and measured impacts

The big spreads suggest that there might be UCC characteristics or assessment characteristics that influence whether or not the measured impact is positive or negative/neutral. To analyse that relationship, we categorised the 93 impact assessments in contingency tables with one of the quantified impacts as one variable and a certain UCC or impact assessment characteristic as the other variable. We selected the 6 impact variables which were quantified most often: decreased freight kilometres (for the consolidated volume), decreased number of freight vehicle trips (for the consolidated volume), decreased fuel and energy consumption, decreased CO₂ emissions, decreased NO_x emissions and decreased PM emissions. Through the contingency tables we linked each impact variable to one or more UCC or

impact assessment characteristics. These characteristics were chosen in order to answer the questions raised in the introduction of this paper. In the context of this paper, the impact on number of freight vehicle kilometres is the most important impact variable. To find out whether there is a statistically significant relationship between the assessed impact and the methodology used for that assessment this variable was linked to three impact assessment characteristics: (i) use of real data for the impact assessment, (ii) use of modelling for the impact assessment, (iii) explanation of the assessment method in the publication. Because of the growing interest to use alternatively powered vehicles it can be expected that UCC vehicles are smaller than the delivery vehicles used before the UCC was in place and therefore that the number of freight vehicle trips will increase. Depending on the loading rate of the delivery vehicles used prior to the UCC, also the number of freight vehicle kilometres and the fuel consumption might increase. That is why we linked change in vehicle size to (i) decreased number of freight kilometres, (ii) decreased number of freight vehicle trips and (iii) decreased fuel and energy consumption. Both in business as usual and the UCC implementation, multiple vehicle sizes can be used. For this analysis, we assumed a change in vehicle size when the largest vehicle used in business as usual differed in maximum weight from the largest vehicle used to do the UCC deliveries. Third, we wanted to assess to what extent the positive environmental impact we observed in Figure 8 is linked to the fact that alternatively powered vehicles were used. That is why whether UCC vehicles ran on a fuel type other than diesel or petrol was linked to (i) decreased CO₂ emissions, (ii) decreased NO_x emissions and (iii) decreased particular matter (PM) emissions and whether UCC vehicles were electric was linked to (i) decreased CO₂ emissions, (ii) decreased NO_x emissions and (iii) decreased PM emissions. Finally, in the introduction, we raised the question whether a UCC with receivers as their customers actually avoid freight kilometres since the LSPs still have to service their other customers in the UCC target area. To assess this, we linked the type of UCC customer ((i) receiver or (ii) shipper/LSP) to decreased or increased number of freight kilometres. For each of these fourteen 2 by 2 tables Fisher's exact test was used to calculate the probability of getting the observed distribution or a more extreme result. The calculated probabilities can be found in Table 1. The results suggest that there is a statistically significant relationship between a measured decrease in the number of freight kilometres for the consolidated volume and two impact assessment characteristics: (i) use of modelling for the impact assessment and (ii) use of real data for the impact assessment. In other words, Fisher's exact test suggests that the used methodology to calculate the impact of implementing a UCC affects the result of that calculation. When real data were used, 66.67% of the impact assessments measured a decrease in the distances travelled whereas all impact assessments measured a decrease when no real data were used. When some modelling was used to assess the impact, 77.78% of the assessments measured a decrease in the distances travelled whereas all impact assessments measured a decrease when no modelling was used. Second, using a threshold of 0.05 the results suggest that there is not a statistically significant relationship between a measured decrease in the number of freight kilometres for the consolidated volume and whether or not the publication explains the assessment method used. The calculated P value, however, is very close to that threshold. Third, no other significant relationships were found.

Table 1. Overview of the calculated two-tail P values of 14 contingency tables using Fisher's exact test

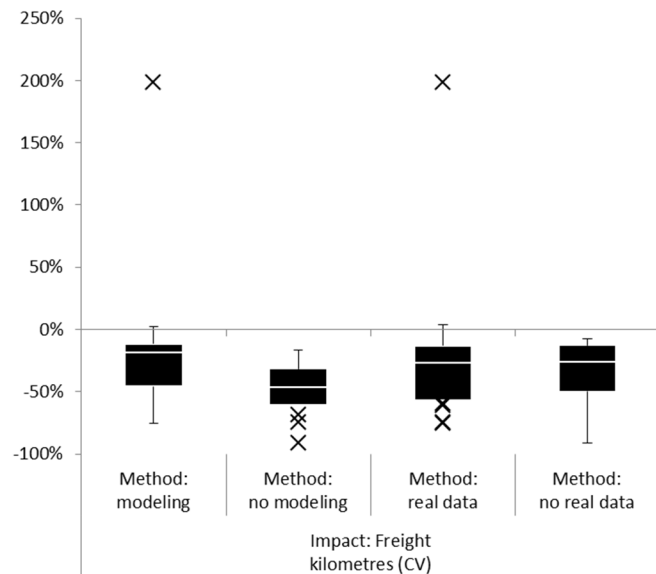
	Decreased freight kms (CV)	Decreased freight vehicle trips (CV)	Decreased fuel and energy consumption	Decreased CO ₂ emissions	Decreased NO _x emissions	Decreased PM emissions
Modelling	0.0106					
Real data	< 0,0001					
Method explained	0.0525					
Smaller vehicle UCC	0.6951	0.5800	1.0000			
Non-traditional fuel type UCC				0.3159	0.2145	0.2145
Electric vehicle UCC				0.6253	0.8075	0.8050
UCC customer: receiver	0.4745					
UCC customer: shipper/LSP	0.5482					

Source: Own setup. When the P value is less than 0.05, we reject the null hypothesis and conclude that the UCC characteristic or assessment characteristic does influence the result of the impact assessment.

To calculate the P-values shown in Table 1 we used all the quantified impacts found in our references, whether they were expressed in terms of percentage or in absolute numbers. In Figure 10 we constructed a box plot of the distribution of the impacts on the number of freight kilometres for the consolidated volume that were expressed in terms of percentage only to know whether using modelling or using real data decreases or increases the measured impact. The box plot shows a less clear relationship between a measured decrease in the number of freight kilometres for the consolidated volume and (i) use of modelling for the impact assessment and (ii) use of real data for

the impact assessment. Especially whether or not real data are used to do the impact assessment does not affect the median value of the impact assessment.

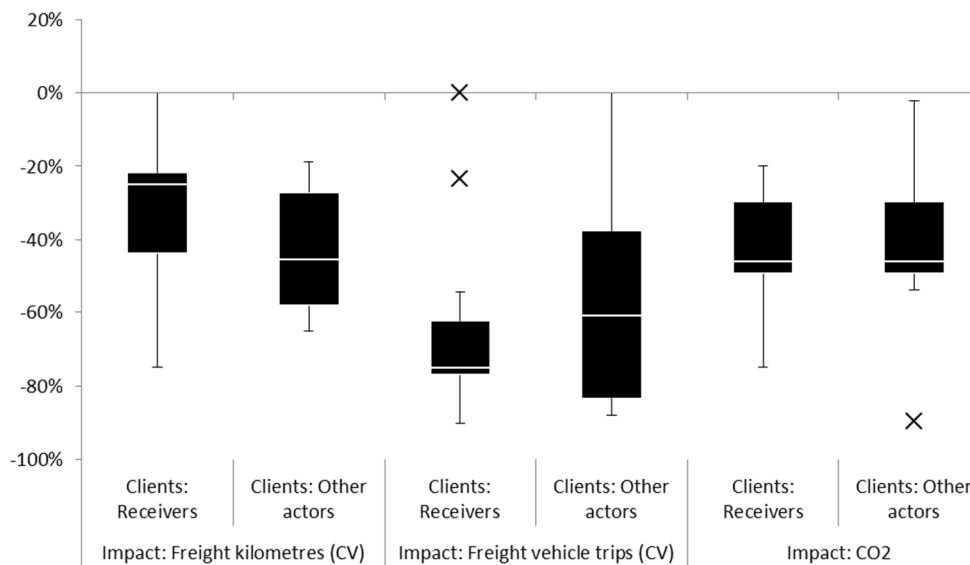
Figure 10. Box-and-Whisker plots of the distribution of the impacts that were expressed in terms of percentage taking into account the assessment method that was used



Source: Own setup. The end of the lower whisker represents the lower quartile minus 1.5 times the interquartile range whereas the higher whisker represents the upper quartile plus 1.5 times the interquartile range. Any data not included between the whiskers are displayed as an outlier with a cross sign. Only impacts that were quantified in terms of percentage for at least 10% of the assessments were taken into account.

The results in Table 1 also suggest that there is no statistically significant relationship between the type of receiver and the impact on the number of freight kilometres for the consolidated volume. Because of the importance of this aspect for this paper, the distribution of a few impacts of UCCs where receivers are clients and where they are not are shown in a box plot (see Figure 11). The evaluated impacts are not chosen at random; only the indicators were selected for which at least 10% of the impact assessments did an assessment. Because we want to compare two groups (Receivers are client or not), for each category, at least 5 impact assessments were required. This resulted in an analysis for (i) number of freight kilometres for the consolidated volume, (ii) number of freight vehicle trips for the consolidated volume and (iii) CO₂ impact. The Box Plot shows that the medians of the groups are relatively similar, except for the impact on freight kilometres. There, the ranges do not differ too much, but the median value for the decrease is much lower when the receivers are the clients. Second, it also shows that there is a huge range, revealing that the assessments differ in how they assess the impact of the type of UCC customer on these three indicators. For the UCCs in Heathrow and Norwich, we observe negative outliers for the impact on freight vehicle trips for the consolidated volume. For Norwich, the status-quo can be explained by the existing 7.5 Gross Vehicle Weight Restriction within the city's core commercial and retail area (Civitas, s.d.). In case of Heathrow, the limited decrease in freight vehicle trips for the consolidated volume is explained by the already high loading rates and high volumes in the business as usual situation (Panero, Shin & Lopez, 2011). For the construction UCC Hammarby, we observe a positive outlier for the impact on CO₂ emissions which is explained by the many trucks that don't have to enter the city centre any more (Browne et al., 2005).

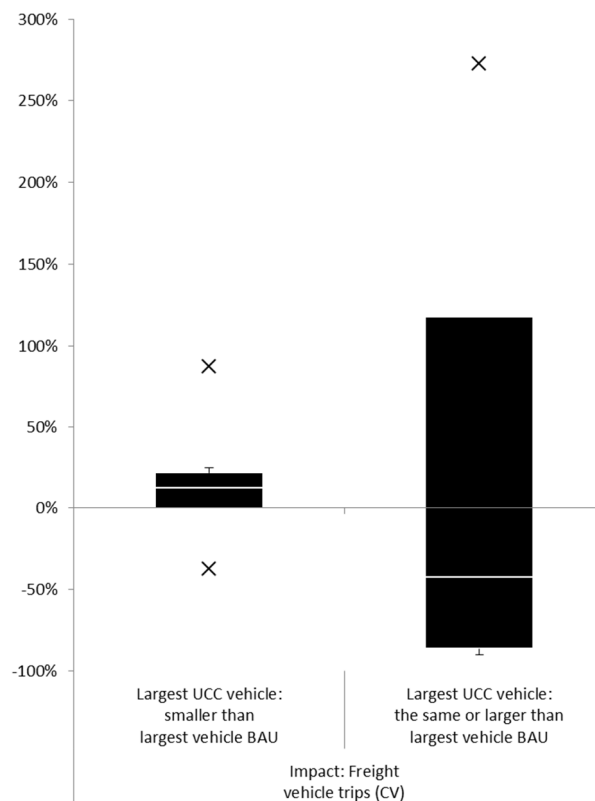
Figure 11. Box-and-Whisker plots of the distribution of the impacts that were expressed in terms of percentage taking into account the type of client



Source: Own setup. The end of the lower whisker represents the lower quartile minus 1.5 times the interquartile range whereas the higher whisker represents the upper quartile plus 1.5 times the interquartile range. Any data not included between the whiskers are displayed as an outlier with a cross sign. Only impacts that were quantified in terms of percentage for at least 10% of the assessments were taken into account.

The results in Table 1 also suggest that there is no statistically significant relationship between the impact on the number of freight vehicle trips and whether or not smaller vehicles are used for the UCC deliveries. Figure 12 shows the distribution of the quantified impacts on freight vehicle trips making the distinction between UCCs of which the largest delivery vehicle is smaller than the largest vehicle used in business as usual and UCCs of which the largest delivery vehicle is the same or larger than the largest vehicle used in business as usual. We can observe an important difference between the two groups. First, the median value represents an increase when UCC vehicles are smaller than before and a decrease when UCC vehicles are the same or larger. Second, the UCCs with smaller vehicles all show an increase of the number of freight vehicle trips except for one outlier value. Finally, there is also a big difference in range but this might be caused by one extreme outlier value in the case of same or larger UCC vehicles. It has to be mentioned here that Figure 12 is based on only 10 quantified impacts and three of these impacts can be categorised as outliers: the highest negative outlier (an extreme increase of the number of freight trips) is again linked to the modelled simulation in the food retail sector where loading rates already are high and volumes are large. Shifting these volumes to vans in a UCC would increase the number of trips and kilometres dramatically (Boerkamps & van Binsbergen, 1999). The other two outliers are values that were calculated in the Lekkerland simulation for the two most extreme scenarios in which all orders smaller than 20 roll cages are distributed through a UCC (operated by a 3PL or operated by Lekkerland itself (Stoopen, 2011)).

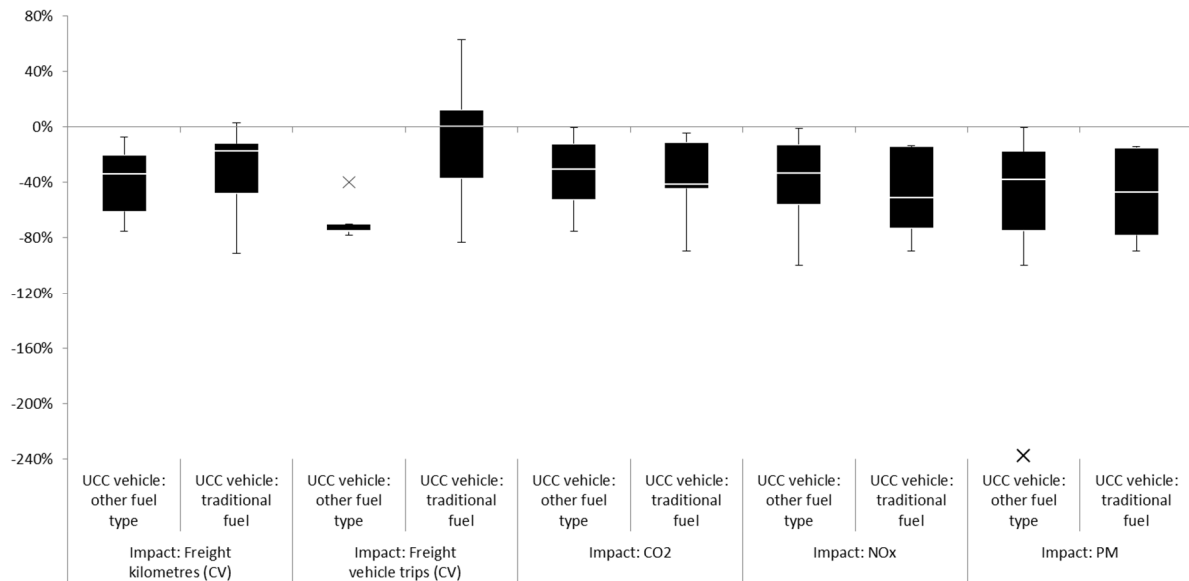
Figure 12. Box-and-Whisker plots of the distribution of the impacts that were expressed in terms of percentage taking into account the size of the UCC vehicle compared to the size of the vehicle used before



Source: Own setup. The end of the lower whisker represents the lower quartile minus 1.5 times the interquartile range whereas the higher whisker represents the upper quartile plus 1.5 times the interquartile range. Any data not included between the whiskers are displayed as an outlier with a cross sign. Only impacts that were quantified in terms of percentage for at least 10% of the assessments were taken into account.

Finally, we also constructed a box plot to visualise the impact of fuel type of the vehicle used for UCC deliveries and UCC impact (See Figure 13). It shows that the median value of the impact on freight kilometres for the consolidated volume is better when non-traditionally fuelled vehicles are used. The interquartile ranges do not differ that significantly though. A remarkable difference can be found, however, when we compare the impact on the number of freight vehicle trips for the consolidated volume. When non-traditionally fuelled vehicles are used, the number of freight trips decreases considerably (median value of -75%) whereas when other types of vehicles are used the impact is sometimes positive and sometimes negative and with a median value of 0%. In Figure 13 we observe two outliers. The first one is a negative outlier with a much lower decrease in the number of freight vehicle trips for the consolidated volume for the Cargohopper in Utrecht (C-Liege, s.d.). The second outlier is an extremely positive impact on PM for the UCC in Stockholm (C-Liege, s.d.). In both cases, it is difficult to explain these outliers because they are not explained in the references.

Figure 13. Box-and-Whisker plots of the distribution of the impacts that were expressed in terms of percentage taking into account whether UCC vehicles were fuelled by traditional fuel types (diesel and petrol) or other fuel types



Source: Own setup. The end of the lower whisker represents the lower quartile minus 1.5 times the interquartile range whereas the higher whisker represents the upper quartile plus 1.5 times the interquartile range. Any data not included between the whiskers are displayed as an outlier with a cross sign. Only impacts that were quantified in terms of percentage for at least 10% of the assessments were taken into account.

2.5 Discussion

According to the 93 UCC impact assessments that we systematically reviewed implementing a UCC decreases the number of urban freight vehicle kilometres. A distinction should be made between the ex-ante assessments measuring a decrease in 79% of the cases and the ex-post assessments measuring a decrease in all of the cases. At first sight, this is a convincing argumentation for implementing and/or supporting UCCs. However, a few reservations have to be made. First, despite the fact that a decrease was ascertained in the majority of the cases not all impact assessments point in the same direction. Some of the ex-ante assessments predicted an increase in the number of kilometres. Second, we ascertained considerable decreases in the number of freight kilometres travelled to deliver the consolidated volume but only found small decreases in the total number of urban freight kilometres meaning that the impact or adoption rate of most evaluated UCCs is rather small. The median value of the measured impact on freight kilometres for the consolidated volume only is -27% with a first quartile value of -53% and a third quartile value of -12%. When we look at the impact assessments that mention the impact on total urban freight traffic, we find a median value of -1%, a first quartile value of -7% and a third quartile value of +3%.

Third, the methodology used to determine the impacts was not explained for 55% of the ex-post assessments and 18% of the ex-ante assessments. This lack of explanation makes it difficult to evaluate the quality of the assessment (Browne et al., 2005). The fact that we also included non-scientific references in our database might play a role in this. People composing dedicated project websites aimed at the general public or reports of research projects that aim to give an overview of existing urban freight measures and their impacts do not always consider it relevant to also mention an assessment method. Fourth, despite the fact that actual pilots and implementations should allow a before-after comparison using real data instead of estimations, only 43% of the ex-post assessments specifically mentioned to have used real data (surveys, counts, measurements, etc.) to quantify the assessment indicators for the UCC and even less (20%) used real data to quantify assessment indicators for the situation before the UCC was implemented. Evaluators are not necessarily to blame here since it is very difficult to collect all the data needed to evaluate all possible impacts of implementing a UCC. Many stakeholders are affected which means that an evaluator needs data from all them to calculate the impact or that a systematic, comprehensive and periodic urban freight survey system has to be in place for the urban area in which the UCC is implemented. Generating the interests of stakeholders in sharing data on urban freight is very difficult when this is not statutory (Allen, Ambrosini, Browne, Patier, Routhier & Woodburn, 2014). Local authorities are not inclined to carry out periodic urban freight surveys

for two reasons. First, because of the many dimensions of the freight system these surveys are very complex and time consuming if they want to cover the entire urban freight spectrum (Holguín-Veras & Jaller, 2012). Second, the mobility efforts of local authorities have been mainly focussed towards passenger transport. That also explains why many urban policy makers only have vehicle traffic counts at their disposal to determine their policy approach for urban freight transport (Allen & Browne, 2008). Vehicle traffic is counted anyway and urban freight data are disaggregated from these data. And the few hundred urban freight surveys that have been carried out were usually conducted on a one-off basis as part of the development of an urban freight strategy or urban planning decision (Allen & Browne, 2008; Allen et al., 2014). Because of the lack of urban freight data not much progress has been made so far in urban freight modelling as well since there are strict data requirements to develop an urban freight model (Allen et al., 2014). Our research confirmed that this lack of data influences the outcome of the impact assessments of UCCs since we found a statistically significant relation between the type of impact assessment and the outcome of that impact assessment: when no real data are used or no modelling is mentioned, the outcome of the impact assessment is always positive.

The fifth reservation to be made on the established positive impact of UCCs is that not all UCC schemes that were tested were also evaluated. Allen et al. (2012), state that quantification of the transport and environmental impacts exists only in 35% of the UCC schemes. In 2005, only 25% of the reviewed UCC schemes were evaluated through an impact assessment. Just over 40% of these evaluations also assessed the impact on urban freight kilometres and only one out of the 17 evaluations compared the effect of the UCC on total urban goods vehicle kilometres (Browne et al., 2005). It means that for the majority of UCC schemes, the impact was never assessed or never published. Due to a lack of data, it is impossible to research whether the impact of the non-evaluated UCCs is in line with the impact that was quantified for the evaluated UCCs. It can be expected, however, that due to publication bias the outcome of our review of published impact assessments is too optimistic. Finally, there is only one impact assessment that also assesses the impact on the kilometres driven outside the city (Leonardi et al., 2012) despite the fact that Browne et al. (2005) already included this distinction in their proposed evaluation framework.

2.6 Conclusions

Urban consolidation centres are a popular measure in the battle against air pollution, greenhouse gas emissions and congestion caused by urban freight traffic. Throughout the past 30 years, multiple UCCs were tested and implemented, and much research was conducted into how to make them economically viable and into their societal and environmental impacts. It is generally accepted that a UCC increases the loading rate of the urban freight vehicles and decreases the number of urban freight vehicle kilometres. In theory, that is the case when the throughput of the UCC is high enough and underutilized freight vehicles deposit their load at the UCC where it is then consolidated. The question is, however, whether these societal benefits actually occur. When a receiver, for example, becomes a UCC client, his LSP deposits the deliveries for that receiver at the UCC but might still have to go into the city to deliver other clients.

This paper reports on the systematic quantitative review of 49 publications mentioning one or more UCC impact assessments. The findings in these publications were systematically recorded in a database which led to a set of data on 93 unique impact assessments. For these assessments, multiple UCC characteristics and assessment outcomes were recorded. Once the data extraction was finished, two statistical methods were used to analyse the database: the Bow-and-Whisker plot graphically depict the variation in our samples and Fisher's exact test to examine the significance of the association between the two kinds of classification (impact on the one hand and a UCC characteristic or an assessment characteristic on the other hand).

The majority (55%) of the assessments we found are ex-ante assessments whereas 43% are ex-post assessment. Based on these assessments, we would have to conclude that the impact of a UCC on the number of urban freight vehicle kilometres is positive: 79% of the ex-ante assessments and 100% of the ex-post assessments observed a decrease. We saw a similar positive trend for the other indicators that were analysed: the impact was mainly positive in the ex-post assessments and slightly less positive in the ex-ante assessments. Only for the impact on number of freight vehicle journeys we found an increase instead of a decrease. Loading rate was also one of the monitored indicators, but despite the fact that increasing the loading rate is one of the objectives of a UCC, less than 10% of the assessments evaluated this.

Using Fisher's exact test we aimed to find a statistically significant relation between some UCC characteristics and the assessed impact. No such relation was found which means that for the UCCs in our database whether their impact was positive or negative was not influenced by the type of vehicle used or by the type of customer. However, the box plot showing the distribution of the impact on freight kilometres whilst differentiating between receivers as customers or other actors as customers shows a considerable difference in median value suggesting that the type of UCC customer does affect how big the impact of the UCC is. This confirms the validity of our research question, especially because none of the references reporting on a UCC with receivers as customers explains how they incorporated the kilometres driven by the LSPs of these receivers to deliver their other customers in the same area. The fact that only one impact assessment also takes into account the kilometres that are driven outside the city also plays a role here. The box plot showing the relation between the fuel type of UCC vehicles and the impact of a UCC reveals that when non-traditionally fuelled vehicles are used the number of freight trips decreases considerably. That decrease is doubtful when UCC vehicles are traditionally powered.

Our analysis also shows that the definite positive impacts that we found might have to be partially put down to the lack of high-quality impact assessments. For 55% of the ex-post assessments the methodology was not explained and only 43% of the ex-post assessments were based on real data. Only in 20% of the cases real data were used to evaluate how the before situation scored on a number of indicators. Fisher's exact test revealed that two impact assessment characteristics (using urban freight modelling and using real data) statistically significantly affect the outcome of the assessment. The outcome was always positive when no real data were used for the assessment or when it was not mentioned that the assessment involved some urban freight modelling. To use real data or urban freight modelling in an impact assessment, reliable and comprehensive urban freight data are needed and these data are usually not available, certainly not on an urban level. Also the fact that some important indicators such as loading rate are only assessed in 10% of the impact assessments is probably due to the lack of data since it is very difficult to measure or estimate the loading rates of the vehicles entering a city. To further improve UCC impact assessments and to make sure reliable conclusions can be drawn from them, high-quality data that cover the entire urban freight spectrum and that are collected periodically are needed.

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Annex A: Items of information recorded in database

- Name UCC scheme
- Year of impact assessment
- Type of impact assessment (ex-ante or ex-post, in the case of ex-post an additional distinction between a trial and an implementation. When it concerns a trial that evolved into an implementation, we considered it to be an implementation.
- Reference used (referring back to the original Microsoft Excel database)
- Number of UCCs
- Timing:
 - Year of start-up
 - Year of close-down
 - Still operational on date of publication
- Location:
 - Continent
 - Country
 - City
- Delivery vehicles used in BAU (new categories added to the database when mentioned in the reference)
 - Vehicle type (truck ($\leq 7.5T$ or $> 7.5T$), van, car, bike, train, barge, other)
 - Fuel type (Traditional, CNG, LNG, LPG, Biogas, Electric, Hybrid, 'Low emission vehicle')
- Delivery vehicle used for UCC (new categories added to the database when mentioned in the reference)
 - Vehicle type (truck ($\leq 7.5T$ or $> 7.5T$), van, car, bike, train, barge, other)
 - Fuel type (Traditional, CNG, LNG, LPG, Biogas, Electric, Hybrid, 'Low emission vehicle')
 - Number of UCC vehicles
- Institutional and operational characteristics (categories adapted from Panero, Shin & Lopez; 2011)
 - Single private ownership and operation
 - Regular privately owned and operated UCC
 - Single site demanding landlord UCC
 - Single company UCC operated by a subcontractor
 - Single company UCC operated by the company
 - Private joint ventures
 - Final deliveries by a newly constituted company
 - Final deliveries by a pre-existing neutral operator
 - Final deliveries by some of the participating companies
 - Public-private partnerships
 - UCC is owned and operated by a newly constituted company
 - UCC is owned and operated by an existing company
 - Publicly owned UCC
 - Operated by an existing private company winning a bid
- UCC customers (who are the paying customers of the UCC, a combination of answers is possible)
 - Receivers (also building contractors receiving construction materials on a building site in the case of a construction consolidation centre)
 - Shippers
 - Logistic service providers
 - Not applicable
- UCC scale
 - Degree of adoption
 - Number of delivery addresses
 - Number of delivering LSPs
 - Number of clients (when type of UCC customers is not clear)
 - Weekly transshipment volume
 - Number of HGVs visiting the UCC
 - Number of cages
 - Amount of tonnes

- Number of items
 - Number of pallets
 - UCC receivers
 - Retail
 - Chain stores
 - Independent retailers
 - Not specified
 - Construction sites
 - Hotels – Restaurants – Bars – Take-aways
 - Households
 - Public institutions
 - B2B
- Enforcement
 - Voluntary or mandatory use
 - Voluntary use (from a local government perspective)
 - Mandatory use (from a local government perspective)
 - Support measures
 - EU project support (at the time of the assessment)
 - Local government subsidies (at the time of the assessment)
 - Time windows
 - Weight restrictions
 - Pedestrian area / Low traffic zone
 - Toll area
 - Minimum loading rate for non-UCC commercial vehicles
 - Obligated GPS system in non-UCC commercial vehicles to allow tracking
 - Low environmental zone
 - Requirement for trucks to use a one-way route system
 - No support measures mentioned
 - Explanation of the rules
- Impact assessment methodology
 - Explained?: When at least one thing is mentioned about the impact assessment methodology, we considered the methodology as explained.
 - Simulation/calculation: When in the explanation of the methodology it is mentioned that for at least one impact calculations were made based on other data (be it real measurements or estimations), this indicator is considered positive
 - Measurements: When in the explanation of the methodology it is mentioned that for at least one impact data were collected to quantify it, this indicator is considered positive
 - Estimations: When in the explanation of the methodology it is mentioned that for at least one impact estimations were used to calculate it, this indicator is considered positive
 - Modelling: When in the explanation of the methodology it is mentioned that at least one model was used to calculate on of the impacts, this indicator is considered positive
- Impact
 - Distance travelled
 - Assessed?
 - Impact on total traffic (% or not mentioned)
 - Impact on total freight traffic (% or not mentioned)
 - Impact on freight traffic through consolidation centre (km per month, tonnes-km per month, % or not mentioned)
 - Number of vehicle journeys
 - Assessed?
 - Impact on number of freight vehicle journeys (for the consolidated volume) (% , number or not mentioned)

- Impact on number of freight vehicle journeys (for a geographic area) (% or not mentioned)
- Energy consumption
 - Assessed?
 - Fuel consumption (% , litre per month or not mentioned)
 - Energy consumption (TOE per month, MJ per month or not mentioned)
- Emissions
 - Assessed?
 - CO (% , kg per month or not mentioned)
 - CO₂ (% , tonnes per month or not mentioned)
 - NO_x (% , kg per month or not mentioned)
 - SO_x (% , kg per month or not mentioned)
 - HC (% or not mentioned)
 - PM (% , kg per month or not mentioned)
 - CH₄ (% or not mentioned)
 - VOC (% , kg per month or not mentioned)
 - Vehicle emissions (% or not mentioned)
 - Local emissions (% or not mentioned)
- Loading rate
 - Assessed?
 - Loading rate (% or not mentioned)
- Additional remarks

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3

How to consolidate urban flows of goods without setting up an urban consolidation centre?⁷

3.1 Introduction

For more than twenty years now, initiating an urban consolidation centre (UCC) has been a popular measure in city logistics (Karrer & Ruesch, 2007). Because inner-city transportation activities are bundled, UCC's combine both high-quality deliveries and a mitigation of the negative effects of motorized goods vehicles entering cities. However, previous research on UCC's clearly shows that many of these freight platforms are granted only a short lifespan (Browne et al., 2005; Van Duin, 2009). First of all, because the cost of the additional transshipment often prevents them of being cost-effective. Therefore, they are dependent on governments willing to subsidize them because of their positive impact on congestion, emissions and the shopping climate. In addition, urban retailers do not always see their added value and therefore often opt out as soon they are expected to pay for the service (Zunder and Ibanez, 2004; Marcucci and Danielis, 2008).

Nevertheless, the idea of consolidating goods from a destination perspective is valuable (van Rooijen and Quak, 2009). From the origin perspective, suppliers, carriers and large retailers already seek to consolidate freight as much as possible as it is cost-efficient for them. However, for cities, this cost-driven consolidation is not necessarily advantageous as trucks are still entering city-centres half-empty. After all, a truck might depart from the supplier's distribution centre fully loaded, but once the first delivery is carried out, it continues its journey half empty. And as a supplier's client-businesses are usually located in different cities, most freight vehicles entering a particular city are not used to their full capacity. In order to avoid the unnecessary nuisance caused to the users of the urban living environment by this inefficient mode of operation, a search for alternative, efficient and cost-effective consolidation concepts is needed.

⁷ Verlinde, S., Macharis, C., Witlox, F. (2012). How to consolidate urban flows of goods without setting up an urban consolidation centre? *Procedia – Social and Behavioral Sciences*, 39, 687-701.

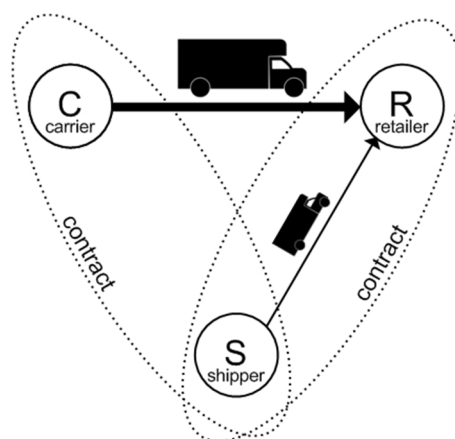
The main purpose of this paper is to identify and classify feasible consolidation concepts aiming to make better use of the loading capacity of freight vehicles in order to reduce the number entering urban areas. The paper consists of three main parts. The first section explains why it is beneficial and sustainable to bundle inner-city transportation activities to a larger extent than is currently the case (Section 3.2). Next, in Section 3.3, the evolution of consolidation within urban logistics during the past fifteen years is sketched based on the results of several European research projects on urban freight measures, tools and initiatives. Finally, in Section 3.4, a general classification of consolidation-oriented tools is introduced together with a brief empirical analysis of already implemented examples.

3.2 Consolidating urban freight flows in order to reduce urban freight kilometres

Urban deliveries are carried out because people buy consumer goods at downtown retail stores. In response to that, retailers order new items from their suppliers to replenish their stock. At that point, supplier and retailer agree on the amount of goods to be delivered, the price (including transport) and the acceptable lead time. The supplier strives to provide the best possible service to his client and tries to fulfil their agreement to the best of his abilities by making sure the requested goods are delivered on time. Some suppliers carry out their deliveries on own-account and are therefore able to enter into direct consultation with the retailer on a mutually favourable delivery date and/or time within the agreed lead time. For the most part, however, suppliers make use of a professional carrier to pick up the goods and to take them to the shopkeeper's premises. Note that, in that case, supplier and carrier enter into an agreement of their own which, among other things, states how much time the carrier is granted to deliver the goods.

This mode of operation is common within urban logistics and is characterized by the lack of contractual obligations between retailer and carrier, also illustrated in Figure 14. As a result, retailer and carrier are only little inclined to consult with each other on the most appropriate delivery date or time. This lack of direct consultation leads to particular inefficiencies which, for their part, cause a considerable amount of unnecessary freight kilometres (Stichting Leve De Stad, 2005). First of all, there is the inefficient ordering behaviour of retailers. As carriers usually work by order of shippers and suppliers, the retailer is never directly faced with the consequential transport bill. This is reflected in his ordering behaviour since he often places his orders scattered in time, depending on when he has got time for it or when he thinks it fits to sales. Consequently, for the most part, suppliers receive small orders from their retailers instead of one bundled order. Secondly, suppliers and carriers are convinced that a short lead time is vital to a good customer service which means they do not save up deliveries but carry them out as fast as possible. Consequently, the flood of small orders results in many small deliveries. This approach also dominates our streets: many small delivery trucks and vans delivering small packages often several times a week at the same premises.

Figure 14. The common mode of operation within urban logistics characterized by the lack of contractual obligations between retailer and carrier



Source: Own setup.

Irrespective of the size of individual deliveries, carriers aspire to use their freight vehicles as efficient as possible by sending off their vehicles fully loaded and aiming at as little empty or half empty kilometres as possible. Consequently, many urban delivery trips are round trips with several delivery addresses which are planned as

efficiently as possible. As most carriers operate on a regional or even national level, not all addresses are located in one city. It means that freight vehicles usually enter the first city on the round trip fully loaded, but are only partially loaded when entering the second or third city. At the urban level, these empty or half empty kilometres are inefficient thus causing unnecessary hindrance and pollution. That is why, from a destination perspective, the adverse effects of urban deliveries would be reduced if flows of goods headed for the city were consolidated more efficiently.

3.3 Observations on the importance of urban consolidation concepts in the field of city logistics

Consolidating goods on the urban level involves more than rationalizing merely inner city retail deliveries. It is about reducing the number of pick-ups and deliveries at urban businesses, public services, construction sites and households. Approaches to achieve that should be innovative as both the availability of different kinds of goods and mitigating the strain urban freight transport puts on the quality of life are essential for a viable city. The first attempts to reduce the negative impact of urban freight transport date back from the early 70's when most Western countries initiated research programs and pilots (CEMT, 1999). Back then, the ultimate goal was not the efficiency itself, but to minimize all possible disruption for passenger traffic by car. Most initiatives, however, died a quick death because very soon governments noticed that the efforts were not proportionate to their likely outcome. As from the 80's, cities all over Europe were faced with similar mobility problems such as congestion, road safety issues, security, pollution, etc. Primarily, policy-makers tried to achieve a modal shift in passenger transport in order to safeguard urban mobility. It is not until the early 90's that also the organisation of urban freight transport was dealt with in order to tackle the urban mobility problems.

During the last 20 years, many approaches and solutions have been proposed and tested. To date, however, little explicit attention has been paid to the concept of urban consolidation. This is clearly shown in the existing classifications of urban freight measures and initiatives since they never refer to consolidation concepts as a separate type or category. First of all, because some classification only categorize restrictive policy measures, e.g. the classification of Browne et al. (2007) which distinguishes nine different kinds of measures which either imply restrictions for specific freight vehicles based on their fuel consumption, emissions, axle-pressure, height, width, length, weight, loading capacity or determine when and where freight vehicles are allowed to drive or to park to get unloaded.

In addition to these restrictive policy measures, authorities can also choose to pursue a more stimulating policy. Munuzuri et al. (2005) distinguish four different groups of actions for policy-makers to mitigate the adverse effects of urban freight transport on the urban environment:

- i. Actions related to the public infrastructure; e.g. the creation of transfer points, such as city terminals, or the promotion of a shift to more environmental friendly modes; like the use of (shuttle) trains or an underground system.
- ii. Actions related to land use management; e.g. creation of parking facilities, such as the provision of load zones.
- iii. Actions related to access conditions; this category includes policy restrictions regarding to space, such as road pricing and vehicle restrictions, and regarding to time, such as time-windows and a ban on night deliveries.
- iv. Actions related to traffic management; e.g. reconsidering the scope of regulations, such as harmonisation of regulations with other local authorities.

The first category mentions the example of city terminals, which are logistics facilities where freight destined for a particular urban region is consolidated. It does not mean however, that all measures aimed at consolidating urban freight flows belong to this first category. For example, restrictions on the load factor of freight vehicles entering the city rather belong to the third category. Other consolidation oriented measures, for example encouraging carriers to cooperate in each other's delivery area, do not belong to any category. This is due to the fact that this break down into categories is not based on the final goal of the suggested actions but on their area of influence. The same goes for most other classifications within urban freight logistics. Russo and Comi (2009), for example, also made a classification based on the area of influence of city logistics measures which slightly deviates from the one of Munuzuri et al. (2005):

- i. Measures related to material infrastructure:
 - a. Linear, if they refer to links of the urban/metropolitan transport network
 - b. Surface (and/or nodal), if they refer to areas that can be reserved for freight operations
- ii. Measures related to immaterial infrastructure (telematics) or Intelligent Transportation Systems
- iii. Measures related to equipment
 - a. Measures on loading units
 - b. Measures on transport units
- iv. Measures related to governance of the traffic network

Quak (2008) for his part relies on the degree to which actions and initiatives affect their context to construct a framework to identify basic dimensions and classification for urban freight transport. He distinguishes two categories each with two subcategories:

- i. Class A: Improvements within the context
 - a. Category A1: Policy initiatives
 - b. Category A2: Company driven initiatives
- ii. Class B: Improvements by changing the context
 - a. Category B1: Physical infrastructure initiatives
 - b. Category B2: Transport reorganising initiatives

Within his framework, Quak identifies 12 different types of initiatives based on 106 examples from the literature on improving sustainability in urban areas. Within the scope of consolidation of urban freight, two types of initiatives merit particular notice, each in a different category: Carrier cooperation initiatives in category A2 and Consolidation centre initiatives in category B1.

The fact that the various classifications do not directly refer to consolidation concepts does not mean that it is an insignificant concept. After all, some variants have been put into practice frequently. This is demonstrated by the results of four successive European research programs listing, categorizing and analysing a big part of the city logistics measures implemented in the different European cities. The first list of measures was given by COST 321 (1999) which identified 56 theoretically feasible measures which were divided into eight categories:

- i. Logistical measures
- ii. Modal choice
- iii. Price of transport
- iv. Infrastructure and physical planning
- v. Traffic management
- vi. Technical measures concerning the vehicle
- vii. Measures concerning the way of driving
- viii. Other measures.

Again, these categories do not refer to the goal which is pursued, but to the method of intervention. As consolidating can be done in different ways, none of these categories directly refers to consolidation of urban freight. Of the 56 identified measures, 13 are, at least to some extent, consolidation oriented (see Table 2). These 13 measures are classified into the first four categories. Column 2 of Table 2 shows to which category the consolidation oriented measure belongs. However, when considering the method used to consolidate, four alternative categories should be distinguished. First of all, the greater part of the measures regards a genuine additional transfer ('AT') point near the city centre. Secondly, four other measures aim at developing or promoting common delivery ('CD') points. Finally, two measures aim at changing the behaviour of carriers ('BC') and another two the behaviour of retailers and/or shippers ('BRS').

Table 2. Consolidation oriented measures within COST 321

Shared use of storage space by retailers	1	CD
Promotion of storage facilities in inner urban areas	1	CD
Outsourcing of freight transport	1	BRS
Transport co-ordination and co-operation of retailers *	1	BRS
Goods distribution centres *	1	AT
Consolidation by means of "urban" containers *	1	CD
Development of lock chambers common to a group of receivers	1	CD
Regional rail network in combination with urban DC *	2	AT
Truck ownership licenses for urban distribution *	3	BC
Road pricing in cities *	3	BC
Optimisation of distribution systems including transport centres *	4	AT
Extension of transshipment facilities	4	AT
To revive railway or fluvial central urban sites as urban distribution centres	4	AT

Source: Own setup based on COST 321, 1998.

Within the COST 321 project, all measures were assessed by a group of experts on their relative potential. The ones which were considered to be the most promising are indicated with * in Table 2. These results clearly show that more than half of the consolidation oriented measures were considered to be potentially beneficial, although, at that time, only goods distribution centres had been put into practice frequently. Beside the judgement of this group of experts, the countries participating in the COST 321 Action studied the effects of some of the measures. They distinguished three groups. The first group are measures with consistently favourable effects. None of the consolidation oriented measures was part of this group. The second group are the measures with contrasted effects. Also none of the consolidation oriented measures was part of this group. The last group, measures with moderate effects, had the following consolidation oriented measures in it:

- Transport co-ordination and co-operation of retailers
- Goods distribution centre
- Consolidation by means of urban containers
- Tour planning
- Goods distribution centres with co-operation of carriers
- Road pricing in cities
- Optimisation of distribution systems

The fact that these measures were only granted moderate effects does not mean that they should be categorised as generally unworthy of implementation. This classification simply indicates that they are of subordinate importance in relation to the city as a whole because generally they only cover a particular part of the entire traffic situation or of the total urban area. Besides this assessment of theoretical city logistics measures, COST 321 also listed actually realized projects throughout Europe. This list shows that, back then, no consolidation concepts other than a UCC were put into practice.

Following the COST 321 results, Best Urban Freight Solutions (BESTUFS) was established in 2000. This thematic network was set up for four years and led to a follow-up initiative, BESTUFS II, also for a period of four years. The goal of BESTUFS was to identify, describe and disseminate best practices, success criteria and bottlenecks with respect to City Logistics Solutions. Based on case studies, BESTUFS and BESTUFSII developed two Best Practice Guides on Urban Freight Transport. These guides discuss 6 strategies, measures or activities contributing to smooth urban goods transport and beneficial for all actors involved: (i) Goods vehicle access and loading approaches in urban areas, (ii) Last mile solutions, (iii) Urban consolidation centres, (iv) Road pricing, (v) Public private partnerships (PPP) in urban freight transport and (vi) Intelligent transport systems (ITS). The traditional consolidation measure, a UCC, is treated comprehensively and documented extensively. The other five do not aim at consolidation directly, but both Road pricing and ITS might, to some extent, also result in more efficient bundling of

urban freight flows. Road pricing measures in urban freight transport are all measures imposing direct fees for the use of urban roads that might be able to influence the urban freight transport systems (Karrer & Ruesch, 2007). It is assumed that road pricing would result in a more conscious use of the urban road infrastructure, leading to smaller volumes entering the city or fewer 'empty kilometres'. Intelligent transport systems for urban goods transport include among others the combination of electronic equipment and devices for traffic management, infrastructure control and signalling using innovative or smart technologies. They have a broad field of application, but one of the possibilities is an electronic freight exchanges system for urban freight transport (or virtual freight distribution centre). However, BESTUFS does not focus on the consolidation potential of these measures in its Best Practice Guides.

The most recent European research project on urban mobility which also incorporates a section on urban logistics is CIVITAS (www.civitas-initiative.org, April 2011). The goal is to help cities to achieve a more sustainable, clean and energy efficient urban transport system by implementing and evaluating a number of measures. Within the category of urban logistics measures, CIVITAS distinguishes eight different themes:

- Clean vehicles / clean fleet
- Distribution scheme
- Fleet management & route planning
- Loading and unloading
- Loading Zone
- Public private co-operation
- Security
- Urban distribution centre

Again, there is a separate category for the traditional consolidation concept: the urban distribution centre. The other categories do not contain measures referring to or resulting in consolidation of urban freight flows.

3.4 Classifying urban consolidation measures and initiatives

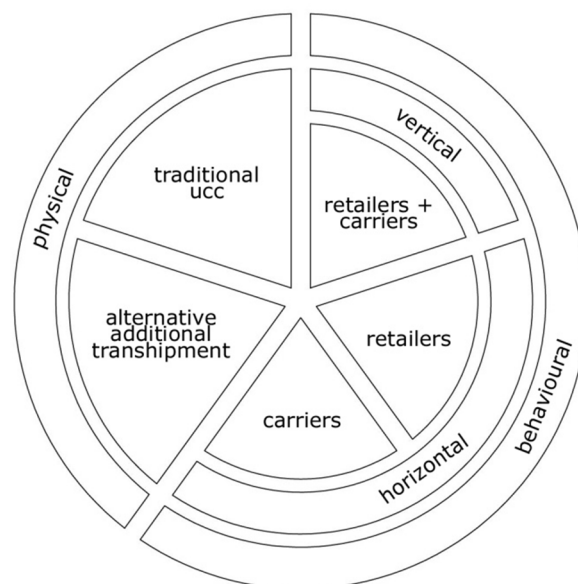
The above survey clearly shows that both literature and research projects on city logistics measures do not treat urban consolidation as a stand-alone concept. This is partly due to the fact that the various classifications use the impact of a measure as the basis for classification rather than the goal which is pursued. The aim of consolidating urban freight flows is to reduce the number of freight vehicles entering the city by making better use of the load capacity of these vehicles. But because this can be done in different ways, these measures never fit into a single category of classification and are never treated as a whole. The most important reason for the lack of clustered attention, however, is that only a few consolidation concepts are currently considered to be a valuable alternative. When in 1998 COST 321 identified various feasible city logistics measures, still 13 out of 56 were consolidation oriented. Afterwards, although reducing the negative impact of urban freight operations gained in importance, most of these measures and initiatives were never explored any further. A third reason is the fact that local policy makers give preference to measures which can be generally applied rather than multiple small-scale and tailor-made initiatives. In addition, their kind of political power will sooner induce restrictive measures than stimulating initiatives. This also explains why, in contrast with other consolidation concepts, urban consolidation centres and, to a lesser degree, road pricing measures were further explored.

There are, however, recent developments justifying a heightened attention for urban consolidation other than through a UCC. First of all, a number of alternative concepts has been field-tested in an urban setting for the first time providing a better understanding of their possibilities. In addition, some other consolidation concepts which have proved to be valuable on a larger scale seem also promising in the field of urban logistics. Secondly, and more importantly, throughout the past 30 years, the UCC concept has been put to the test in several European cities and urban regions showing that it is far from always successful (Browne et al., 2005; Van Duin, 2009). Furthermore, it was found that the common restrictive urban logistics measure, establishing time-windows, is both economically and environmentally inefficient (Quak, 2008). These are the right circumstances to set up a classification of urban consolidation measures, actions and initiatives of all kinds in order to gain an insight into their qualities and possibilities as consolidation tries to combine lesser nuisance with sustainable and efficient deliveries.

The first and most important distinction is based on the extent to which receivers and/or carriers have to change their internal processes in order to join in on a particular initiative or action. As already established earlier, the inefficient bundling from a city perspective is mainly due to the lack of cooperation and consultation between receiver and carrier. There are two possible ways to tackle these inefficiencies: get around them or deal with them internally. In the first case, the empty urban kilometres are avoided by adding an independent and additional transshipment point to the supply chain. Carriers no longer deliver directly to the receiver but, whether or not voluntarily, make use of a third party to do so. As this paper aims to look for consolidation concepts other than a traditional UCC, the distinction is made between such a physical consolidation centre on the outskirts of the city centre in which the local government plays either a key or supporting role and alternative transshipment points which differ from it to some extent. What both options have in common is that they aim to disturb the traditional order and delivery routine of both carrier and retailer as little as possible. These measures and initiatives are referred to as 'physical' as it involves a concrete additional transshipment operation.

The second option is to tackle the different causes of the fact that half empty freight vehicles are entering our cities. Today, the cargo of a particular truck or van often is destined for several delivery points in different cities meaning that the load rates are inadequate from a destination perspective. To raise these urban load rates, at least one of the stakeholders has to make changes to his internal procedures and processes, e.g. a retailer can cut back his weekly number of orders with a particular supplier in order to enlarge the size of the deliveries to his premises. Because of these internal adaptations, these kinds of actions are called 'behavioural'. Within this category of behavioural concepts, a second distinction has to be made between what we call 'horizontal' and 'vertical' concepts. The horizontal concepts aim at a particular stakeholder group within the supply chain, being carriers or receivers, the vertical ones aspire to ameliorate the vertical consultation between the different stakeholder groups. The framework for classification is shown in Figure 15. Further details on these categories and the corresponding test cases are presented below.

Figure 15. Proposed classification for consolidation oriented measures



Source: Own setup

3.4.1 Traditional urban consolidation centre

Cities trying to encourage urban freight consolidation often set up or support a UCC. Within the scope of a research project on UCC's, Browne et al. (2005) defined a UCC as a logistics facility that is situated in relatively close proximity to the geographic area that it serves be that a city centre, an entire town or a specific site (e.g. shopping centre), from which consolidated deliveries are carried out within that area. A range of other value-added logistics and retail services can also be provided at the UCC. Logistics companies with deliveries scheduled for the urban area or site are able to transfer their loads at the UCC and thereby avoid entering the congested area. The UCC operator

sorts and consolidates the loads from a number of logistics companies and delivers them, often on environmentally friendly vehicles, to an agreed delivery pattern.

Typical for this kind of measure is temporary or even structural governmental support to get and/or keep the centre operational. This choice for support is understandable as intensive use of a UCC guarantees the best possible optimization of freight vehicle movements within the urban area because it can be adopted on a large scale both geographically and across branches of trade. Moreover, it enables governments to control the kind of vehicles entering their city, e.g. smaller vehicles which cause less hindrance when loading or unloading or environmentally friendly vehicles. There is a large number of field-tested UCC's which have been described comprehensively by Browne et al. (2005), Karrer & Ruesch (2007) and Van Duin (2009). These pilots and test cases show that many of these freight platforms are granted only a short life because the cost of an additional transshipment prevents them of being cost-effective (Browne et al., 2005; Van Duin, 2009). Therefore, they are often destined to disappear when governmental subsidies are lost. Furthermore, both carriers and receivers are not demanding an additional transshipment point, particularly when it is cost-raising. In general, receivers are reasonably pleased with the way they are delivered. After all, suppliers and carriers conform as much as possible to the needs of their receivers (Holguín-Veras et al., 2005). Also the interest of carriers to use urban freight facilities is often overrated when planning a UCC (Quak, 2008). Nevertheless, a high participation of both receivers and carriers is essential as it determines the amount of goods being delivered to the UCC and therefore is one of the important factors of success (Van Duin, 2009).

3.4.2 Alternative additional transshipment point

Although it appears that far from all UCC's are a success, it does not mean that the idea of an additional transshipment point has to be sidelined completely. Because the main problem of traditional UCC's is that the break-even volume is rarely made, potentially successful alternatives should focus on traded volume. In Norfolk in 2007, an Urban Transshipment Centre was set up from an existing privately operated transshipment centre which already had a large amount of delivery points within the Norfolk urban region (www.civitas.eu, April 2011). Although only four new customers were recruited, there is a high level of satisfaction with the service amongst existing customers. An analogous example is Utrecht, a moderate Dutch city of 311.000 inhabitants, which has no less than three urban consolidation centres. These centres actually are the existing distribution centres of three private carriers. All three of them do not have to comply with the time windows set by the Utrecht City Council in exchange for assuring high load rates and the use of environmental friendly vehicles (www.utrecht.nl, April 2011).

Another alternative is to downscale the scope of the consolidation initiative and to focus on a particular delivery area. In France in 2001, a concept called 'Espace de Livraison de Proximité' (ELP) or 'Nearby Delivery Area' was tested in several cities and is still in place in Bordeaux, Paris, Dijon, Rouen and Lyon (www.lapetitereine.com and www.bestufs.net, April 2011). A similar area is dedicated to goods vehicles for the loading and unloading of goods destined for the nearby shops. It is often located in an underground car park where goods are unloaded from the incoming freight vehicles and then loaded onto electric tricycles for the final distribution leg. That way, both freight vehicle kilometres and the global time for delivery are reduced as goods destined for this particular district are unloaded at once. And more importantly, loading and unloading operations are facilitated without modifying current transport contracts, freight vehicle drivers have dedicated spaces at their disposal and the road occupancy of freight vehicles is reduced drastically. In 2006, 700.000 deliveries were carried out this way resulting in a total reduction of 660.000 km of diesel vehicle mileage. In 2003, the same concept was tested in Bordeaux proving that it is also advantageous when applied on an even more local neighbourhood or street scale (www.bestufs.net, April 2011). The 2006 experiment in Rouen proves that mixing an ELP and cargocycles is very efficient, adaptable and cheap (www.usti-nl.cz, April 2011). This concept bears quite a lot of resemblance to the traditional UCC, but deviates from it because it is completely privately operated and serves a particular (small scale) area.

Both linking an urban transshipment point to an existing privately operated distribution centre and the nearby delivery point concept are geographically oriented and therefore still closely related to the traditional urban consolidation centre. The third alternative transshipment point concept does not aim to bundle the deliveries to the various receivers in a particular urban area, but departs from the finding that all shops part of a particular franchise chain have the same offer on their shelves and are supplied by the same suppliers. Each of these suppliers delivers often small amounts of goods to every shop part of the chain. Intres is a Dutch service organisation uniting more than 1200 retailers. Through Intres, retailers can join in on completely elaborated franchise concepts. The

organisation thought it would be cheaper and more convenient to its franchisees if deliveries for a particular shop were consolidated. In addition, this can also be favourable from a city perspective as deliveries to a particular shop are bundled into a single freight vehicle. Intres chose to test this concept on its Livera retail chain which consists of 136 franchise stores selling women's underwear, nightwear and swimwear (Commissie Stedelijke Distributie, sd.; www.livera.nl and www.intres.nl, April 2011). The different suppliers of the Livera shops were asked to mutually collaborate in the transport sphere in order to diminish the number of journeys to a particular shop, but they turned out not to be prepared to do so. After calculating the savings when a single carrier would distribute all of the deliveries to the different Livera shops, Intres contracted one carrier and had all suppliers deliver their cargo for the Livera shops at his depot. During its testing phase, the concept brought profits to all stakeholders as the supplier pays less distribution costs, Intres is able to charge a percentage for its mediating role, the selected carrier works more efficiently and the retailers is interrupted less frequently. In addition, as fewer delivery vehicles call in at a particular shop in order to supply it, citizens, commuters and shoppers experience fewer nuisances because of it. Only to the carrier that was not chosen, the concept is less advantageous.

3.4.3 Adapted behaviour by receivers

As already stated earlier, there are other ways to consolidate urban freight flows more efficiently from a city perspective besides introducing an additional transshipment point to the supply chain. It can also be done by adjusting the conventional working methods of some of the stakeholders. Thorough analyses of the existing behavioural concepts which have gone beyond theory prove that the main stakeholders able to influence the number of urban freight vehicle movements are the carrier and the receiver. Furthermore, the existing examples also make clear that both of them are only inclined to participate in any kind of initiative if they think to personally benefit from it. In the case of the receiver, that appears to be a problem as the bare fact that the number of freight vehicles entering the city is reduced does not yield a financial profit. At the most, it leads to a more pleasant shopping climate for his customers and less interruptions by carriers delivering something. That is why concepts oriented towards the receiver would also have to be advantageous to them in other ways in order to receive bottom-up support.

The existing consolidation concepts aimed at receivers can be divided into two different categories. The first option is to encourage the receiver to make some adjustments to his procedures and processes. For example, the Dutch project on demand driven consolidation called 'Vraaggestuurd Bundelen' persuaded retailers to change their ordering behaviour (Stichting Leve De Stad, 2005). Often retailers do not take into account that an order from their part puts a complete system into action. When an order reaches the supplier, he immediately engages a carrier to take the goods to the retailer, as he is convinced that fast deliveries are essential to a good customer service. He does not wait a possible second or third order from the same receiver within the next few days which means that retailers who do not bundle their orders, unintentionally cause more trips to their premises than necessary as they do not always need the goods straight away. Another example of adapted behaviour is the Paris Consignity project which is a network of automated lockers for pick up and deliveries (www.usti-nl.cz, April 2011). One of the major developments of Consignity is the supply of spare parts to a major elevator manufacturer for its maintenance service. Previously, every day 100 employees were circulating between the manufacturer's 5 spare parts warehouses located close to Paris and various intervention points at businesses and private buildings in the city centre. Numerous trips were made without optimization and much lost time due to congestion. The purpose of Consignity is to minimize the movements of the technicians by providing the spare parts they need closer to the buildings they operate in. Supplying the Consignity lockers is done at night by a single carrier.

One step further is genuine consultation and even cooperation between different receivers. The same Dutch project on demand driven consolidation tried to have retailers which are delivered by the same supplier or carrier agreeing on a mutual delivery day or time which means that carriers do not have to take into account different retailer's preferences when planning their delivery tours (Stichting Leve De Stad, 2005). Somewhat more far-reaching is the cooperation between different receivers on the Belgian industrial estate De Prijckels. This is not an 'urban' example, but might also have a future within a city context. The estate comprises 280 acres of land and houses 96 companies of which 90 are an SME (Van Eetvelde et al., 2008; POM West-Vlaanderen, 2008; www2.vlaanderen.be and www.dbt.ugent.be, April 2011). In 2002, in response to the many burglaries on the estate, five companies decided to engage a surveillance company together. Thanks to this concentration of forces, they were able to negotiate a long-term agreement at a very keen price. Because of this success, the founding companies decided to start cooperating in other areas too. They mapped the waste flows, negotiated common conditions with the company collecting garbage

at the estate and mutually agreed on what day of the week they should be collecting it. Therefore, fewer kilometres are driven in order to collect the same amount of garbage. Furthermore, some companies on the estate also order their fuel oil and diesel together, try to purchase paper and office utensils in bulk or engage a single parcel delivery service provider to have all their parcels collected and delivered once a day. Also the already cited Livera example is based on cooperation between retailers.

Even another step further is the Swedish SMILE project which had the aim to develop a web-based food logistics system, linking 40-50 small food producers in the region with 5 purchasers in the city of Malmö (www.civitas-initiative.org, April 2011). The food producers do not individually hire transport to bring their produces to their client, but make use of a common food logistics system which is owned and operated by both the producers and the purchasers. Similar to the Livera example, a single carrier is hired to carry out all transport involved, but new to this is that receivers and suppliers closely work together in order to reduce travel distance of fresh food supply.

The previous four examples clearly show that there either has to be an immediate cause to start cooperating or a supervisor taking the lead. When stores are part of a retail chain, and in urban areas that is the case for almost 3 shops out of 5 (Locatus, 2011), deliveries and orders are centrally managed and therefore already consolidated. However, this consolidation does not apply to the urban level as the different outlets usually are settled in different cities. Because local governments often are in demand to reduce the number of freight vehicles, they are forced to coordinate these kinds of cooperation. The above cited projects show that in some cases, when the number of retailers to align is not too high and/or when the mutual competition is not too severe, it can be done. Another example can be found in London where the government supports big urban receivers in developing a logistics plan. It is called a Delivery Servicing Plan and it should guarantee a consistent approach of the deliveries as it helps managing deliveries to reduce the number of trips, identifying where safe and legal loading can take place and commissioning delivery companies who can demonstrate their commitment to best practice (www.tfl.gov.uk, April 2011). An analogue system has been set up for urban construction sites (www.tfl.gov.uk, April 2011).

3.4.4 Adapted behaviour by carriers

As opposed to receivers, carriers in urban settings do benefit directly from freight consolidation because every empty or half empty kilometre costs them. When a carrier has to call at several delivery points during a particular run, he prefers the distances between two successive delivery points to be as short as possible because it saves him time and money. Therefore, carriers already plan their routes as efficient as possible, but they have to take into account the often scattered locations, the supply preferences of the receiver and various governmental regulations on urban deliveries. Some carriers developed innovative approaches to decrease the distances between the different delivery points in order to keep down the lid on costs which are at the same time beneficial for the urban environment. The first example is Centraal Boekhuis, a Dutch company specializing in the distribution of books in The Netherlands and Flanders, the Dutch-speaking part of Belgium (www.boekhuis.nl, April 2011). It links 500 publishers and more than 1500 booksellers selling books in traditional bookstores and specialized retail chains, but also at supermarkets, gas stations, toy stores and museums. Centraal Boekhuis has got a fine-meshed distribution network at its disposal through its own transport company De Vervoerscentrale. From an efficiency point of view, Centraal Boekhuis chose to also use this network to distribute other goods which can easily be transported with books and which have to be delivered at stores already on their route or close to shops they are already delivering.

Another possibility for carriers to limit the distances between two delivery points is to concentrate on a limited geographical area, e.g. a particular city or region. However, to ensure a certain demand for his services, the carrier has to take some measures in order to be competitive. Duncker, a Dutch transport company, succeeds in this by specializing in a particular kind of transport, namely refrigerated transport (www.020stadsdistributie.nl, April 2011). Duncker only delivers the Amsterdam city centre and consolidates the refrigerated cargo at a distribution centre just outside the city. By analogy with the urban consolidation centre concept, the different suppliers deliver their goods at the Duncker warehouse. This example shows that, although this kind of concept usually is set up and (partially) funded by a local government, it can also be adopted and successfully applied by private companies. A more common approach to limit the working territory is to closely cooperate with carriers who operate in a different area. This approach is frequently used in international haulage but could also be adopted on a more regional level. Teamtrans, for example, is a collaboration of 13 Dutch carriers who divided the Dutch territory in 13 service areas based on postal codes (<http://www.teamtrans.nl>, April 2011). Each of the carriers serves one of these areas

operating from his central depot. Within that area, he does not only distribute goods for his own customers, but also for the 12 other carriers. At night, his cargo destined for a location outside his service area is transported to the depot of the carrier serving that area. This collaboration results in an efficient bundling of goods and a decrease in the number of kilometres driven to deliver the goods and has a positive impact on congestion as in the morning, when traffic is at its heaviest, the goods are already near their final destination.

Although the above examples lead to less freight vehicles on the urban roads, they still are private initiatives of which the initiator is not primarily concerned with the urban living environment but with the success of his company. However, they do illustrate that also in real terms carriers are able to reduce their urban trips whilst remaining competitive. Local governments cannot enforce similar systems, but can try to encourage them in order to reach their own goals for example by giving incentives for improving the load rates in city freight distribution. The city of Göteborg set up a pilot project in that sense designed as a voluntary scheme in co-operation with the transport industry (www.civitas.eu, April 2011). Within this project, the criteria for entering the inner city zone for distribution vehicles was a combination of a 65% load factor, a limited time gap between stop time and running time and complying with the emission restrictions linked to the already existing Environmental Zone. The pilot involved 8 vehicles which were equipped with technology for the registration of the driven routes and the load rates. The participating carriers were given positive incentives to encourage them to respect the 65% load factor. The conclusions of the project were first of all that it is possible to discuss urban freight issues and to come to agreements with carriers and secondly that in order for a similar scheme to become successful at a large scale, it is necessary to combine incentives and restrictions. Besides Göteborg, not many other municipalities experimented with load factor raising incentives or regulations. There are, however, other concepts they could initiate that originally were not developed for local freight traffic, for example cargo pooling (www.trivizor.com, www.mobimix.be, April 2011). The concept departs from the idea that free space in a freight vehicle could be rented out to suppliers or carriers wishing to transport cargo to a destination on (or close by to) the route of the vehicle. In advance, the cargo is transported to a transshipment point which, in the case of urban freight transport, often would be the distribution centre of the carrier carrying out the transport. In practice, an internet platform could be set up to match free space with non-allocated cargo.

3.4.5 Direct contact, consultation and/or collaboration between carriers and retailers

The four previous solutions for low urban freight load rates do not address the main cause of this problem, notably the lack of consultation between carriers and retailers. Remarkably, even amongst the selected test cases and examples of consolidation oriented city logistics measures, there are no examples of collaboration or at least consultation between these two stakeholders. However, a Belgian project by the Flanders Institute for Logistics on off-peak deliveries shows that bringing all stakeholders together on the initiative of a neutral partner can make a difference (Sel et al., 2011). The aim of the project was to shift freight movements to the off-peak hours in order to achieve a more reliable supply chain and cut costs as delays due to congestion would be avoided. This idea was field tested for the supply of the warehouses of a Belgian retailer. Until now, night deliveries were not possible because the warehouses of the retailer were closed between 10 pm and 6 am. In theory, it would be beneficial to all stakeholders (and specifically to the retailer and the carrier) to make use of these nightly hours. In practice however, the issue was never discussed because the retailer and the carrier do not have a contract between them. Within the scope of this project, all parties were brought around the table and made engagements on this issue. Now, since the testing project, 3 participating suppliers permanently partly deliver this retailer at night instead of during the day and that to everyone's satisfaction. Afterwards, the stakeholders pointed out that the biggest achievement of the project was facilitating contacts between receivers and carriers as they normally never mutually confer.

3.5 Conclusions

Local governments tackle the urban mobility problems in their cities by interfering with both passenger and freight traffic. Although the attention for urban freight logistics is more recent, also in that field a great deal of measures, initiatives and actions has been developed, diverging from very restrictive measures to positive incentives. There is a specific kind of measures, which were termed urban consolidation concepts, hoping to reduce the number of empty or half empty freight vehicles entering cities by consolidating the incoming freight flows in a way advantageous to the city and its citizens.

The threefold objective of this paper was to substantiate the benefits of consolidation going from the typical urban retail supply chain, to analyse the position of the various urban consolidation concepts within the literature and research on city logistics and to categorize the already adopted concepts in order to provide a starting point for further research into alternative freight flow bundling concepts. The first conclusion to be drawn is that the main cause for the inefficiencies at the urban level is the lack of direct consultation between carrier and receiver resulting in a flood of small orders and many small deliveries. Secondly, this paper clearly shows that within the existing literature and research on city logistics, urban consolidation was never treated as a stand-alone concept. Only urban consolidation centres have been examined in detail, the other concepts were, mainly during the initial period of city logistics research, treated superficially. Finally, analysis of the existing examples of urban (and other) consolidation lead to a classification of consolidation oriented measures and initiatives. They can be divided into two main categories: physical and behavioural concepts. The physical category contains all possible additional transshipment points of which the urban consolidation centre is the best known one. The behavioural concepts again are subdivided into two categories: horizontal and vertical concepts. When these concepts aim at changing or adjusting the behaviour of only one stakeholder, they are called horizontal. However, when vertical consultation and cooperation within the supply chain is needed, the concepts are called vertical. Practice demonstrated that the two main stakeholders to be addressed with these behavioural concepts are the carrier and the receiver. The many cited examples establish that there is a future for alternative urban freight bundling but that all four categories need further research and development.

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<http://www2.vlaanderen.be/economie/energiesparen/reg/kmo/praktijkervaringen/G20080404-ZO-Bedrijventerrein.pdf>

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http://www.certu.fr/fr/_Mobilit%C3%A9_et_d%C3%A9placements-n25/Marchandises_en_ville-n52/IMG/pdf/4_pages_ELU.pdf

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4

Does a mobile depot make urban deliveries faster, more sustainable and more economically viable: results of a pilot test in Brussels⁸

4.1 Introduction

Courier, express and parcel (CEP) service providers operate worldwide networks. The first and last-mile are an integral part of these networks but can be a real challenge when taking place in an urban setting (www.dhlsupplychainmatters.dhl.com, 24 March 2014). Urban areas are characterized by narrow streets, mixed traffic and/or congestion. This all makes it difficult to keep the inner-city deliveries and pick-ups reliable, affordable and fast. At the moment, the majority of these deliveries are done by diesel or petrol trucks and vans. In Italy, for example, 88.5% of the freight vehicle fleet runs on diesel and 11.5% on petrol (Schoemaker et al., 2006). The number of alternatively propelled or fuelled distribution vehicles is rather low. In 2012, the share of renewable energy in fuel consumption of transport (passenger and freight) in the 28 EU countries accounts for 5.1%, varying from 0.0% in Cyprus to 12.6% in Sweden (<http://epp.eurostat.ec.europa.eu>, 24 March 2014). The high share of diesel combustion engines in urban freight transport leads to pollution from exhaust emissions which include among others Carbon Monoxide (CO), Carbon Dioxide (CO₂), Nitrogen Oxides (NO_x) and Particulate Matter (PM) (Schoemaker et al., 2006). As a response to this negative environmental impact, it is expected that the number of cities with some form of congestion charging or roadway traffic restraints will increase in the near future which would make the first and last-mile even more challenging. That is why there is an interest in alternative solutions that can deal with all these constraints.

⁸ Verlinde, S., Macharis, C., Milan, L., Kin, B. (2014). Does a mobile depot make urban deliveries faster, more sustainable and more economically viable: results of a pilot test in Brussels. *Transportation Research Procedia*, 4, 361-373.

A new transport concept would have to be cost-efficient and allow the service provider to keep the same level of customer service. At the same time, it would have to be environmentally friendly, allow avoiding congestion and prepare the logistics service provider for toll charging or traffic restraints. A possible example of such a concept is a Mobile Depot (MD) that is used in combination with electrically supported cyclocargos. An MD is a trailer fitted with a loading dock, warehousing facilities and an office. In the morning, the trailer is loaded with all inner-city deliveries for that day and is then driven to a central parking location. From there, the final deliveries are carried out by dispatch riders on electrically supported cyclocargos.

The MD concept was tested by TNT Express in Brussels within the framework of the European FP7 project STRAIGHTSOL. The goal of the three month demonstration was to assess whether this solution is beneficial to all stakeholders and could be a valid option for the future. The purpose of this paper is to present this assessment and to evaluate if and how this concept has a future. The rest of the paper is organized as follows. In Section 4.2, we provide the background to the demonstration. Section 4.3 introduces the Multi Actor Multi Criteria analysis as the applied evaluation method. Section 4.4 lists the stakeholders, their criteria and the weights they attributed to these criteria. In Section 4.5 we compare the current situation with the demonstration and in Section 4.6 we discuss the results of the Multi Actor Multi Criteria analysis. Finally, conclusions and possibilities for future research are presented in Section 4.7.

4.2 Mobile Depot

4.2.1 Courier, express and parcel service operations

CEP service providers provide a service to companies or private persons who want to have a particular shipment sent to a particular location within a certain time constraint. The CEP process starts when the service provider collects the shipment at the premises of his customer. From that moment on, the shipment is pushed through the network of the service provider. The three types of CEP networks, i.e. Express, Courier and Parcel, are not organized in the same way (Winkelmann et al., 2009). Parcel services are transports of largely standardized packages and usually have a non-guaranteed delivery time of two or three days. These standard parcels are usually transported by road based on a (multi-stop) network of mostly scheduled delivery trips (Winkelmann et al., 2009). Courier services are generally urgent shipments sent at short notice and have the shortest delivery time within the CEP market range of services. They are based on a direct service network, without stops. During the transportation, shipments are under constant personal supervision of the driver (Winkelmann et al., 2009). Finally, express services are time-sensitive and usually guaranteed by a specific day (usually the next day) and specific time. The transports are usually consolidated through a hub and spoke network (Winkelmann et al., 2009). It means that the service provider operates a central hub and distant depots. Each of these depots is directly connected to the hub (often through an overnight air connection) but the depots are not interconnected. Once collected, the small package or parcel is taken to the closest depot, usually by road. At the depot, a bar code label is placed on the consignment that includes all relevant information about the shipment. Afterwards, the shipment is carried to the hub. At the hub, the shipment is pushed onto a conveyor system equipped with advanced sortation equipment which takes the individual shipments to a specific chute representing one destination. From the chutes, the shipments are then manually loaded into cages which are either placed into trucks or loaded into containers for aircraft. Once sorted, the shipments leave the hub and are carried to the depot closest destination. From there, the final delivery is arranged (www.dhl.com; www.ups.com; www.tnt.com; 24 March 2014).

CEP service providers subcontract most of their first and last mile activities to local transport companies because of the high cost of urban deliveries, the fluctuation and seasonality of freight flows and the local regulatory framework (Ducret and Delaitre, 2013). Often, there are up to two, three or even four levels of subcontracting. The carriers doing the first and last mile are therefore often very small transport companies operating only one or a small number of vehicles (Ducret and Delaitre, 2013).

Transport costs tend to be considerably higher for the first and last mile in comparison to the long-haul leg of the transport due to composition and decomposition costs and traffic congestion in metropolitan areas (Rodrigue et al., 2013). Especially the congestion makes it difficult to keep the time constraints. In addition, the traditional freight vehicles that are used for express services also cause considerable pollution from exhaust emissions. That is why

express service providers are constantly looking for innovative ways to do the first and last mile and are open to modal shifts that could decrease the transport costs as well as the environmental impact.

4.2.2 Mobile Depot

One possible innovative way to do express pick-ups and deliveries in cities is to use a Mobile Depot (MD) which is a trailer fitted with a loading dock, warehousing facilities and an office. In the morning, the trailer is loaded with all inner-city deliveries for that day and is then driven to a central parking location in the city. From there, the final deliveries are carried out by dispatch riders on electrically supported cyclocargos. One expected benefit of this solution is that it would decrease the number of diesel kilometres as multiple vans are replaced by 1 truck/trailer combination and several electrically supported tricycles. Reducing the number of diesel kilometres is also expected to reduce the emission of pollutants. Depending on the type of urban area where the MD is used, efficiency and time gains are possible which, in combination with the kilometre reduction, can be expected to reduce the eventual cost per stop paid by the express delivery service provider.

To our knowledge, the use of a trailer as an MD is new. A list of best practices that was made within the framework of the European FP7 project BESTFACT mentions two concepts that relate to the MD. On the one hand, the use of battery-electric tricycles and vans for retail distribution is quite popular (London, Paris, Stuttgart-Ludwigsburg, Utrecht, Karlsruhe) (www.bestfact.net, 24 March 2014). Apart from that, there are cities where an alternative to a diesel van is used to get shipments in and out of the city: in Paris and Utrecht last mile deliveries are done by boat (www.bestfact.net, 24 March 2014). There are also the older examples of the CargoTram in Dresden (www.dvb.de, 24 March 2014) and the Cargohopper in Utrecht (www.cargohopper.nl, 24 March 2014).

4.2.3 Mobile Depot demonstration in Brussels

The MD was used by TNT Express for a period of three months (28 May 2013 – 22 August 2013) to do their pick-ups and deliveries in a part of the city-centre of Brussels. It concerns postal code areas 1030, 1040 and 1210 or the municipalities Schaarbeek, Etterbeek and Sint-Joost-ten-Node (Figure 16). It is an area of just over 12 square kilometres which is densely populated and highly urbanized. There is no commercial dominance in the area. The area was chosen by TNT Express because of its relatively high drop density of small shipments.

Figure 16. Map of the Brussels-Capital Region with postal codes 1030, 1040 and 1210 highlighted



Source: Own setup.

Regular TNT Express deliveries and pick-ups in Brussels are carried out from the TNT depot at the Brussels freight airport Brucargo. Two types of vehicles are used for that. Diesel trucks to do the pallet deliveries and pick-ups and diesel vans for parcels and documents. The parcels and documents destined for a particular part of the Brussels-

Capital Region are loaded onto the vans each morning. Around 9 am, the vans start their milk round doing both pick-ups and deliveries. Around 6 pm, they return to the depot from where the new parcels and documents leave for their final destination. Because the cyclocargos that are used in combination with the MD cannot transport big volumes, the pallet deliveries are not further taken into account.

For the duration of the demonstrations, TNT Express carried out the last-mile deliveries and first-mile pick-ups in the centre of Brussels from an MD (Figure 17). Each morning, the trailer was loaded at the TNT hub with all deliveries destined for postal codes 1030, 1040 and 1210 for that day and then driven to a predefined central location in the Parc du Cinquantenaire. The park is close to the chosen demonstration area, the depot of the subcontractor doing the cyclocargo deliveries and provides the space that is needed for the MD to manoeuvre and for the loading and unloading of the cyclocargos. The MD arrived there around 9.15 am. From there, the deliveries and pick-ups were, depending on the volume of that day, carried out by four dispatch riders on electrically driven cyclocargos. During the twelve weeks the MD was tested, 1292 pick-ups and 5286 deliveries were done and 4534 cyclocargo kilometres and 2544 truck kilometres were driven.

Figure 17. Picture of the Mobile Depot



Source: TNT Express.

4.3 Evaluation method

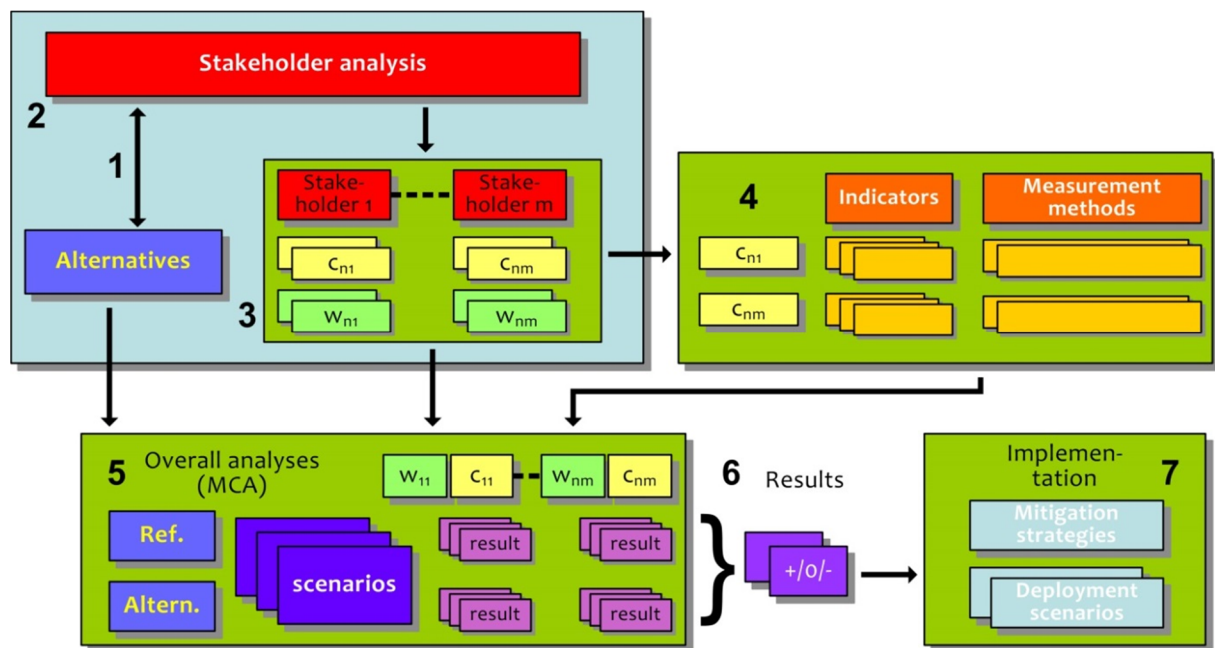
The goal of testing a new concept like the MD for a period of three months is to allow a comparison with how deliveries and pick-ups were done before to find out whether the new concept makes a real improvement. When assessing this, it is crucial to take into account the various objectives of all stakeholders involved. We have seen in the past that many innovative city distribution concepts failed because they only addressed the objectives of one of the stakeholders (Macharis and Melo, 2010). Urban distribution centres, for example, tend to meet the objectives of citizens and local authorities by reducing the number of urban freight kilometres but usually fail in meeting the economic objectives of the private stakeholders (Browne et al., 2005).

In this paper, we use the Multi Actor Multi Criteria Analysis (MAMCA) to evaluate the use of an MD for inner-city express deliveries. This methodology is an extension of the traditional Multi Criteria Decision Analysis (MCDA) (Fandel and Spronk, 1985; Guitoni and Martel, 1998). MAMCA allows evaluating different alternatives (policy

measures, business concepts, scenarios, technologies, etc.) explicitly taking the stakeholders that are involved in the decision making process and their objectives into account by putting together a value tree for each stakeholder separately instead of only one value tree (MCDA). The methodology was developed by Macharis (Macharis 2000, 2005 and 2007) and has been used for many applications, mainly in transport related decision making problems (for an overview, see Macharis, De Witte and Ampe, 2009).

The MAMCA consists of two main phases (Macharis, 2005). The first phase is mainly analytical and gathers all the information needed to perform the analysis. The second phase is the synthetic or exploitation phase and consists of the actual analysis. These two phases are split into respectively four and three steps (Macharis et al., 2009) which are depicted in Figure 18. The first step involves defining the problem and determining which alternatives will be evaluated. The second step is a stakeholder analysis to determine all relevant stakeholders as well as their objectives. In the third step, these objectives are translated into criteria and each of the criteria is given a weight that reflects how important the according objective is to the stakeholder. The fourth step links one or more measurable indicators to each criterion. In the fifth step, these indicators, which can be quantitative or qualitative, are used to evaluate the different alternatives on the different criteria. How a specific alternative scores on a specific criterion as well as the weight the stakeholder attributes to that criterion is then aggregated into an evaluation table. Once the table is filled in, any MCDA method can be used to assess the different strategic alternatives (such as AHP, PROMETHEE, MAVI, ELECTRE, MACBETH, etc.) The multi criteria analysis (MCA) developed in step 5 eventually leads to a classification of the proposed alternatives. More important than the ranking, the MCA reveals the critical stakeholders and their criteria. The MAMCA provides a comparison of different strategic alternatives, and supports the decision-maker in making his final decision by pointing out for each stakeholder which elements have a clearly positive or a clearly negative impact on the sustainability of the considered alternatives. The final step of the MAMCA translates the results of the analysis into policy recommendations, mitigation strategies and deployment scenarios.

Figure 18. Multi Actor Multi Criteria Analysis



Source: Macharis, 2007.

4.4 Stakeholders, criteria and weights

The process of listing the stakeholders, their criteria and their weights was also done for the MD concept like it was tested in Brussels. Table 3 lists the stakeholders, specifies their role and their interests. Table 4 lists their criteria and the weights they attributed to these criteria (based on interviews in the case of the logistics service provider and the local authorities and on surveys for the shippers, receivers and citizens).

Table 3. Mobile Depot stakeholder analysis

Stakeholder	Role	Interest
Logistics Service Provider (TNT Express)	Initiator and owner demonstration Delivers express parcels	Provide as much service possible at the lowest cost possible
Shippers	Ships TNT Express parcels Paying customer Have no choice in type of pick-up vehicle	Want to keep receiving the same service at the same price
Receivers	Receive TNT Express parcels Companies and individuals in Brussels Have no choice in type of delivery vehicle	Want to keep receiving the same service even if practical operations are changed
Citizens	People living, working and spending free time in Brussels	Want to be able to live their lives in a safe and healthy environment
Local authorities (Brussels-Capital Region)	Municipality of Brussels	Improve liveability of the city in terms of pollution, safety and congestion

Source: Own setup.

Table 4. Mobile Depot criteria and weights

Stakeholder	Criterion	Criterion definition	Weight
Logistics Service Providers	Viability of investment	A positive return on investment	27
	Profitable operations	Making profit by providing logistics services	25.9
	High level service	Receiver and shipper satisfaction	22.8
	Green concerns	Positive attitude towards environmental impact	14.8
	Employee satisfaction	Employees are satisfied with their work and working environment	9.5
Shippers	Cost deliveries	Low out-of-pocket costs for transport	35.1
	High level service	Receiver satisfaction	31.5
	Successful pick-ups	Punctual and secure pick-ups with no damage	22.9
	Green concerns	Positive attitude towards environmental impact	10.4
Receivers	Transportation costs	Low costs to receive goods	46.7
	Convenient high level deliveries	Deliveries that do not compromise the receiver operations	29.4
	Attractive urban environment	Nice and liveable surroundings	14.1
	Green concerns	Positive attitude towards environmental impact	9.8
Citizens	Safety	Positive impact on road safety	36.7
	Emissions	Reduce emissions of CO ₂ , NO _x , PM _{2.5} , PM ₁₀	31.4
	Urban accessibility	Reduce freight transport, less	24.6

	Visual nuisance	congestion Less space occupancy by trucks	7.3
Local authorities	Quality of life	Attractive environment for citizens	61.0
	Network optimization	Optimal use of existing infrastructure	22.5
	Social political acceptance	Citizens support for measures	9.8
	Cost measures	Low costs to implement the measures	6.7

Source: Own setup.

4.5 Impact assessment

A closer look at the criteria listed in Table 4 reveals that some criteria partly or even completely overlap. The criterion 'high level service' of the shippers, for example, is linked to the 'convenient high level deliveries' criterion of the receivers. Although the stakeholder point of view is very well suited for the evaluation of the MD concept, this overlap demonstrates that it is not fit to collect the data needed to evaluate the MD concept. To overcome that, the stakeholder criteria were categorized into four impact areas and linked to measurable indicators (Balm and Quak, 2012). The four distinguished impact areas are: environment, society, economy and transport. They are based on the argumentation of Behrends (2011) that stakeholder criteria can be categorized according the three dimensions of sustainability and are extended with a fourth one, transport, due to the urban freight transport context (Civitas POINTER, 2009).

For a period of just over 12 weeks, TNT Express deliveries and pick-ups in a particular part of Brussels were carried out from an MD with 4 electrically supported tricycles. During that period, data on the selected indicators were collected if possible or derived, calculated or modelled if they were impossible to measure. To be able to make a comparison with the traditional way of working, we collected data on the same indicators for the same period in 2012 when a slightly larger area was serviced by 4 diesel vans. Afterwards, all data were condensed to a weekly average for the same geographic area, per vehicle kilometre or per shipment if possible. When data were collected through a survey, people were asked for their opinion about both 'business as usual' (BAU) and the MD demonstration.

In this section, we will compare BAU and the MD demonstration based on the collected data for the four distinguished impact areas in order to assess the impact using an MD to do inner-city express deliveries and pick-ups.

4.5.1 Environmental impact

The scale of the demonstration was too small to be able to measure an impact on the air quality in the demonstration area. That is why the impact on the emission of pollutants was calculated based on the number of kilometres driven by a specific type of vehicle using the STREAM emission factors (Den Boer et al., 2011). These emission factors take into account the vehicle type, the load factor and the type of road and are expressed in gram or milligram per kilometre. During the demonstration, on average, 504 tricycle kilometres and 141 truck trailer kilometres were driven per week. Usually, TNT does not keep track of the number of kilometres driven during a trip. Therefore, it was assumed that the 2 diesel vans needed to do the deliveries and pick-ups in the demonstration area followed the same routes as the bikes and both made the trip between the TNT Express depot and the demonstration area. In total, that adds up to 1291 large diesel van kilometres. The road type was considered urban for all trips. Load factors for the vans and the electric cyclocargos are not measured by TNT. Therefore, the value for a load factor of 50% was used for all calculations. The truck-trailer combination drove 10 routes each week (between the TNT Express depot and the MD parking location). Half of these trips were driven without trailer. That is why the lowest STREAM emission factors were used for half of the truck trailer kilometres. For the other half, the average values were used. Table 5 shows the impact of using an MD for inner-city express deliveries based on these data and assumptions. We observe considerable decreases in the emission of CO₂, SO₂, PM_{2.5} and PM₁₀. For NO_x, we observe an increase of nearly 50% which is caused by the high NO_x emissions of the truck-trailer combination compared to the NO_x emissions of the vans used previously.

Table 5. Impact of using a Mobile Depot for inner-city express deliveries on the emission of pollutants using STREAM emission factors

	Business As Usual	Mobile Depot	Impact MD
CO ₂ (g/vkm)	340	258.5	-23.97%
SO ₂ (mg/vkm)	2.6	1.97	-24.23%
NO _x (g/vkm)	1.25	1.85	+ 47.78%
PM _{2.5} (mg/vkm)	145	59.73	-58.81%
PM ₁₀ (mg/vkm)	30.5	23.77	-22.07%

Source: Own setup.

4.5.2 Societal impact

The main impact for society is the environmental impact which is treated in Section 4.5.1.

To know how the public feels about the demonstration, we surveyed people on the streets close to where the MD was parked. 57 people were personally addressed to answer 8 questions. We explained what an MD is, how it works and we showed a picture of it. Only 12 agreed to take part. The other 45 refused to take part because of time constraints and/or because they felt their opinion on the MD was not relevant because of a lack of knowledge on mobility and logistics. The 12 participating people were asked to score their attitude towards inner-city deliveries with diesel vans and towards inner-city deliveries from an MD with cargo bikes. Scores could range from 1 (strongly positive) over 3 (neutral) to 5 (strongly negative) (with 2 and 4 in between). The MD received an average score of 1.50 whilst the current way of working received an average score of 3.50. We also asked people whether or not they believe that the MD concept contributes to (i) a more pleasant neighbourhood, (ii) a better accessibility of the neighbourhood, (iii) improved traffic safety and (iv) less physical and visual nuisance in comparison to the use of diesel vans. People believe that the use of the MD and the cyclocargos will have a positive effect on all of these topics. They strongly believe the use of an MD and cyclocargos will have a positive impact on the visual and physical nuisance caused by freight traffic (average score of 1.92). A more pleasant neighbourhood and a better accessibility score 2.00 and 2.08 respectively. People are less sure about the positive impact on traffic safety (average score of 2.27).

Using an MD to do deliveries and pick-ups has its impact on two types of employees. First of all, the planners working at the depot of TNT Express at the airport have to adapt to the new concept. Secondly, the dispatch riders have to operate from the MD instead of from a fixed depot. Both groups were surveyed to know the impact of the MD concept on employee satisfaction. In total, six planners and five dispatch riders were surveyed, in both cases all employees involved. They were asked to score their attitude towards their current way of working and towards working with or from the MD. Scores could range from 1 (strongly positive) over 3 (neutral) to 5 (strongly negative) (with 2 and 4 in between). On average, the current way of working scored 1.80 and the MD demonstration 3.40. Among the planners, the current way of working scored 1.80 and the MD demonstration 3.50. Among the dispatch riders, the current way of working scored 1.80 and the MD demonstration 3.30.

The final impact for society is the spatial consumption. We calculated the spatial consumption needed for one week of deliveries and pick-ups. The weekly average number of stops during the demonstration was 457 stops for deliveries and 87 stops for pick-ups. We considered the space needed at the TNT depot, the space needed on the road for driving and the space needed for making the stops. Delivering with vans requires 8858.1 m² a week compared to 2461.1 m² when using the MD.

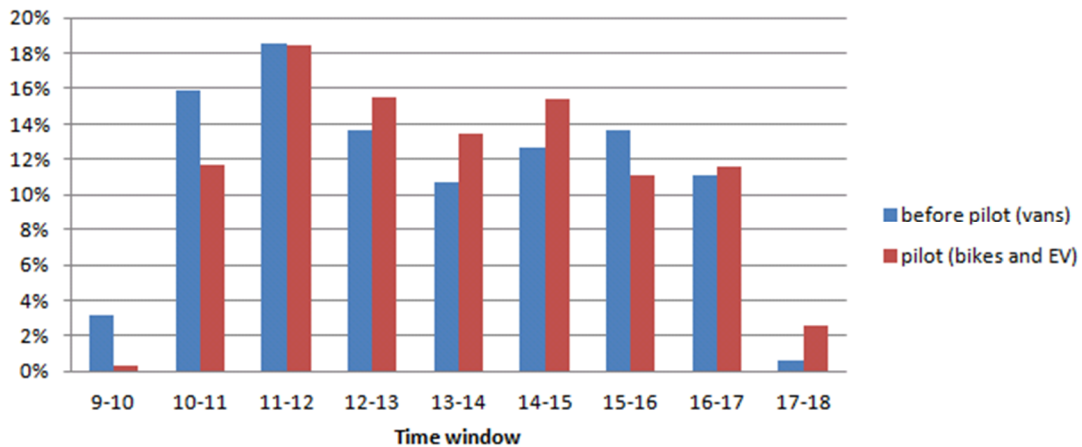
4.5.3 Transport impact

In this section, through a number of selected parameters, criteria and indicators, a preliminary assessment of the demonstration’s transport related attributes is done.

Delivering through the MD has an impact on the punctuality of the deliveries and pick-ups. In the before situation, 95.27% of the shipments was delivered on time whilst during the demonstration only 87.56% was delivered on time (wrong addresses, companies that are closed or people that are not at home are not taken into account here).

According to TNT Express, the lower degree of punctuality can partly be attributed to the fact that this was a demonstration project and both TNT Express and its subcontractor had to adjust their operations. The histogram below (Figure 19) shows the times of the day a delivery or pick-up is made. It clearly shows that more shipments are delivered and picked up before lunch hour when it is done with diesel vans. This can be explained by the MD trip between the airport and the parking location and by the additional handling needed to load the cyclocargos.

Figure 19. Average distribution of the number of stops over time



Source: Own setup.

Being delivered through the MD does not impact the supply chain visibility and information availability. The senders and receivers in Brussels were to fill in an online survey to know whether the use of the MD impacts their customer satisfaction. They received a flyer with a link of the dispatch rider during the demonstration but none of them filled in the survey. This might indicate that none of them were dissatisfied with the provided service or noticed a difference with the previous way of working. TNT Express also did not receive any complaints.

4.5.4 Economic impact

In the short run, using an MD will not influence the operating revenues as senders cannot choose whether or not their shipment will be delivered through the MD. During the demonstration, there was an increase in operating costs. Doing the deliveries and pick-ups through the MD is twice as expensive compared to the initial situation with vans. It comprises the cost for the bicycle deliveries, for the truck for the MD transfer, for loading the shipments onto the cyclocargos by the bicycle courier service provider and the extra cost for late pick-ups and heavy and outside shipments. It also comprises additional warehouse and infrastructure costs, i.e. the depreciation and the cleaning of the MD, the cost for the parking ban (so that other vehicles do not block the road for the MD) and the rental of the parking location. Apart from the operating costs, also the high investment costs to develop and manufacture the MD have to be taken into account.

4.6 Multi Actor Multi Criteria Analysis

4.6.1 Scenarios

In total six scenarios were formulated to be compared with Business As Usual (BAU). One of these scenarios was the demonstration. The other five scenarios were defined in close collaboration with TNT Express.

The scenarios used in the MAMCA analysis are:

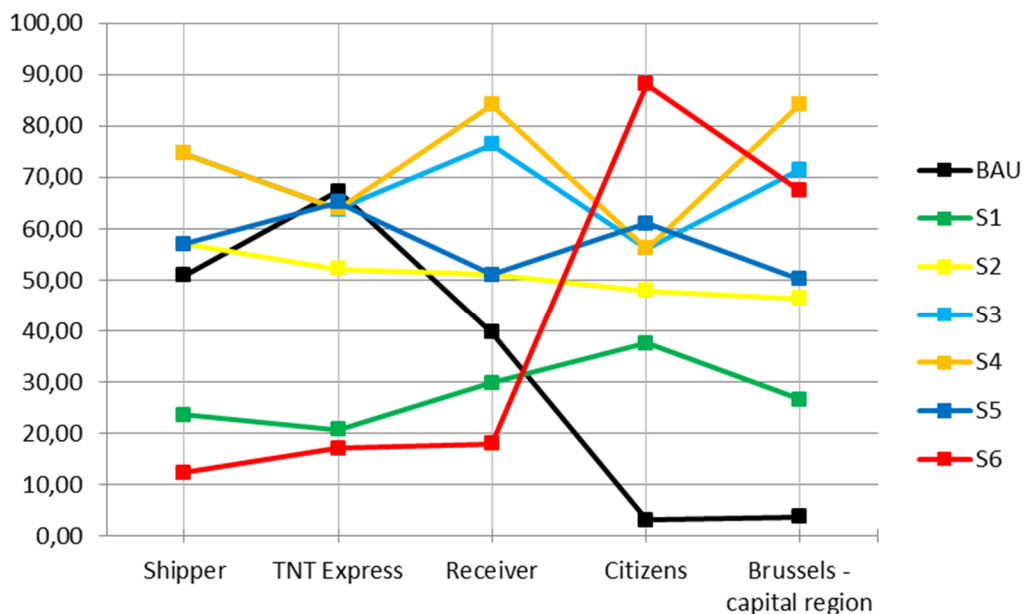
- Business As Usual (BAU): Inner-city TNT Express deliveries and pick-ups from the airport depot with diesel vans
- Scenario 1 (S1): One MD for postal codes 1030, 1040 and 1210. This is the scenario as tested during the demonstration. The MD was used at 40% of its full capacity and for TNT Express deliveries and pick-ups exclusively

- Scenario 2 (S2): One MD used at 90% of its full capacity and for TNT Express deliveries and pick-ups exclusively
- Scenario 3 (S3): One MD used at 90% of its full capacity and for TNT Express deliveries and pick-ups exclusively under a congestion charging scheme with a (low) toll of € 1.00 per km
- Scenario 4 (S4): One MD used at 90% of its full capacity and for TNT Express deliveries and pick-ups exclusively under a congestion charging scheme with a (high) toll of € 2.40 per km
- Scenario 5 (S5): One MD used at 90% of its full capacity for both TNT Express and other express service providers
- Scenario 6 (S6): Multiple MDs used at 90% of their full capacity for all TNT Express deliveries and pick-ups in the Brussels-Capital Region

4.6.2 Results

Based on the input of the stakeholders, the demonstration and some calculations/modelling, a multi-actor view could be constructed and analysed (Figure 20). We chose to use the GDSS PROMETHEE method to do the MAMCA. The interpretation of Figure 20 is as follows: the actors are represented by vertical lines and the alternatives (scenarios) are displayed as horizontal line graphs. The intersection of the horizontal alternative line graphs with the vertical stakeholder lines shows to what extent the alternative contributes to the objectives of this stakeholder.

Figure 20. Multi actor view MAMCA



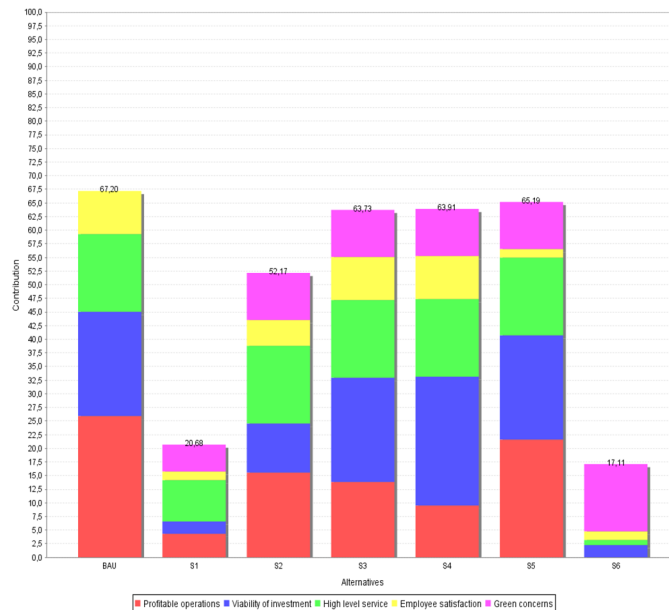
Source: Own setup.

From the graphical representation of preferences shown in Figure 20, it can be concluded that BAU (Business as usual) does not address the objectives of the societal stakeholders (i.e. citizens and the Brussels-Capital Region) while it does score relatively high for the economic stakeholders (i.e. TNT Express, Receivers and Shippers), especially for TNT Express. It means that a new solution should be able to keep addressing the objectives of the economic stakeholders while also addressing the ones of society. It is clear that the demonstration (S1) as it was carried out does not do that. Overall, it appeals the least to the objectives of the different stakeholders. The categorisation into economic and societal stakeholders also makes sense when evaluating the other scenarios. The economic stakeholders rank the different scenarios in the same way, except BAU, which is ranked first by TNT and only third or fourth by the shipper and the receiver respectively. Also the societal stakeholders have similar preferences. They only differ in how they rank S6 (multiple MDs) and S5 (multi-LSP MD). The toll scenarios (S3 and S4) address the objectives of the Brussels-Capital Region much better than the objectives of the citizens. Overall, it can be said that the toll scenarios score best. They address the combined objectives of all the stakeholders in the best way. That does

not mean, however, that these are the scenarios with the best chance of a consensus. That consensus is best reached by S2 (MD at 90%) which is shown by the fact that the S2 line has the least peaks and troughs.

A further analysis can be obtained by looking at the individual stakeholders. When we focus on TNT Express (Figure 21), it is again very clear that for them BAU scores better than any of the other scenarios while the demonstration scores very badly in comparison. The other scenarios, except for S6 (multiple MDs) score better than the demonstration because some of the barriers for making the MD successful are taken away. In S2 (MD at 90%), the MD is used at almost full capacity, in S3 and S4 (the toll scenarios) they are rewarded for the environmental gains they create by using the MD and in S5 (multi-LSP MD), the drop density is increased. These interventions increase the score on their two most important criteria: viability of investment (weight 27.0%, Table 4) and profitable operations (weight: 25.9%, Table 4). The contribution to the green concerns of TNT Express of S2-S5 also adds to the fact that these scenarios score relatively high.

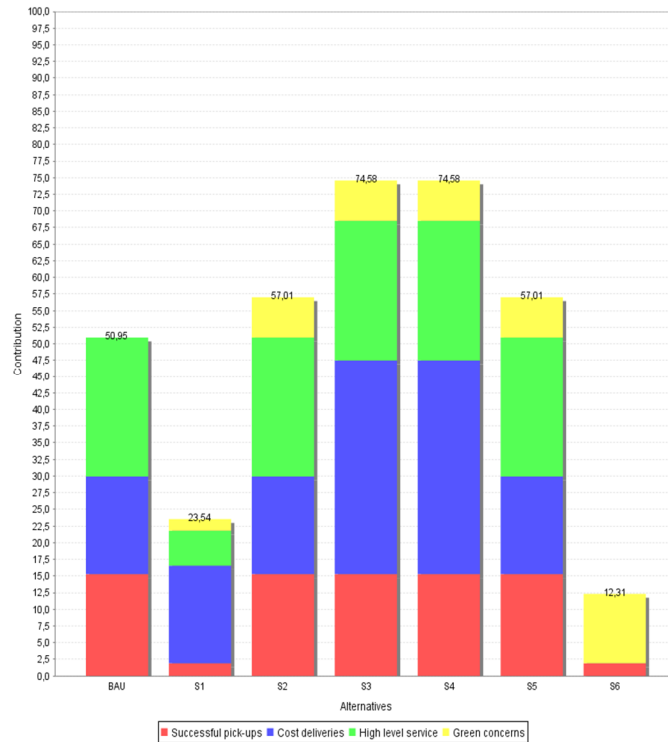
Figure 21. Mono actor view MAMCA TNT Express



Source: Own setup.

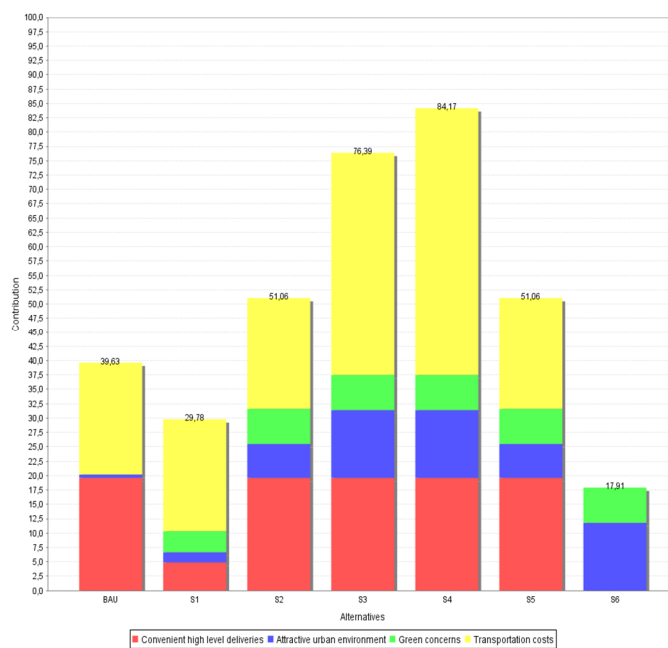
When we have a look at the other economic actors (i.e. Shippers and Receivers), it is clear that the demonstration does not appeal to them either (Figure 22 and Figure 23). Similar to TNT Express, S6 (multiple MDs) also does not score well. The other scenarios do have an added value compared to BAU which can be found in the contribution to the green concerns, the lower delivery/transportation cost and/or the attractive urban environment.

Figure 22. Mono actor view MAMCA Shippers



Source: Own setup.

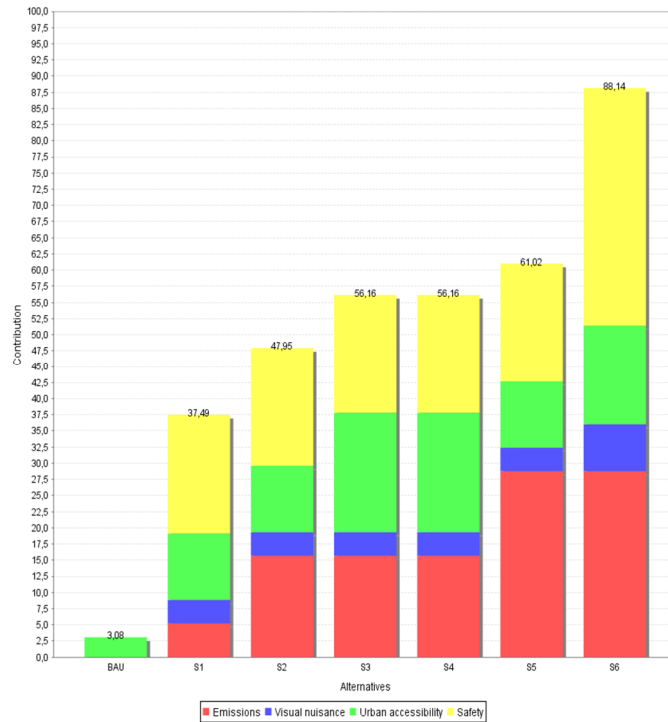
Figure 23. Mono actor view MAMCA Receivers



Source: Own setup.

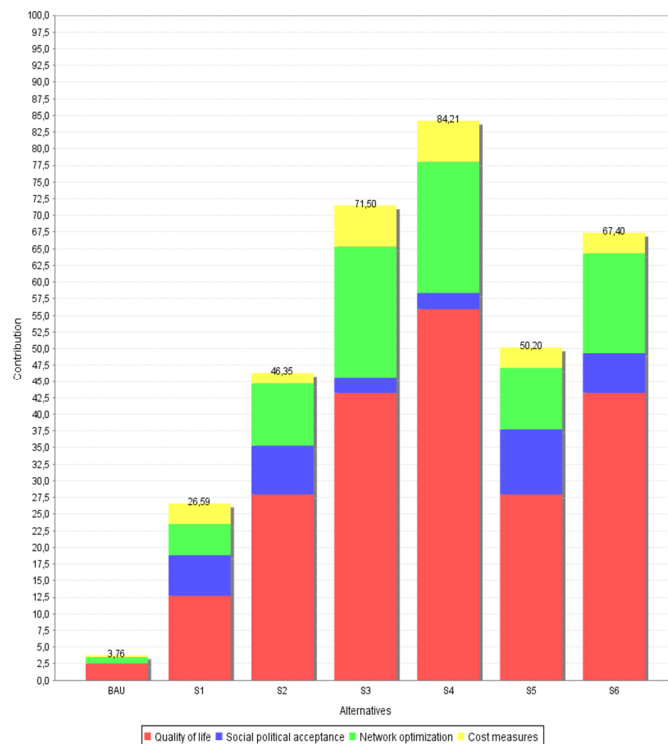
Using an MD does address the objectives of both societal actors (i.e. Citizens and the Brussels-Capital Region, Figure 24 and Figure 25). Opposite to the economic actors, the demonstration already scores considerably higher than BAU. The variations to the demonstration score even better mainly because they address the objectives of lower emission of pollutants (which is captured by the objective 'a good quality of life' for the Brussels-Capital Region) and urban accessibility (or network optimization) in a better way. The high citizens' score for S6 (multiple MDs) is also caused by the contribution to their 'traffic safety' objective which they gave a weight of 36.7% (Table 4).

Figure 24. Mono actor view MAMCA Citizens



Source: Own setup.

Figure 25. Mono actor view MAMCA Brussels-Capital Region



Source: Own setup.

4.7 Conclusions

A Mobile Depot (MD) is a trailer fitted with a loading dock, warehousing facilities and an office. The trailer is used as a mobile inner city base from where last-mile deliveries and first-mile pick-ups are done with electrically supported cyclocargos. In the morning and evening it is used to transport shipments from and to a peripheral depot. To know

whether this innovative concept can help to keep or make inner-city deliveries and pick-ups reliable, fast and sustainable TNT Express tested an MD for a period of three months in Brussels.

The MD demonstration by TNT Express in Brussels was a successful demonstration. TNT succeeded in integrating the concept in their operational structure in Brussels. Even though the punctuality dropped from 95% to 88%, there were no complaints by senders or receivers about this new way of working. Emissions of pollutants dropped significantly, from 24% for CO₂ up to 99% for PM_{2.5} emissions. The number of diesel kilometres decreased from 1291 van kilometres per week to 141 weekly truck kilometres.

It remains unsure, however, whether and how TNT can further operationalize the MD. The dispatch riders prefer working from their own depot. Planners of TNT also prefer to work with the vans, mainly because the MD solution is more expensive. Apart from the investment cost, which was partly covered by the European Commission through the STRAIGHTSOL project, operations during the demonstrations were 2 times more expensive than the regular operations.

To be able to fully assess the possible future of the MD, a Multi Actor Multi Criteria Analysis was done comparing business as usual with the demonstration and 5 possible future scenarios. Based on this analysis it can be concluded that the objectives of the economic stakeholders (i.e. TNT Express, shippers and receivers) are fairly well addressed by BAU while the objectives of the societal stakeholders (i.e. citizens and local authorities) are better addressed by the MD scenarios. Overall, the demonstration as it was carried out does not score well for any of the stakeholders. The toll scenarios address the combined objectives of all the stakeholders the most. The scenario with the best chance of a consensus, however, is the scenario where nothing is changed to the demonstration except for the used capacity of the MD (from 40% during the demonstration to 90%). A further analysis of the individual stakeholders shows that the viability of investment and profitable operations criteria of TNT Express have to be met better for the MD concept to become really interesting. The analysis of the scenarios shows that this can be done by using the MD at full capacity and by increasing the drop density. The MAMCA also showed that when using the MD, TNT Express does create benefits for the other stakeholders for which it is not compensated. Internalising the external costs could do that for example. Based on our results, it would be interesting to further test the MD under these new conditions.

Acknowledgements

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Annex C: Sensitivity analysis MAMCA

Shippers

The ranking of alternatives for the shippers is very robust (Figure 26, Figure 27). The weights allocated to successful pick-ups and high level service can vary from 0% to 100% and the weights of cost deliveries can vary from 11.22% to 100% without inducing any change in the ranking of the scenarios. A rank reversal between S2 and S6 only appears when the weight of green concerns is doubled (Figure 36). S3 remains, however, the most preferred scenario until a weight is allocated as far as 64% for green concerns.

Figure 26: Stability level 1 - Shippers (Mobile Depot)

Stability level : 1				
Criteria	Min Weight	Value	Max Weight	
Successful pick-ups	0,00%	22,94%	100,00%	Green
Cost deliveries	0,00%	35,14%	100,00%	Green
High level service	0,00%	31,52%	100,00%	Green
Green concerns	0,00%	10,40%	64,08%	Green

Figure 27: Stability level 7 - Shippers (Mobile Depot)

Stability level : 7				
Criteria	Min Weight	Value	Max Weight	
Successful pick-ups	0,00%	22,94%	100,00%	Green
Cost deliveries	11,22%	35,14%	100,00%	Green
High level service	0,00%	31,52%	100,00%	Green
Green concerns	0,00%	10,40%	21,04%	Orange

TNT Express

The ranking of the first alternative is mainly affected by the weights allocated to green concerns and viability of investment. However increasing the weight of high level service perpetuates the current priority of alternative scenarios (Figure 28, Figure 29)

Increasing the weight of profitable operations higher than 50% will allow a rank reversal between S2 and S4. Decreasing this weight under 21.87% will lead to substantial change on the ranking of the scenarios where S4 and S3 might be preferred over BAU and S5. This result has to be taken with care, as TNT Express was more likely to increase than decrease this weight (Figure 37).

The higher weight allocated to viability of investment, the higher the score of S4. If TNT Express would attach more importance to the viability of investment criterion by assigning a weight above 38%, forwards S4 as most attractive scenario (Figure 38).

The weight allocated to employee satisfaction criterion might vary from 6.6.7% to 100% without any change in the ranking of the first alternative (Figure 39).

A weight above 17.63 for green concerns (Figure 40) might lead to prefer S5 as BAU.

Figure 28: Stability level 1 - TNT Express (Mobile Depot)

Stability level : 1				
Criteria	Min Weight	Value	Max Weight	
Profitable operations	21,87%	25,93%	100,00%	Green
Viability of investment	0,00%	27,01%	39,03%	Yellow
High level service	0,00%	22,79%	100,00%	Green
Employee satisfaction	6,67%	9,48%	100,00%	Green
Green concerns	0,00%	14,80%	17,63%	Orange

Figure 29: Stability level 7 - TNT Express (Mobile Depot)

Stability level : 7				
Criteria	Min Weight	Value	Max Weight	
Profitable operations	23,84%	25,93%	26,72%	
Viability of investment	26,21%	27,01%	32,20%	
High level service	12,02%	22,79%	100,00%	
Employee satisfaction	6,67%	9,48%	11,18%	
Green concerns	0,00%	14,80%	17,63%	

Receivers

The ranking of the scenarios is robust for all the receivers' criteria (Figure 30). The best alternative S4 remains the same whatever the weights allocation. A weight of 26.47% for attractive urban environment would lead to a rank reversal between S6 and S1 (Figure 41). As for green concerns, a rank reversal might appear between BAU and S1 in case of a weight higher than 28.56% (Figure 31, Figure 42).

Figure 30: Stability level 1 - Receivers (Mobile Depot)

Stability level : 1				
Criteria	Min Weight	Value	Max Weight	
Convenient high level deliveries	0,00%	29,40%	100,00%	
Attractive urban environment	0,00%	14,14%	100,00%	
Green concerns	0,00%	9,80%	100,00%	
Transportation costs	0,00%	46,65%	100,00%	

Figure 31: Stability level 7 - Receivers (Mobile Depot)

Stability level : 7				
Criteria	Min Weight	Value	Max Weight	
Convenient high level deliveries	12,09%	29,40%	100,00%	
Attractive urban environment	0,00%	14,14%	26,47%	
Green concerns	0,00%	9,80%	28,56%	
Transportation costs	25,40%	46,65%	100,00%	

Citizens

The ranking of the scenarios is very robust for all the citizens' criteria. A rank reversal between S3 and S5 might appear if the urban accessibility weight is higher than 34% (Figure 32, Figure 33, Figure 43).

Figure 32: Stability level 1 - Citizens (Mobile Depot)

Stability level : 1				
Criteria	Min Weight	Value	Max Weight	
Emissions	0,00%	31,37%	100,00%	
Visual nuisance	0,00%	7,26%	100,00%	
Urban accessibility	0,00%	24,65%	78,82%	
Safety	0,00%	36,72%	100,00%	

Figure 33: Stability level 7 - Citizens (Mobile Express)

Stability level : <input type="text" value="7"/>				
Criteria	Min Weight	Value	Max Weight	
Emissions	22,32%	31,37%	100,00%	■
Visual nuisance	0,00%	7,26%	100,00%	■
Urban accessibility	0,00%	24,65%	34,23%	■
Safety	0,00%	36,72%	100,00%	■

Brussels-Capital Region

It is clear that the ranking of the different scenarios is robust for the criteria quality of life, network optimization and measures costs. However, a high change in the social political acceptance weight might change the ranking (Figure 34). When the Brussels-capital would favour the social political acceptance criterion with a weight over 37.71%, S5 would become the most preferred scenario. The initial weight of social political acceptance needs to be doubled to notice a change in the ranking of BAU and S3 (Figure 35, Figure 44). The ranking is thus robust.

Figure 34: Stability level 1 - Brussels-Capital Region (Mobile Depot)

Stability level : <input type="text" value="1"/>				
Criteria	Min Weight	Value	Max Weight	
Quality of life	0,00%	61,02%	100,00%	■
Social political acceptance	0,00%	9,78%	37,71%	■
Network optimization	0,00%	22,47%	100,00%	■
Cost measures	0,00%	6,73%	100,00%	■

Figure 35: Stability level 7 - Brussels-Capital Region (Mobile Depot)

Stability level : <input type="text" value="7"/>				
Criteria	Min Weight	Value	Max Weight	
Quality of life	0,00%	61,02%	100,00%	■
Social political acceptance	0,00%	9,78%	18,67%	■
Network optimization	3,50%	22,47%	100,00%	■
Cost measures	0,00%	6,73%	52,13%	■

Figure 36: Evolution of the scores for green concerns – Shippers (Mobile Depot)

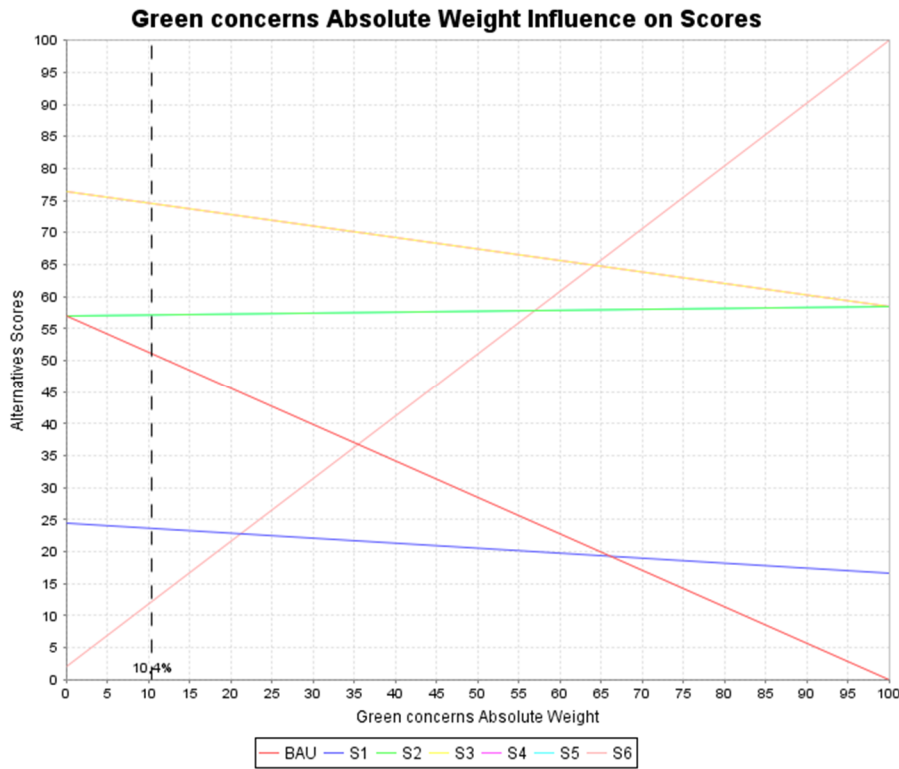


Figure 37: Evolution of the scores for profitable operations – TNT Express (Mobile Depot)

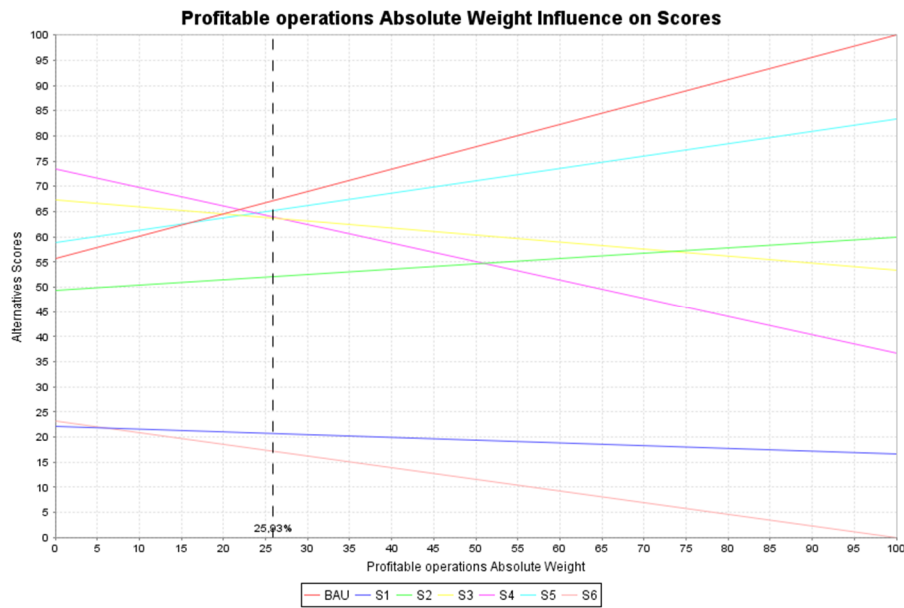


Figure 38: Evolution of the scores for viability of investment – TNT Express (Mobile Depot)

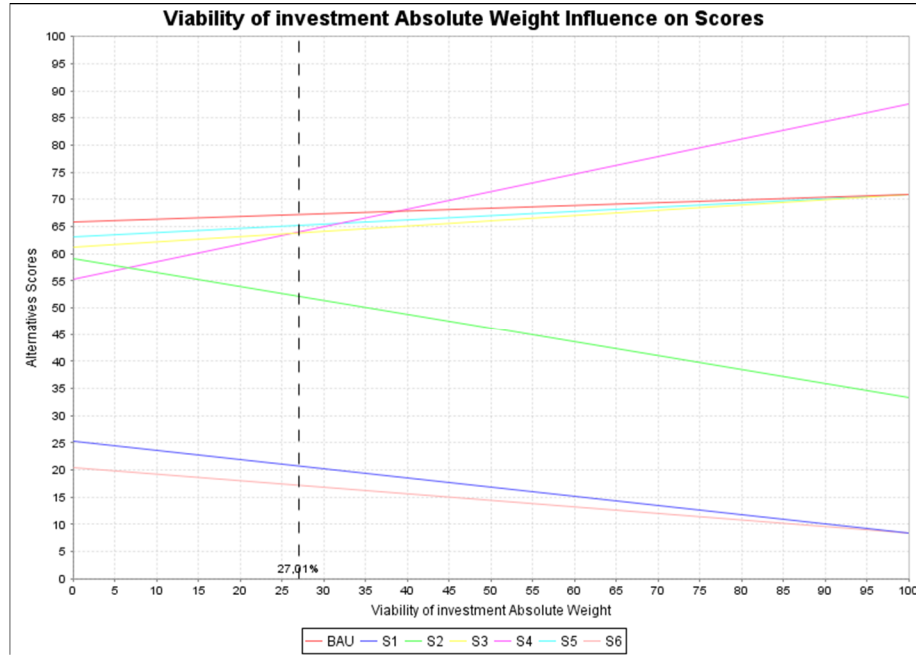


Figure 39: Evolution of the scores for employee satisfaction – TNT Express (Mobile Depot)

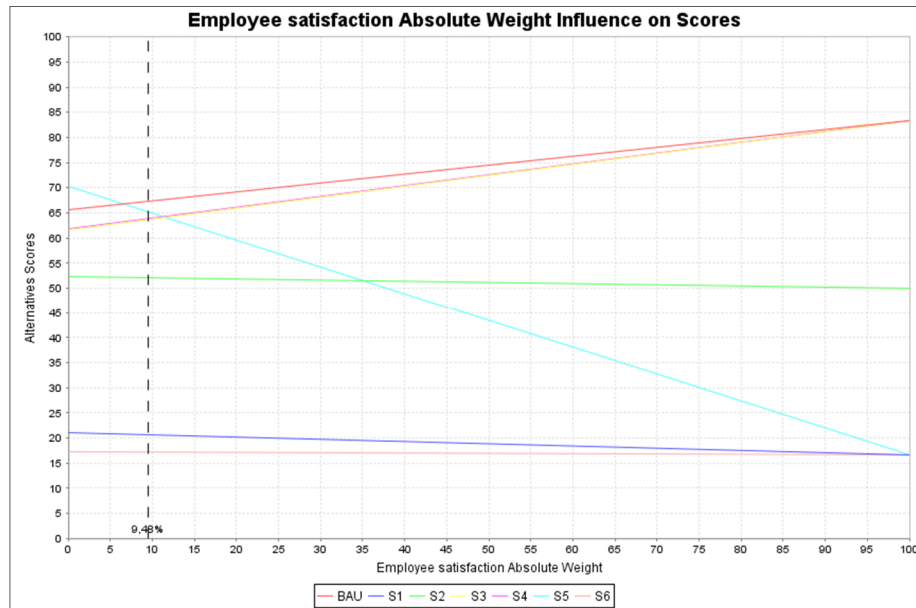


Figure 40: Evolution of the scores for green concerns – TNT Express (Mobile Depot)

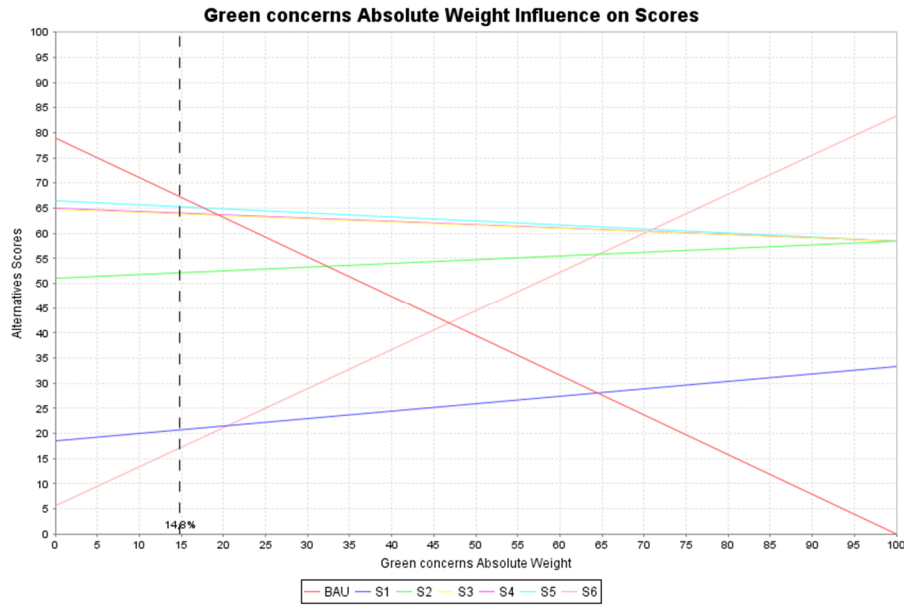


Figure 41: Evolution of the scores for attractive urban environment – Receivers (Mobile Depot)

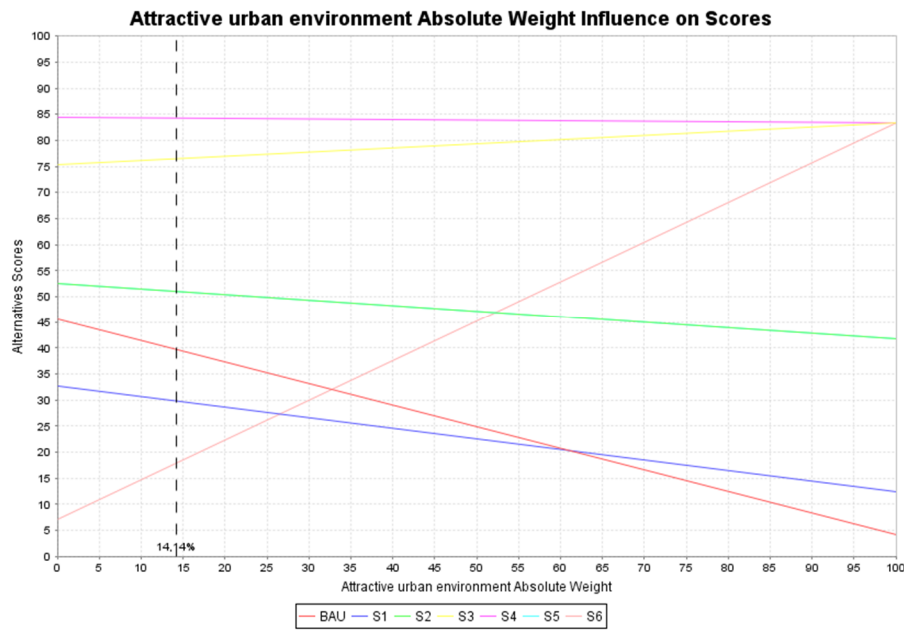


Figure 42: Evolution of the scores for attractive green concerns – Receivers (Mobile Depot)

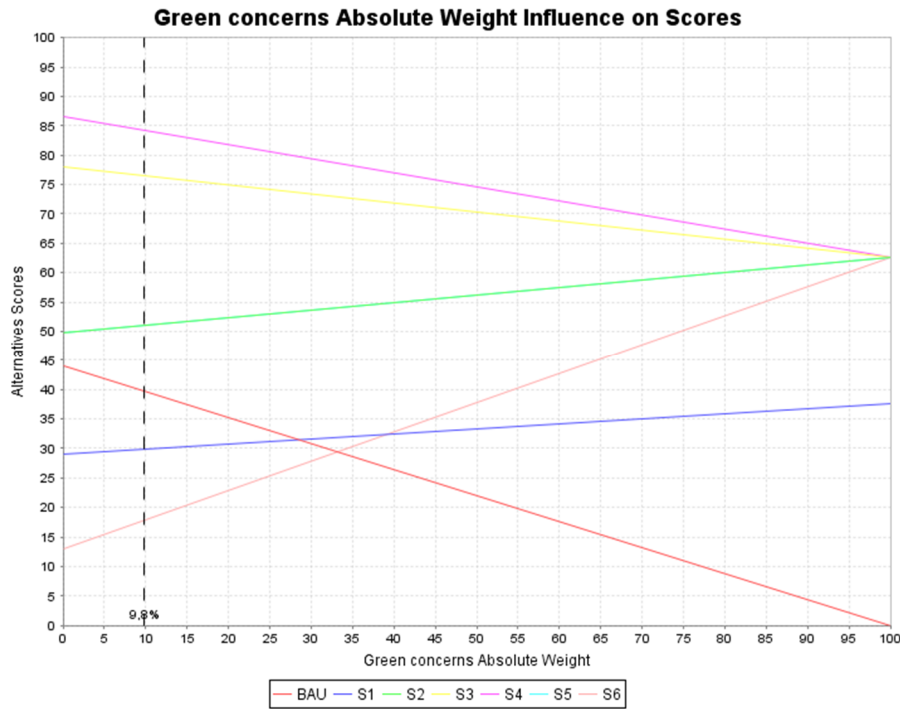


Figure 43: Evolution of the scores for urban accessibility – Citizens (Mobile Depot)

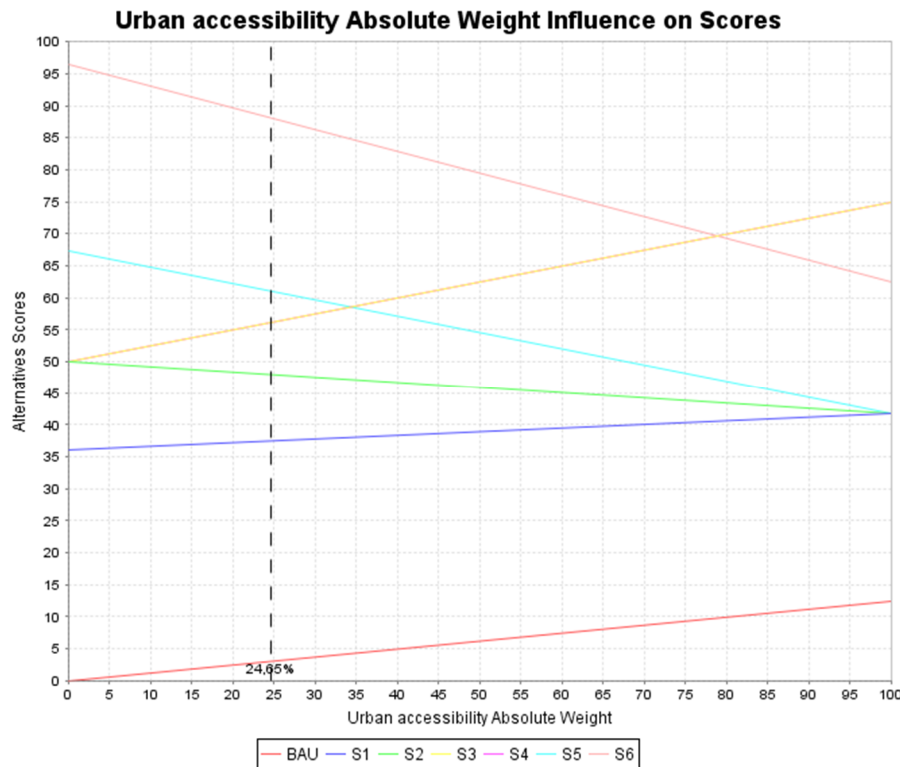
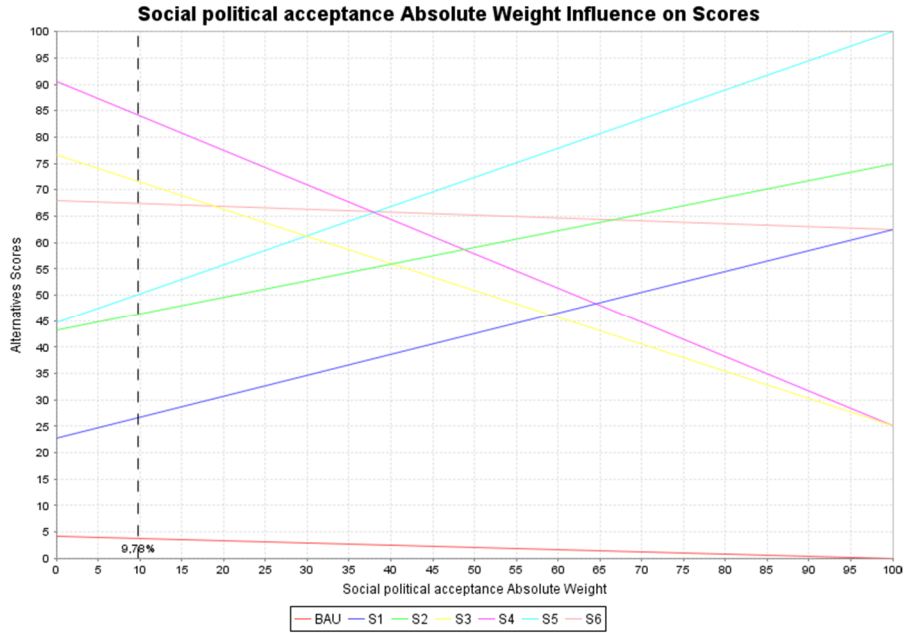


Figure 44: Evolution of the scores for social political acceptance – Brussels-Capital Region (Mobile Depot)



5

Night-time delivery as a potential option in Belgian urban distribution: a stakeholder approach⁹

5.1 Introduction

The lack of suitable infrastructure for deliveries, noise emissions, conflicts with other road users during delivery operations, jammed trucks in pedestrian zones or historic centres, traffic disruption in the inner city, and environmental pollution. According to 43 European urban governments, these are the main problems concerning urban freight transport in their cities (Ruesch and Glücker, 2001). Despite the fact that these problems are well-established, they are very difficult to resolve because having goods delivered frequently and efficiently is essential for a liveable city. A liveable city is more than just a place to live. It has to accommodate several other functions, such as working, public services, shopping, entertainment, education and tourism (De Munck and Vannieuwenhuysse, 2008; Witlox, 2006). For each of these functions, tons of goods have to be brought into the city. But the way these deliveries are done nowadays puts a strain on the quality of life because of the negative impact on the environment, on traffic safety and on urban mobility.

In the literature on urban logistics, introducing night-time deliveries, also called off-peak or off-hour deliveries, is often cited as a possible solution. The concept is rather straightforward: deliveries take place in the off-peak hours, thus reducing congestion during rush hours. However there are also a number of potential stumbling blocks such as the noise pollution during the 'quiet' hours, the more expensive labour costs, and liability issues. Balancing the pros and cons against each other is all the more complicated because one should take into account the often conflicting

⁹ Verlinde, S., Debauche, W., Heemeryck, A., Macharis, C., Van Hoeck, E., Witlox, F. (2010). Night-time delivery as a potential option in Belgian urban distribution: a stakeholder approach. In: Viegas, J., Macario, R. (Eds.) *General Proceedings of the 12th World Conference on Transport Research Society (11-15 July 2010, Lisbon, Portugal)*. Lisbon: WCTR.

interests of the different stakeholders involved. For example, some retailers prefer to be delivered in the early morning because they want to have their merchandise in their shops before they open up. But local residents do not want noisy trucks in their streets during the night, and commuters and other residents do not like trucks blocking the road when they have to travel to work.

In Belgium the Federal Science Policy Administration issued a research project on evaluating how night-time deliveries can be considered as a potential option for (partly) solving the problems concerning freight transport in Belgian cities. The ultimate aim of the program is to reconcile the different stakeholder demands and to assess the overall socio-economic impact of night-time deliveries. As part of this project, the public support for night-time deliveries in Belgian cities was measured, making use of a Multi Actor Multi Criteria Analysis (MAMCA), which, as a stakeholder oriented tool to evaluate transport projects, was developed at the department MOBI of the Vrije Universiteit Brussel (VUB) (Macharis et al., 2007). This paper presents both the MAMCA-approach, which allows the points of view of several stakeholders and their quantitative and qualitative criteria to be incorporated in one analysis, and the results of the analysis. These aspects are dealt with in Sections 5.3 and 5.4 of this paper. In Section 5.2, we focus on some relevant findings of earlier research on night-time deliveries, whereas in Section 5.5, our conclusions are summarized.

5.2 Night-time deliveries as a possible solution for urban freight transport problems

One option to optimize the economic life and the urban distribution, while decreasing the negative effects of urban freight traffic, is to switch to night-time deliveries. In this policy measure no goods vehicles are permitted to enter a specified geographical area within the inner urban area to make collections and deliveries during a large period of the working day (Allen et al., 2004). Currently, in Belgium, like in most countries, deliveries are usually carried out by day. To our knowledge, there are no general statistics on delivery times, but some city administrations map their distribution patterns. In 2004, the city of Ghent studied the feasibility of an urban distribution centre and interviewed 215 traders within the city centre (Stad Gent, 2004). Twenty-eight percent of the respondents were owners of bars, restaurants and hotels, 18 percent traded in fashion and accessories, 17 percent provided other services, 14 percent were other retailers and only two percent were supermarkets. They were all asked at what time of the day their two main suppliers deliver their goods. The results of the inquiry are shown in Table 6.

Table 6. Delivery times in Ghent

Time of day	abs	%
Before 9 am	34	9%
9 am – 11 am	118	32%
11 am – 2 pm	62	17%
2 pm – 6 pm	29	8%
After 6 pm	14	4%
Highly varying	101	28%
Does not know	6	2%
Total	364	100%

Source: Stad Gent, 2004.

Nearly half of the deliveries take place between 9 am and 2 pm. Only a minority, nine percent, is made before 9 am, and even less, only four percent, is carried out after 6 pm. In other European countries such as the Netherlands and Great Britain, we notice a same pattern (Schoemaker et al., 2006; Allen et al., 2000). The majority of deliveries occur in the morning, only a negligible percentage is carried out during the off-peak hours. The small share of night deliveries in Ghent is even more striking because there is a time window between 6 pm and 11 am. This time window is government-imposed to increase traffic safety and liveability and to create an attractive urban shopping environment. Obviously, in this case, many exceptions were granted because at least 25 percent of the deliveries took place outside the set timeframe.

The literature on the (theoretical) advantages and disadvantages of night deliveries is extensive. Table 7 summarises the findings of earlier research. It shows the impact of night deliveries on five points of interest for urban distribution: congestion, road safety, the environment, social vitality, economic viability, and on the logistics chain. The conclusion is that shifting deliveries to the off-peak hours is a measure with positive social and economic consequences, which is also feasible provided that the government sets up the right framework to keep any negative effects under control. These possible negative effects are: noise, safety, both for the driver and the goods, liability issues and extra costs to the receiver.

In the Netherlands, SenterNovem which is an agency for sustainability and innovation thought it would be interesting not only to sum up the pros and cons of night-time deliveries, but also to really calculate the impact of a possible shift. In 2008 they studied whether the benefits would compensate the extra costs if all Dutch supermarkets were delivered in the off-peak, provided the implementation of an adjusted policy to keep the above-mentioned negative effects under control (Dassen et al., 2008). The model is based on a qualitative analysis of the impact of night distribution from which the quantifiable effects (i.e. energy consumption, transport costs, emission of pollutants and number of traffic victims) were calculated. Six retail chains cooperated. They provided the researchers with data on their delivery operations such as the average distance travelled, the actual driving time, the fuel consumption, the average fuel price, etc. SenterNovem used these numbers to determine through projection the total financial and environmental impact of night deliveries both on the micro and the macro level.

Table 7. The impact of night deliveries

	Indicator		Impact
Points of interest for urban distribution	Congestion	+	Shifting deliveries to the off-peak hours decreases congestion.
	Traffic safety	+	Decreasing the number of trucks and vans during the off-peak-hours diminishes the risk of casualties.
	Environment	+	Even when trucks do not change their itinerary, not standing still in traffic jams with running engines will reduce their emission of pollutants dramatically.
	Social vitality	±	Liveability by day will ameliorate because trucks will not populate the streets. At night, on the other hand, noise levels might exceed the acceptable, which can be countered by firm noise standards.
	Economic viability	+	Drivers do not lose time in traffic jams, which allows them to deliver more in less time.
Logistics chain	Total logistics cost	±	It is uncertain what the impact of night deliveries on the total logistics cost would be, since the wages of the drivers would raise, but the gain of time would cut costs.
	Reliability	+	The risk of delays is much lower when delivering at night because there is no congestion.
	Flexibility		No impact
	Safety	-	When delivering at night, truck drivers often get unguarded access to a shop which hampers security. There are technical solutions such as delivery boxes, but they imply extra costs. There is also a liability issue when goods are damaged or lost during delivery operations because usually there is no staff present to accept the delivery. The presence of night security might solve this problem, but it also implies an extra cost.
	Speed		No impact
	Image		No impact

Subsidies necessary?	N	No subsidies are necessary; this policy might even be cost-cutting.
Initiator		Government (legal framework) and supplier (agreement on delivery times with the receiver)
Social effect	+ / ++	The impact of night deliveries is very positive. Attention should be paid to the noise levels of both truck and driver.
Economic effect	+ / ++	Night deliveries are more expensive because of the night work needed, but then again transport becomes more efficient and reliable. Attention should be paid to the safety of the goods.
Feasibility	~ / +	Night deliveries are feasible in certain logistic chains, when the safety of goods is not an issue, or for retail chains who organize their own logistical arrangements.

Source: De Munck & Vannieuwenhuysse, 2008.

The calculations show, for example, that a national operating retail chain could save ten percent on fuel by switching to night deliveries. On a national level, that could mean an annual saving of fourteen million litres fuel. It was also found that a regional operating chain could save up to 858000 Euros a year; whereas for a national operating chain, this could lead up to almost five million Euros. The possible environmental consequences are even more striking. The emission of soot and fine dust could be reduced with forty-two to forty-four percent. SenterNovem concludes that there are great benefits in using the early mornings and late evenings to supply retail chains. It will lead to less pressure on our road network and to an improved use of its capacity. It will also reduce costs, energy use and emissions of pollutants.

Although this Dutch project is an indicator of the possible scale of the positive effects of a shift to off-peak deliveries, the ease with which it assumes that the negative effects can be easily overcome might not be very realistic. In most urban settings, there is a spatial integration of the different qualities city life incorporates. This is often encouraged by local governments because these hybrid neighbourhoods generate a vibrant, attractive and safer city (Vannieuwenhuysse and De Munck, 2008). Therefore, in addition to the 'economic' stakeholders, one should also take into account the needs of the different 'social' stakeholders. Broadly speaking, there are three groups of stakeholders: (i) trade and industry, (ii) society, and (iii) public policy-makers (Witlox, 2006). Trade and industry include suppliers, carriers, receivers, wholesalers and distribution companies. Society consists of inhabitants, employees, commuters, consumers, and tourists. Public policy-makers are local, regional and national governments. All these stakeholders, each with their own often conflicting interests, take measures to mitigate the adverse effects of urban distribution to them personally (or as a group) which in turn often cause additional nuisance to the other stakeholders. Therefore, governments aim for a sustainable urban distribution which means that they want to establish a framework within which the various aims and objectives of the stakeholders are reconciled as much as possible.

5.3 How to measure public support for night-time deliveries in Belgian cities?

5.3.1 Methodology

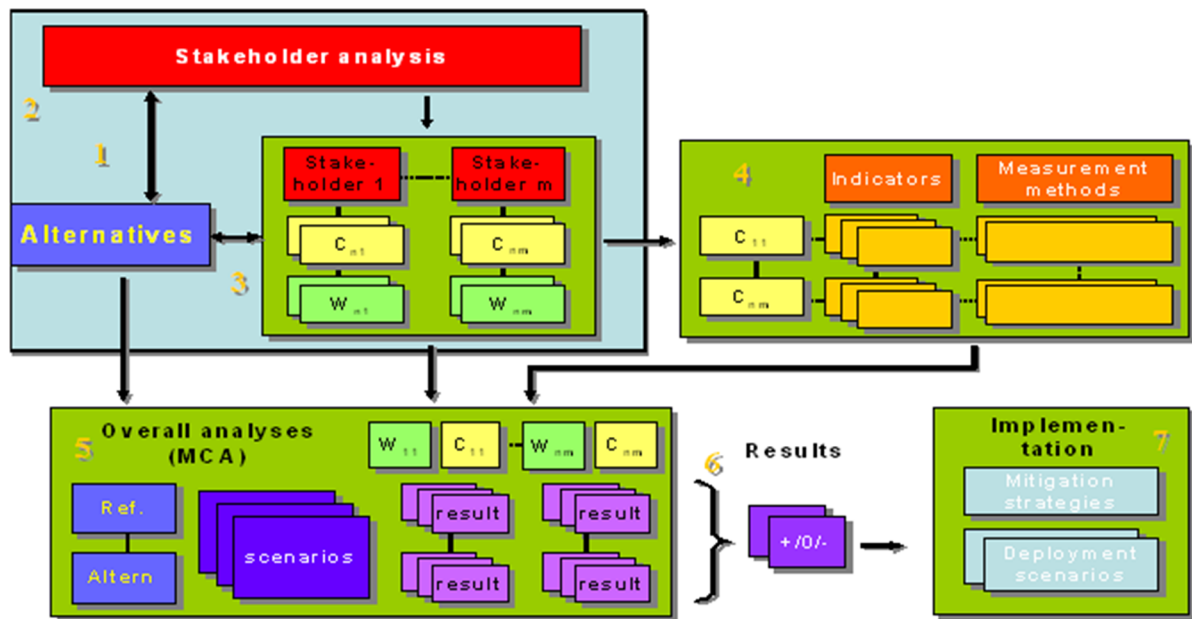
Evaluating (new) transport projects (either new infrastructure or new initiatives) implies having a method that is able to take into account different conflicting objectives and can reconcile tangible and intangible criteria. Today, five commonly used methods exist: the private investment analysis (PIA), the cost effectiveness analysis (CEA), the economic-effects analysis (EEA), the social cost benefit analysis (SCBA) and the multi-criteria analysis (MCA) (Macharis et al., 2007). The latter two are the most frequently used. Recently, however, both in management literature and practice, the concept of stakeholder and stakeholder management has become a very important issue. A technique that combines the MCA technique with the notions of stakeholder and stakeholder management in an explicit way is the so-called Multi Actor Multi Criteria Analysis (MAMCA) (developed by Macharis, 2004). This approach takes the advantages of a MCA (namely the fact that effects may be expressed in different units and that trade-offs become more explicit) and those of stakeholder management (the fact that stakeholders are crucial actors

in contributing to the success or failure of the implementation of a policy). In the context of the evaluation of night-time distribution, the participation of stakeholders is vitally important. As explained above, the urban setting involves many different interests, which makes the decision on whether or not to deliver in the off-peak highly controversial. MAMCA provides a comparison of different strategic alternatives by pointing out its advantages and disadvantages for all stakeholder groups.

The MAMCA-methodology consists of seven steps, and is depicted in Figure 45:

1. The definition of the problem and the identification of the alternatives: The first stage of the methodology consists of defining the alternatives. These alternatives can represent different policy options or actions to be taken.
2. The identification of stakeholders and their key objectives: In this step the stakeholders are identified and asked for their goals/aims concerning the decision problem at hand.
3. The objectives are translated into criteria and a weight is allocated to each of them: The choice and definition of evaluation criteria are based primarily on the identified stakeholder objectives and in order to assign a weight to these objectives the AHP method is used. The Analytic Hierarchy Process (AHP) (Saaty, 1986) is a frequently used MCA-method. By means of pair wise comparisons the priority of each objective for the stakeholders is determined.
4. For each criterion, one or more indicators are constructed: In this stage, the previously identified criteria are translated into variables that can be used to measure (quantitatively or qualitatively) to what extent an alternative contributes to each individual criteria.
5. An evaluation matrix is constructed which aggregates each alternative contribution to the objectives of each stakeholder group.
6. The multi-criteria analysis provides a ranking of the various alternatives and shows their weak and strong points: The Multi Actor Multi Criteria Analysis provides a comparison of different strategic alternatives and supports the decision maker in making his final decision by pointing out for each stakeholder which elements have a clearly positive or a clearly negative impact on the sustainability of the considered alternatives.
7. The actual implementation: Sensitivity analysis shows how consistent the judgments are: When the decision is made, steps have to be taken to implement the chosen alternative by creating deployment schemes. As the method provides insights in the advantages of each alternative for each stakeholder group, this information can be explicitly taken into account while developing the mitigation strategies.

Figure 45. Multi Actor Multi Criteria Analysis



Source: Macharis, 2004.

5.3.2 The different steps of the Multi Actor Multi Criteria Analysis in the case of off-peak deliveries

In the following section the different steps of the methodology of the MAMCA will be explained for the specific case of off-peak deliveries. Through this analysis the support for a possible shift to off-peak deliveries can be assessed for each of the stakeholder groups as the end result is a ranking of the previously defined scenarios.

Step 1: Defining the alternatives

The first step consists of identifying and classifying the possible alternatives submitted for evaluation. In this case, there are two alternatives: delivering businesses in cities during daytime or at night. Based on these alternatives and on a profound study of the problems of urban distribution and of the typical characteristics of night deliveries, five possible scenarios were defined. They differ as to when deliveries are made and which accompanying measures have been taken.

Scenario 1: Day deliveries

Scenario 1 assumes that deliveries in cities are made during the day in compliance with currently imposed time windows. The actual practice shows it would be mainly between 9 am and noon (Stad Gent, 2004; Schoemaker et al., 2006; Allen et al., 2000). This scenario can be seen as the reference scenario.

Scenario 2: Night deliveries between 7 pm and 7 am

In scenario 2 all deliveries are shifted to the late evenings, nights and early mornings when the demand for transport is low. At these times commuter traffic virtually stops. Most commuters leave their homes between 6:30 am and 8:45am, with a peak between 7 am and 8:15 am (Verhetsel et al., 2007). Statistics on everyday congestion in Belgium point out in the same direction: the earliest traffic-jams appear at 6:30 am and end around 9:15am (www.touring.be, 12th of March 2009). They are at their longest at 8:35 am. The evening rush hour is more spread. People arrive home between 4:30 pm and 8 pm, with an early peak between 4:30 pm and 6 pm. As from 7 pm the number of commuters still on the way drops dramatically. According to Touring Mobilis the evening traffic jams reach their peak between 6 pm and 6:30 pm. This shows that in Belgium the hours between 7 pm and 7 am can be considered as off-peak.

Scenario 3: Off-peak deliveries between 7 pm and 11 pm

As previously mentioned, off-peak deliveries have several undesirable side effects. They are generally directly linked to the nocturnal time of delivery, for example the higher nuisance caused by loading and unloading trucks and the higher wages for drivers and workers. To find out whether a well thought-out partial use of the off-peak hours to deliver goods might mitigate these side effects, two alternative scenarios were introduced.

In scenario 3, deliveries are only allowed between 7 pm and 11 pm, based on the following:

- At 9:30 pm only 9.0% of the Belgians already went to bed (Glorieux et al., 2008). Another 3.5% is getting ready to do the same.
- At 11 pm more than half of the population is asleep (56.0%). One hour later, already 83.0% is sleeping and at two o'clock, nearly everybody went to bed (96.1%).
- Labour legislation is less strict on companies introducing night work when it is performed before midnight. (<http://www.belgium.be>, 12th of March 2009).

Scenario 4: Off-peak deliveries between 3 am and 7 am

In scenario 4 deliveries can only be carried out between 3 am and 7 am. We can assume that some stakeholders might prefer these hours because they are the off-peak hours closest to the 'normal' delivery hours in the morning.

Scenario 5: Night deliveries between 7pm and 7 am, combined with noise standards and a subsidy scheme

Literature on night-time deliveries and pilots show that the noise nuisance caused by trucks driving, loading and unloading is an important obstacle for introducing off-peak deliveries in cities (Dassen et al., 2008). Therefore, in this scenario, as in scenario 2, all deliveries are shifted to the late evenings, nights and early mornings. But this time, this shift is combined with a specific set of measures aimed at mitigating the nuisance. The scenario refers to the Dutch Piek-programme. At the end of 1998 the renewed "Decree Retail Trade Environmental Protection" came into force (www.piek.org, 12th of March 2009). It stipulated that the noise emission generated when loading and unloading goods between 7 pm and 7 am must comply with strict peak noise standards. Given the products that were used at that time, industry and commerce could not comply with these strict standards. They were forced to come up with innovative measures. The Dutch government supported the implementation of these new products with a long-term subsidy scheme, also called the Piek-programme.

Step 2: Defining the stakeholders and their objectives

The second step consists of identifying all relevant stakeholders and their objectives. As mentioned earlier, concerning urban distribution there are three main groups of stakeholders. When evaluating night-time distribution, this general categorization is still valid, although the subcategories should be slightly rearranged according to the mutually different or coinciding objectives within or between the different groups. This leads to four separate stakeholders: the receiver, the transport sector, society as a whole, and the employee.

The receiver

The attitude of the receiver is a very decisive success factor (Holguín-Veras et al., 2005). They determine the delivery time and usually prefer to be delivered in the morning right before or right after opening up. In spite of them being mutually very divergent, the different types of receivers are considered to be one group due to their common objectives concerning deliveries which are:

- Competitiveness
- Customer satisfaction
- Smooth delivery (just in time deliveries, without delays, right in front of the shop, at a convenient time)
- Attractive urban shopping environment
- Goods safety (both the delivered goods and the stocks)

- Motivated employees

The transport sector

The second group of stakeholders is the transport sector. This group comprises carriers, but also logistic suppliers, the distribution sector and other related stakeholders, for example suppliers and harbours. These are the objectives that the transport sector uses to evaluate every possible change in their delivery operations:

- Delivery cost
- Customer satisfaction
- Technical feasibility
- Organizational feasibility
- Motivated employees

Society

The third stakeholder is society as a whole. Since the users of the urban space (inhabitants, commuters, tourists, shoppers) and the government have the same objectives regarding urban distribution, they are considered as one group for this analysis. Their objectives are as follows:

- Efficient urban distribution
- Cost-efficient accompanying measures
- Attractive urban environment
 - Smooth traffic
 - Traffic safety
 - Limited noise nuisance
 - Limited emissions of pollutants

The employee

The fourth group of stakeholders are the employees. It concerns all the employees, truck drivers, employees working in the stores, at the port, etc. Their objectives for their work environment are:

- Health
- Safety
- Wage
- Flexibility
- Social life
- Stress

Steps 3 & 4: Translate the objectives into criteria and indicators and allocate a weight to each criterion

After identifying the alternatives and the different stakeholders with their key objectives, the next five steps of the MAMCA-methodology aim to obtain and to process information on the impact of the different alternatives on the stakeholders' objectives. When analysing the advantages and disadvantages of night-time deliveries, most of the defined criteria cannot be expressed in numbers or are not the subject of existing statistics, for example an attractive shopping environment or motivation of the employee. Therefore this information was gathered through 18 interviews with representatives of the different stakeholder groups.

The interviews were held on established lines and included three phases. First of all, the above defined objectives were presented while asking for possible gaps. Secondly, the interviewee could indicate the importance of each of the objectives by assigning points. A total of 100 points had to be spread over the different objectives. Finally, a score between -2 and +2 had to be given to each scenario for the different objectives. Afterwards, the different scores for objectives were transformed in order to get pair wise comparisons which are used to establish the weights for the

criteria. Furthermore, an evaluation matrix was constructed which aggregates each alternative contribution to the objectives of each stakeholder group.

Step 5: Overall analysis and ranking

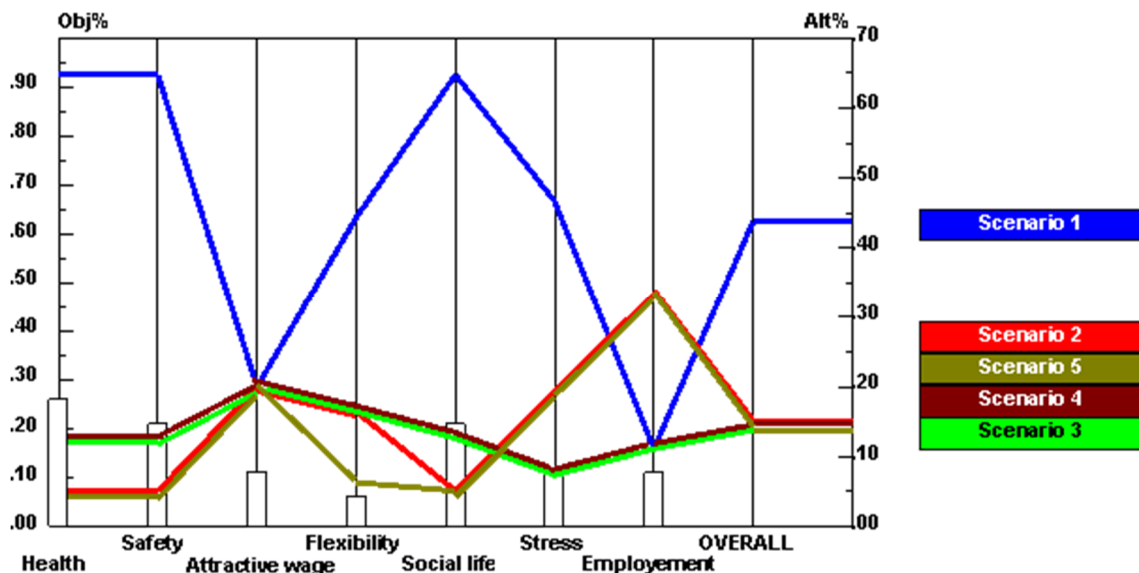
In order to carry out the overall analysis and ranking we use Expert Choice™, specialized software that makes use of the AHP method. The results of this analysis are shown in Section 5.3.3.

5.3.3 Results

Employee

Figure 46 below shows the results for the stakeholder 'employee'. The figure can be interpreted as following: the objectives are represented by vertical bars and the alternatives (scenarios) are displayed as horizontal line graphs. The intersection of the alternative line graphs with the vertical objective lines shows the priority of the alternative for the given objective, as read from the right axis labelled Alt%. The objective's priority is represented by the height of its bar as read from the left axis labelled Obj%.

Figure 46. Mono actor view MAMCA employee



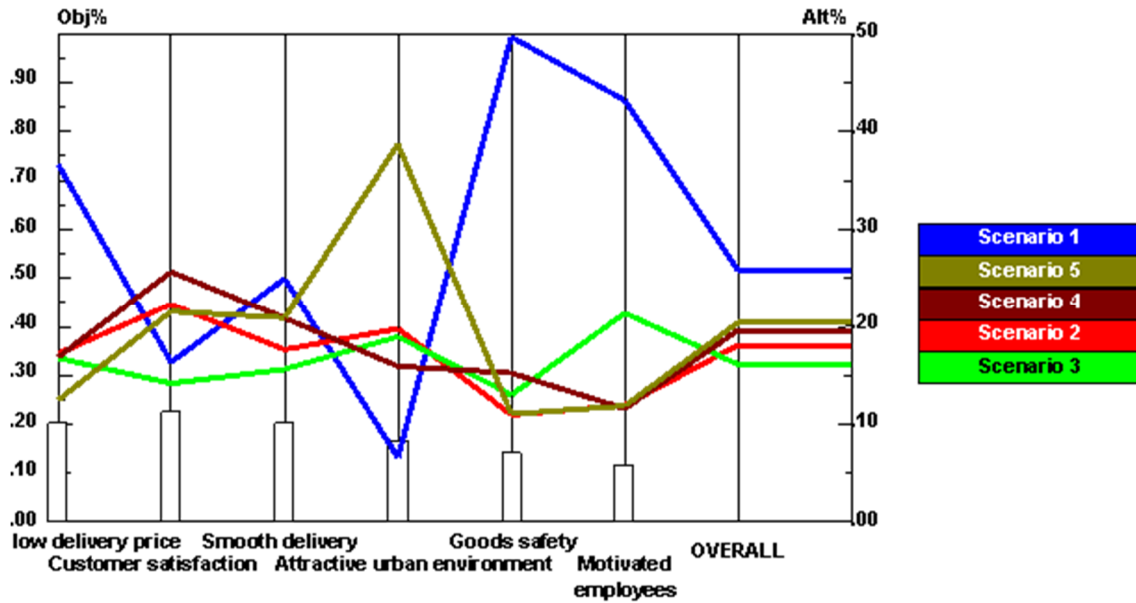
Source: Own setup.

For the stakeholder 'employee', the overall best scenario is scenario 1. The second best is scenario 2, followed by scenarios 5, 3 and 4. It means that the stakeholder 'employee' prefers day deliveries and considers them as the best alternative. Figure 46 also shows that scenario 1 has the highest scores for the three most important objectives, being 'health', 'safety' and 'social life' which is easily explained as working at night is more dangerous, less healthy and very disturbing for your social life. Only for the objective 'employment' scenario 1 does not have the highest score, but scenarios 2 and 5 do. These are the scenarios with night deliveries between 7 pm and 7 am, with or without a subsidy scheme and noise standards.

Receiver

The results for the stakeholder 'receiver' are shown below in Figure 47. Again, scenario 1 comes out as the overall best alternative. Subsequently, we have the four other scenarios with very close scores. Scenario 1 obtains a high score for the objectives 'low delivery price', 'goods safety' and 'motivated employees'. When we look at the objective 'attractive urban environment', scenario 5 is seen as the best alternative as delivering at night with a subsidy scheme and noise standards results in a truck free urban environment during the day and is not disturbing at night. The most important objectives for this stakeholder group are 'customer satisfaction', 'low delivery price' and 'smooth delivery'. For the objective 'customer satisfaction' scenario 4 is the best alternative, for the other two objectives scenario 1 scores best.

Figure 47. Mono actor view receiver

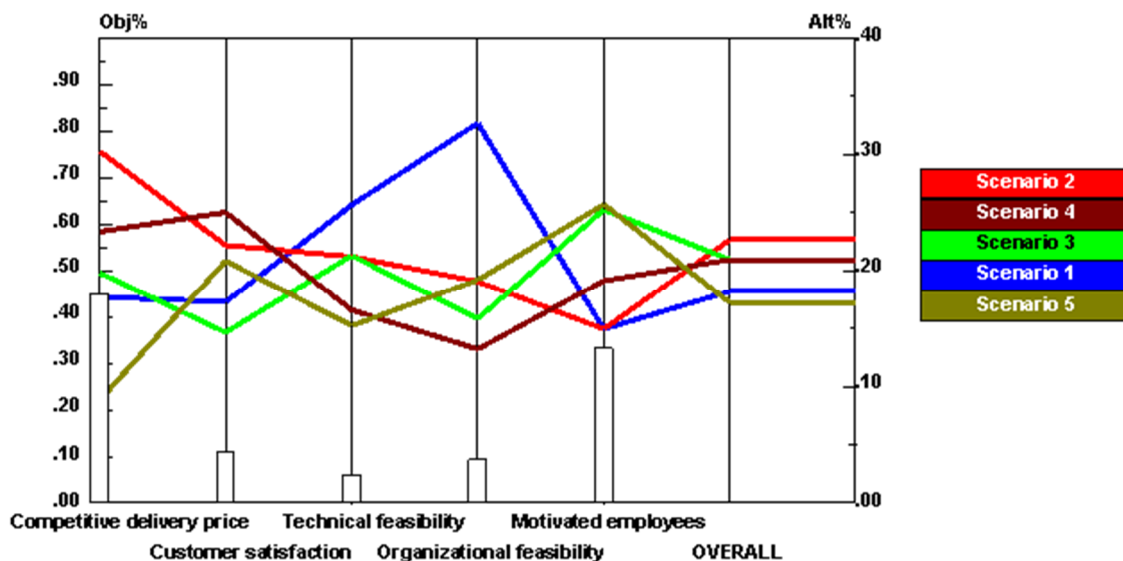


Source: Own setup.

Transport sector

The model seen from the perspective of the stakeholder 'transport sector' is shown in Figure 48. The results are remarkably different from those of the previously discussed stakeholders. Scenario 2 (night deliveries between 7 pm and 7 am) is overall perceived as the best option. Subsequently scenario 3 (off-peak deliveries between 7pm and 11pm) and scenario 4 (off-peak deliveries between 3 am and 7 am) are good alternatives. With regard to the less important objectives 'technical feasibility' and 'organizational feasibility', scenario 1 (day deliveries) scores best. As for the most important objective, being 'competitive delivery price', scenario 2 offers the best alternative. The transport sector thinks that they would be able to lower transport costs when delivering in the off-peak hours, which would lead to more competitive delivery prices. The second important objective is 'motivated employees' which, according to the transport sector, could be reached best through night deliveries coupled with a subsidy scheme and noise standards.

Figure 48. Mono actor view MAMCA transport sector

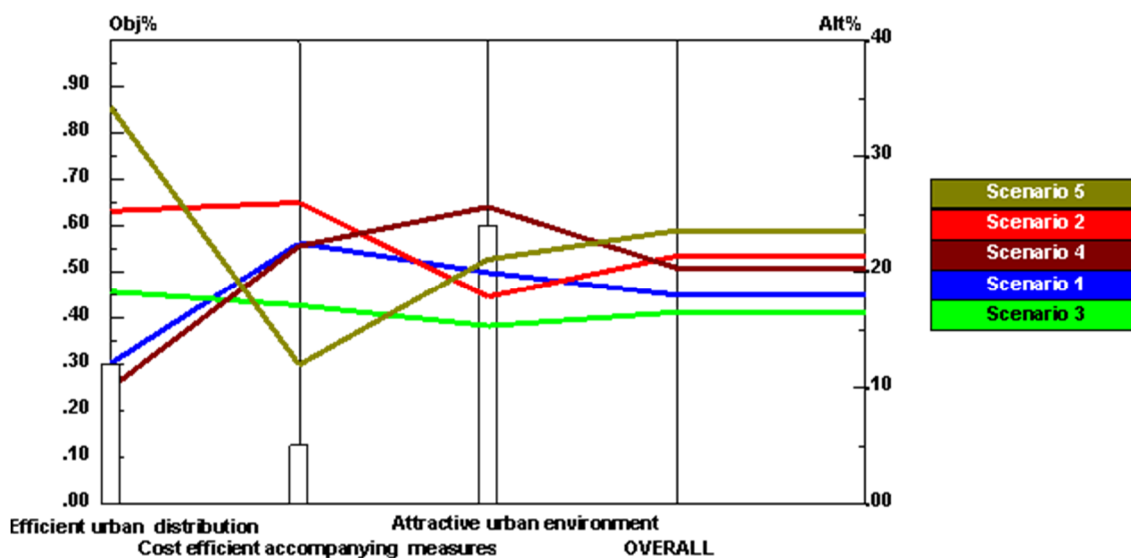


Source: Own setup.

Society

With regard to urban deliveries, the stakeholder 'society' aims for three objectives, namely efficient urban distribution, cost efficient accompanying measures and an attractive urban environment. For these three objectives scenario 5 receives the best score, followed by scenario 2 and scenario 4. Strikingly, scenario 1 (day deliveries) is not considered as the best alternative. The objective with the highest weight is 'an attractive urban environment'. It attains the highest score for scenario 4. This scenario is also the best option for the objective 'cost efficient accompanying measures'. As for the objective 'efficient urban distribution', scenario 5 (night deliveries between 7 pm and 7 am with a subsidy scheme and noise standards) has got the highest preference (Figure 49).

Figure 49. Mono actor view MAMCA society



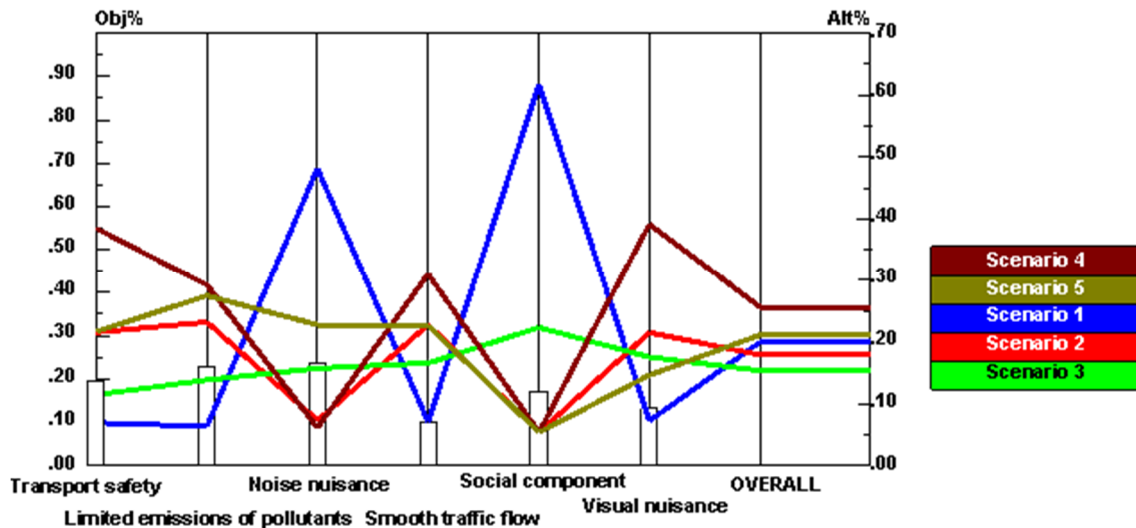
Source: Own setup.

Subcriteria within society

According to the interviewed representatives of the stakeholder group 'society', the objective 'attractive urban environment' is defined by 6 sub criteria, being 'transport safety', 'limited emissions of pollutants', 'noise nuisance', 'smooth traffic flow', 'visual nuisance' and the question whether it is desirable to shift to a 24-hour economy, called the 'social component'. The results of the analysis for these sub criteria are shown in Figure 50. Overall, the best

scenario is scenario 4 (off-peak deliveries between 3 am and 7 am). Notable in Figure 50 is that when scenario 4 attains a high score, scenario 1 has got a very low score and vice versa. With regard to the objectives 'noise nuisance' and 'social component', day deliveries are preferred because of the noise caused by the loading and unloading operations and the issue whether a further shift to a 24-hour economy is desirable. As far as the other objectives are concerned, society prefers scenario 4.

Figure 50. Mono actor view MAMCA society, sub criteria



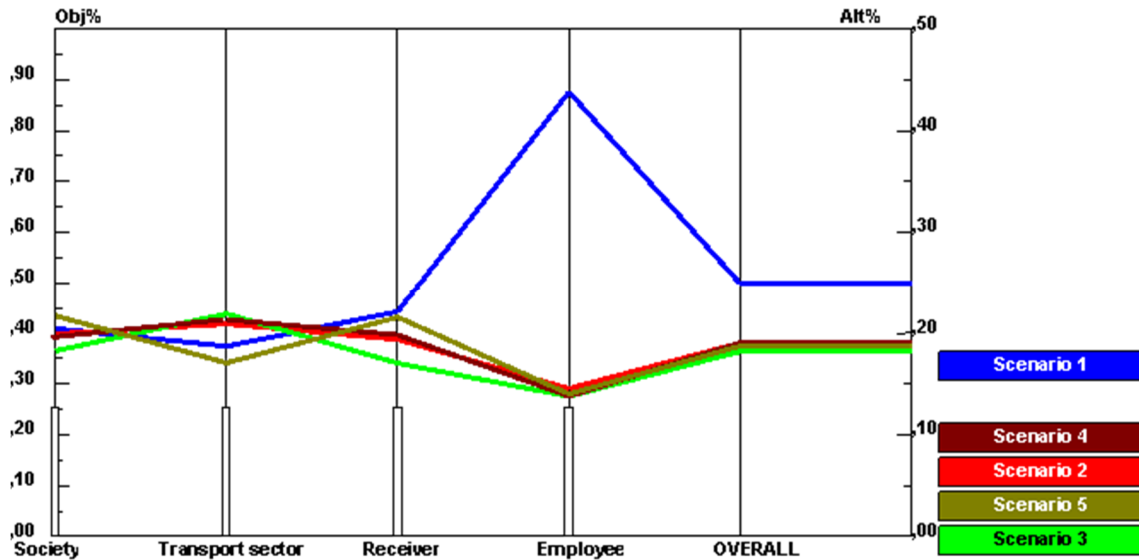
Source: Own setup.

Overall optimal scenario

Figure 51 shows that the optimal scenario, considering the preferences of all stakeholder groups which were considered to be of equal importance, is scenario 1 (day deliveries), followed by scenario 4 and scenario 2 respectively. As mentioned before, scenario 1 is the optimal scenario for the stakeholders 'employee' and 'receiver'. Scenario 3 is the scenario with the highest score for the stakeholder 'transport sector' and scenario 5 for 'society'.

The analysis of these results shows clearly the conflicting interests of the different stakeholder groups. Employees prefer day deliveries, since here 'health', 'social life' and 'safety' prevail. Receivers choose day deliveries as well, because the primary objectives here are 'smooth delivery' and a 'low delivery cost'. In contrast, for the stakeholder 'transport sector', totally different results were observed. Day deliveries are only ranked at place four and instead scenario 2 is considered as the best alternative. This can be explained by the fact that a 'competitive delivery price' is very important for this stakeholder group and therefore. Also striking is the fact that the 'transport sector' considers scenario 5 to be the most appealing one to its employees, as the stakeholder group 'employee' indicates to prefer scenario 1. Like the 'transport sector', 'society' does not choose day deliveries as the best option. They do consider scenario 2, scenario 4 and scenario 5 to be optimal which can be explained by the fact that for 'society' the objectives 'efficient urban distribution', 'cost efficient accompanying measures' and an 'attractive urban environment' are the most important objectives. It is very obvious that day deliveries have a low score for these objectives.

Figure 51. Multi actor view MAMCA



Source: Own setup.

5.4 Conclusions

Night-time deliveries might be an answer to some of the problems in Belgian cities, such as congestion, pollution and inefficient delivery operations. As the contribution of freight traffic to these problems is rather unclear and as there are both advantages and disadvantages to shifting deliveries to the off-peak hours, it would be interesting for urban government to assess the public support for a similar shift. The most appropriate methodology consists in a Multi Actor Multi Criteria Analysis (MAMCA), which enables to incorporate the often conflicting interests of the different stakeholders in one comprehensive analysis.

The executed MAMCA on night-time deliveries gave the following results: two of the four stakeholder groups, 'employee' and 'receiver', prefer deliveries to be carried out as they are today, namely by day. The opinion of the stakeholder group 'transport sector' is completely opposite, as they prefer to deliver between 7 pm and 7 am. The fourth stakeholder group, 'society', prefers night-deliveries as well, but only when accompanied by a subsidy scheme and noise standards. These findings suggest that the public support for an overall implementation of night-time deliveries is rather low. But at the same time, the research shows there is some room for implementation in Belgian cities, but only if the time period, the type of business and the accompanying measures are carefully selected.

Acknowledgements

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Annex D: List of interviewees

Stakeholder	Date interview
Employees	
ABVV	8/06/2009
Receiver	
Fedis	28/04/2009
VOKA	10/04/2009
Horeca Brussels	
UCM	20/04/2009
UWE	
Unizo	10/05/2009
Transport Sector	
SAV	23/04/2009
Fedis	28/04/2009
VIL	22/04/2009
Febetra	2/06/2009
Society	
Stad Gent	4/06/2009
VIM	20/04/2009
Dienst toerisme Gent	15/05/2009
Straten Generaal	13/05/2009
MOW Vlaanderen	27/04/2009
VSGB	12/05/2009
Fietsersbond	4/05/2009

6

Which types of freight flows can be shifted to the off-hours? A review and case study of Flanders (Belgium) using a new freight flow classification framework¹⁰

6.1 Introduction

Many large European cities are struggling to satisfy the mobility needs of individuals and businesses while guaranteeing pleasant urban living environments. An enjoyable and vibrant city accommodates several functions, such as housing, employment, production, public services, shopping, education and tourism (De Munck & Vannieuwenhuysse, 2008; Witlox, 2006). The transportation required by the spatial divergence of these functions entails a wide range of negative impacts on the urban living environment, e.g., road congestion, emissions, high CO₂ levels, noise nuisance and oil dependence. Therefore, since the early 1990s, both (local) governments and researchers have been developing measures to decrease the negative impact of urban freight operations (Quak, 2008). Since the beginning, it was believed that shifting deliveries to the off-hours would positively affect peak-hour congestion (Browne, Allen, Anderson & Woodburn, 2006; Holguín-Veras et al., 2005). Iyer et al. (2011) modelled the traffic impact of various off-hour delivery programs and demonstrated that as larger tax incentives were offered, congestion decreased throughout the regional highway network. Their research does not necessarily imply that introducing additional off-hour deliveries would decrease actual road congestion because the demand for urban freight and

¹⁰ Verlinde, S., Macharis, C., Witlox, F. (2014). Which types of freight flows can be shifted to the off-hours? A review and case study of Flanders (Belgium) using a new freight flow classification framework. Manuscript submitted to *Transport Reviews*

passenger transport is very high. However, this research supports that off-hour deliveries can alleviate some of the pressure. The results of multiple off-hour delivery trials indicate that other societal benefits can be expected. Most importantly, off-hour deliveries enable carriers to avoid traffic congestion, which reduces their fuel consumption and therefore their emission of pollutants (e.g., Dassen, Colon, Kuipers & Koekebakker, 2008; Freight Transport Association, 2009; Holguín-Veras et al., 2011). Although some studies question the overall environmental benefits of rescheduling deliveries (Sathaye, Harley & Madanat, 2010), most researchers recognise positive environmental effects. There is no consensus, however, about the impact on traffic safety. On the one hand, the degree of heterogeneity in the traffic mix determines the risk of traffic accidents with fatalities or injuries (Tiwari, 2000). Shifting more trucks to the off-hours would decrease interactions between vulnerable road users and trucks and therefore have a positive impact on traffic safety. On the other hand, driver sleepiness is increasingly recognised as an important factor contributing to the burden of traffic related morbidity and mortality (Nabi et al., 2006).

Allen et al. (2008) reviewed 30 United Kingdom urban freight studies and concluded that, on average, 4% and up to 14 % of deliveries in British cities were conducted during the evening, night or early morning (between 7pm and 6am). This trend is confirmed by Schoemaker, Allen, Huschebeck & Monigl (2006) for other European cities. The body of literature on off-hour deliveries identifies two main reasons for this low share. First, in many cities, off-hour deliveries are prohibited because it is assumed that the act of loading and/or unloading freight vehicles causes noise levels that cannot be tolerated at these hours. However, multiple test projects have already demonstrated that noise nuisance can be circumvented if specially adapted rolling stock is used (Douglas, 2011; Senter Novem, 2008; Vlaamse Overheid, MOW, Haven- en Waterbeleid, 2011). Second, receiver attitudes are typically negative (Holguín-Veras et al., 2005). Carriers, wholesalers and suppliers conducting their own logistics indicate that although off-hour deliveries would be cheaper, receivers do not want them. Receivers prefer to receive goods during operating hours because they fear the extra costs of evening or night work for staffed deliveries or security for unassisted deliveries. Another difficulty is the lack of contractual obligations between the receiver and carrier (Stichting Leve De Stad, 2005). The receiver is the final addressee for the delivery, but if he is not the sender of the goods, he usually does not choose nor pay the carrier. Receivers and carriers therefore typically do not consult with one another on the most appropriate delivery date or time.

The existing literature on off-hour deliveries demonstrates the benefits of off-hour deliveries, highlights the reasons why urban off-hour deliveries are unpopular and develops solutions to overcome these stumbling blocks. However, the fact that some deliveries already are conducted during off-hours suggests that this can become common practice in most cities. Our work aims to determine whether specific types of freight flows can be shifted to off-hours more easily than others and to identify the freight flow characteristics influencing that shift. We followed a three step approach. First, we developed a new framework to systematically describe and classify types of freight flows. Section 6.2 describes and explains our framework. Second, using this framework, we reviewed the existing literature in search of established characteristics of freight flows influencing their suitability to off-hour deliveries. Section 6.3 presents the results of this literature review. Finally, we interviewed representatives of 41 companies successfully providing off-hour deliveries about the rationales and procedures of their off-hour operations, which allowed us to compare their answers to the results of previous research. Section 6.4 discusses the method used to conduct these interviews and section 6.5 describes the findings. Section 6.6 concludes and provides opportunities for further research on this topic.

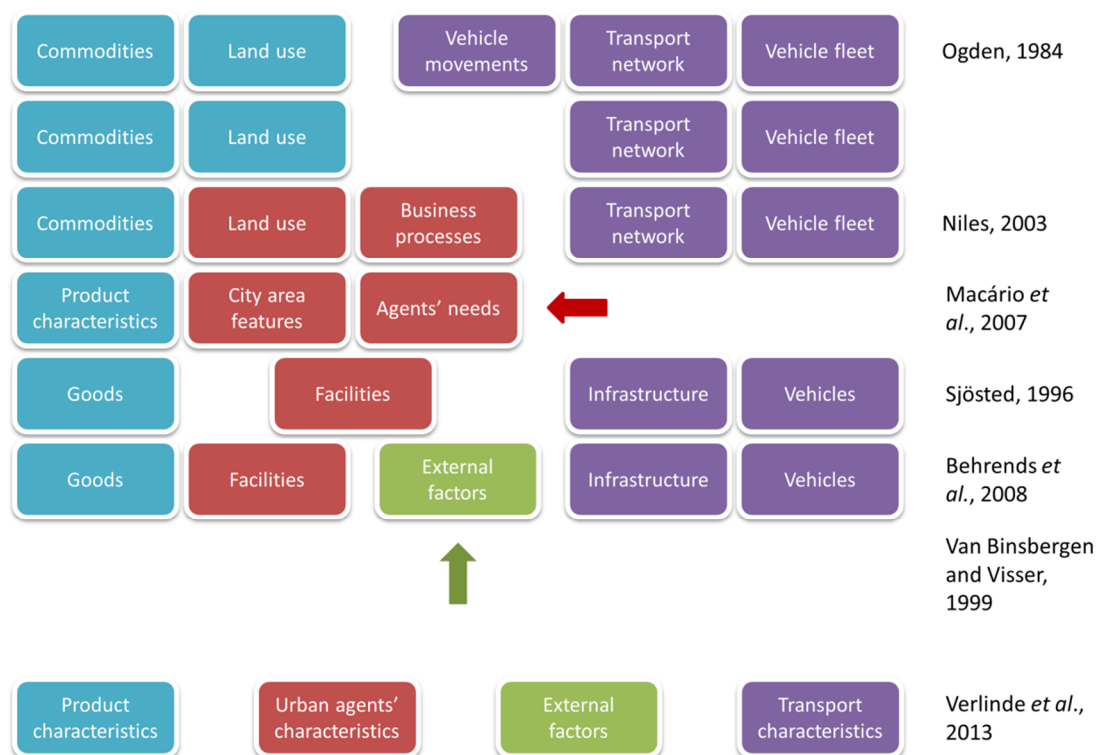
6.2 Theoretical Framework to Classify Urban Freight Flows

One of the first comprehensive analyses of urban goods movements was conducted by Ogden (1992). His seminal work (1984) incorporates an analysis framework and is a tool to structure and categorise freight issues and policy responses to those issues. His framework defines and specifies the various components of urban freight tasks in terms of supply-demand interactions. He identifies two demand variables, commodities and land use, and three supply variables, transport networks, vehicle fleet and vehicle movements. The first four components characterise, to some extent, urban freight flows. The fifth component, vehicle movements, is a consequence of the other four components. This perspective is also supported by Niles (2003), who refined Ogden's framework by considering vehicle movements, or truck movements, as the interactions between demand and supply. Niles also expands the framework by including a third variable on the demand side, business processes, which he defines as the methods by which businesses conduct their work. He states that these processes influence the timing, quantity, and packaging characteristics of freight flows. Macário et al. (2007) introduced the concept of the logistic profile, which is based on

the hypothesis that it is possible to identify, for some well-defined areas inside a city, a reasonably homogeneous group of logistic needs based on the following three points: product characteristics, city area features and agent needs. Although this concept was developed from a different starting point, product characteristics and city area features are comparable to the demand variables included in Ogden's framework. The third key point, agent needs, can be regarded as an extension of Ogden and Niles' frameworks as a fourth demand component that also characterises freight flows.

Therefore, the following four components characterise the demand side of urban freight flows: commodities (or product characteristics), land use (or city area features), business processes and agent needs. Because the latter three describe the characteristics of the urban agent and overlap, they will be grouped into a single category, urban agent characteristics. This categorisation is supported by the framework developed by Sjösted (1996) as a system oriented conceptual model to capture the complexity of transport. His framework identifies the following four basic elements determining how freight is transported, which correspond to the components defined above: goods, facilities, infrastructure and vehicles. The four subsystems in his framework (accessibility, land use, transport and traffic) are consequences of these basic elements and therefore not relevant to characterising urban freight flows. This model was refined by Behrends (2011) and Macharis, Milan & Verlinde (2013). Behrends, Lindholm & Woxenius (2008) extended the Sjösted model using the following four external factors influencing the urban freight system: legal and institutional, financial, political and cultural, and practical and technological. Some of these external factors not only influence the urban freight system but also characterise urban freight flows and should therefore form a fifth category. This aspect is supported by the Adapted Layer Model developed by van Binsbergen & Visser (1999). They also consider some external factors important when describing and evaluating urban freight initiatives: available resources, urban population, needs and demands and output and impact of urban freight flows. Furthermore, their three layer framework supports the idea that urban agent characteristics are a major influence of urban freight flows because the actors are placed in separate layers. Our final framework and classification of urban freight flows considers infrastructure and vehicles together in one category, transport characteristics, which produces the following four components characterising urban freight flows: (i) product characteristics; (ii) urban agent characteristics, (iii) external factors, and (iv) transport characteristics. The framework development is depicted in Figure 52.

Figure 52. Development of a framework to classify urban freight flows



Source: Own setup.

6.3 Literature Review

Many books, papers and research projects on urban freight measures and initiatives mention off-hour deliveries, explain the concept and list the theoretical positive and negative effects. The existing research focusing on off-hour deliveries mainly addresses three different issues. First, professional stakeholders are reluctant to engage in off-hour deliveries. This topic has been thoroughly examined by Holguín-Veras and his fellow researchers. Their aim is to determine how private stakeholders can be persuaded to change their habits and shift deliveries to off-hours, especially in New York City. Since 2005, these researchers have described the relationships among the various professional stakeholders by surveying these stakeholders on the governmental policies that might persuade them to shift deliveries, and they have modelled the impact of large-scale implementation of some of these government policies (Holguín-Veras et al., 2005; Holguín-Veras, Pérez, Cruz & Polimeni, 2006a; Holguín-Veras et al., 2006b; Holguín-Veras, Silas, Polimeni & Cruz, 2007; Holguín-Veras, 2008; Holguín-Veras, Silas, Polimeni & Cruz, 2008; Holguín-Veras, 2012; Holguín-Veras et al., 2013; Jaller & Holguín-Veras, 2013). Verlinde, Novikova, Macharis & Witlox (2009) assessed the attitudes of the different stakeholders towards night-time deliveries. A second issue explored is the noise nuisance experienced by residents during nightly loading and unloading operations. Since the early 2000s, retail chains have been especially interested in implementing off-hour deliveries to their supermarkets. However, in many European cities, retailers were unable to shift to off-hours because their equipment (both trucks and rolling stock) did not meet restrictive noise legislation requirements. This situation forced manufacturers and carriers to develop low noise equipment and solutions. To test these solutions and demonstrate the economic viability of off-hour deliveries, several pilot studies have been conducted (AGV, 2000; Brom, Holguín-Veras & Hodge, 2011; Dassen et al., 2008; Douglas, 2011; Holguín-Veras et al., 2011; Holguín-Veras, Marquis & Brom, 2012; Niche, 2006a; Niche, 2006b; Palmer & Piecyk, 2010; Senter Novem, 2008; Vlaamse Overheid MOW, Haven- en Waterbeleid, 2011). A third part of this body of literature builds on the results of these pilot studies and estimates the effects of large scale implementation of off-hour deliveries (e.g., Senter Novem, 2008; Holguín-Veras et al., 2011; Holguín-Veras, 2012; Holguín-Veras et al., 2012; Holguín-Veras et al., 2013).

Research on the specific types of freight flows that are suited to off-hour deliveries has not been conducted. However, the above studies of off-hour deliveries all consider this issue indirectly through the successful and

unsuccessful pilot projects that are described. For this literature review, 23 papers and research reports were selected. In each study, we searched for specific freight flow characteristics that are indicative of successful shifts to off-hours. We grouped these characteristics into our four categories as follows: (i) product characteristics, (ii) urban agent characteristics, (iii) external factors, and (iv) transport characteristics. Table 8 provides an overview of the papers we selected and the number of references we identified for each category. Some of these references are mentioned in multiple papers. Therefore, the numbers in Table 8 are not indicative of the importance of a particular type of characteristics. The remainder of this section provides additional analysis for the four categories.

Table 8. Studies consulted for the literature review

	Number of references identified				
	Product characteristics	Urban agent characteristics	External factors	Transport characteristics	Total
Mannering et al. (1993)	0	0	0	0	0
Dekker (1998)	3	14	0	1	18
AGV (2000)	0	3	0	1	4
Holguín-Veras et al. (2005)	2	5	0	7	14
Holguín-Veras (2006)	0	0	0	0	0
Holguín-Veras et al. (2006a)	2	17	6	4	29
Holguín-Veras et al. (2006b)	0	0	1	0	1
Niches (2006a)	0	0	2	0	2
Niches (2006b)	0	1	0	0	1
Holguín-Veras et al. (2007)	2	6	5	6	19
South London Freight Quality Partnership (2007)	1	2	1	1	5
Dassen et al. (2008)	2	7	5	9	23
Holguín-Veras (2008)	0	4	5	7	16
Holguín-Veras et al. (2008)	9	9	15	13	46
Senter Novem (2008)	1	8	2	3	14
Silas & Holguín-Veras (2009)	3	4	14	1	22
Delaitre (2010)	0	8	8	28	44
Palmer & Piecyk (2010)	0	0	0	0	0
Sathaye (2010)	0	0	0	0	0
Brom et al. (2011)	0	2	0	0	2
Holguín-Veras et al. (2011)	3	3	0	0	5
Douglas (2011)	0	11	6	6	23
Holguín-Veras et al. (2012)	0	5	0	0	5
Total	25	88	64	81	258

Source: Own setup.

6.3.1 Product Characteristics

Perishable goods are considered very well-suited to off-hour deliveries. In fact, in some cases, off-hour deliveries are inevitable due to the extremely short shelf life of the goods. For example, Holguín-Veras et al. (2005) refer to newspaper distribution and transportation of vegetables to consumer markets. When retailers prefer their merchandise to be on the shelf before the first customers arrive, perishables, which are usually delivered on a daily or very frequent basis, can only be delivered during off-hour. Thus, Holguín-Veras et al. (2006a) consider foodservice establishments to be good candidates for off-hour deliveries because the vast majority of their goods must be delivered fresh (meat, fish, bread, vegetables, etc.). Additionally, Dassen et al. (2008) and Dekker (1998) mention shelf life as a reason to consider off-hour deliveries. In the Netherlands, Senter Novem (2008) conducted a pilot study with three large retailers. At the time of the pilot study, off-hour deliveries were prohibited or severely

restricted throughout the Netherlands. These three retailers were allowed to provide off-hour deliveries at some of their shops on the condition that they would use 'silent' trucks and equipment. Remarkably, all three retailers preferred to shift their fresh deliveries to off-hours (but not their regular, non-air-conditioned deliveries).

In addition to shelf life, three other product characteristics are mentioned. First, Dekker (1998) argues that valuable goods should not be transported during off-hours because the risk of theft increases at night. Furthermore, Dekker (1998) mentions that goods that require exceptional transport and do not necessarily require proof of delivery are suitable for off-hour deliveries.

Holguín-Veras and his fellow researchers reveal that the industry segment also influences the attitude of both receivers and carriers towards participating in off-hour deliveries. Silas & Holguín-Veras (2009) argue that industry segments may vary in receptiveness to off-hour deliveries for several reasons (e.g., operational practices, economic reasons). Their research indicates that receivers of food, alcohol, wood/lumber, metal, paper products, and medical supplies are particularly inclined to participate in off-hour deliveries in exchange for tax deductions. Holguín-Veras et al. (2011) argue that the best candidates for off-hour deliveries are the food and consumer goods sectors based on the number of deliveries generated and the inclination of each industry segment to participate in off-hour deliveries. This argument was supported by the companies that were willing to participate in their pilot study.

6.3.2 Urban agent characteristics

The urban agents involved in urban freight transport are the senders and receivers located in urban areas. In the literature on off-hour deliveries, most attention is paid to the receivers. They tend not to accept off-hour deliveries because it increases their operational costs and/or calls for security investments (Vilain & Wolfrom, 2001). Holguín-Veras et al. (2005) argue that they incur increased operational costs from (i) facility operations, (ii) overtime wages, and (iii) night-time differentials paid to employees. The degree to which a receiver can keep these costs to a minimum highly influences whether or not he is ready to accept off-hour deliveries.

Many receivers want deliveries to be processed by their staff members, which is considerably more expensive at night (Holguín-Veras, 2006). Therefore, Dekker (1998) argues that larger companies are better suited to off-hour deliveries because extra fixed costs can be distributed over many deliveries. This argument is supported by the South London Freight Quality Partnership (2007) and Holguín-Veras et al. (2007), which also argue that mid-size and large businesses are suitable targets for off-hour deliveries and that companies that already receive off-hour deliveries receive twice as many deliveries than companies receiving deliveries during regular hours do. This is also confirmed by Douglas (2011) as all companies willing to participate in the 'Quiet Deliveries Demonstration' scheme were large retailers. Holguín-Veras et al. (2008) argue that facilities that house a significant number of businesses, such as government offices, large academic centres, shopping centres, etc. are good targets for off-hour deliveries. Holguín-Veras et al. (2011) call these facilities Large Traffic Generators (LTGs) and estimate that they generate approximately 4-8% of the total freight deliveries in Manhattan. These LTGs tend to have their own centralised delivery stations, which allow them to receive off-hour deliveries and then distribute the cargo to the consignees during regular hours without inconveniencing the actual receivers. Receivers who are open at night are able to accept off-hour deliveries without increasing labour costs. That is a second reason why Holguín-Veras et al. (2006a) argue that foodservice establishments are good candidates for increasing off-hour deliveries. Their survey of 68 New York restaurant owners reveals that being open at night is one of the main factors increasing receiver willingness to accept off-hour deliveries.

If staffed deliveries are prohibitively expensive, unstaffed deliveries are also an option. To ensure the security of the delivered goods (and of the other goods on the receiver premises), a secure drop-off location is needed, such as a drop box, locker, trunk of a car or a van, sealed container or trailer, separate room at the receiver premises or nearby (Dekker, 1998; Holguín-Veras et al., 2005; Holguín-Veras et al., 2012). However, if providing a secured place implies additional receiver investment, it will be difficult to accept off-hour deliveries. Senter Novem (2008) also observes that receivers are less willing to participate in off-hour deliveries if they must modify their loading and unloading infrastructure. Legal liability is a second issue with unstaffed deliveries, that is, whether ownership transfers when the goods are stored at the secured place (Dekker, 1998).

The location of the receiver also influences the effect of off-hour deliveries on costs. A receiver located in a commercial area will be more receptive to off-hour deliveries (Holguín-Veras et al., 2006a; Silas et al., 2009). The

marginal transport cost is low because the carrier can deliver to several receivers. Furthermore, the geographic location of receivers and carriers dictates the logistics operations and delivery routes of carriers and ultimately of delivery costs. Carriers are more likely to conduct off-hour deliveries if their base is relatively close to their first delivery stop because the additional cost associated with traveling to the service area is relatively small. Overall, the analysis conducted by Silas et al. (2009) suggests that carriers located close to congested urban areas should be targeted for off-hour delivery programs. Other locational factors also play a role. First, time gains of 50% or more can be obtained in larger cities, while the gain is smaller in less congested areas (Dassen et al., 2008). Second, the number of local residents who might experience noise nuisance from off-hour deliveries also impacts the successful shift to off-hour deliveries (Dassen et al., 2008). Not only distance plays a role, but also the amount of ambient noise at night (Douglas, 2011). According to Delaitre (2010), quiet equipment is 10% more expensive. Finally, carriers can reduce or eliminate parking fines by providing off-hour deliveries in areas that suffer from high parking pressure and where parking regulation is severely enforced (Holguín-Veras et al., 2006a).

In addition to these cost factors, behavioural modelling of two policy scenarios (i.e., government subsidies to restaurants accepting off-hour deliveries and tax deductions for an employee processing off-hour deliveries) reveals that the propensity to accept off-hour deliveries increases with the number of deliveries on Thursdays and Fridays and with the size of the tax deduction provided, while the propensity decreases with the number of deliveries during the week (Holguín-Veras et al., 2006a).

6.3.3 Transport characteristics

Although the receiver is the final addressee for a delivery, transportation is usually paid for by the sender, which explains why receivers are not motivated to change their habits to accept off-hour deliveries, that is, because they do not directly benefit from lower transportation costs. Furthermore, senders do not insist on off-hour deliveries. Senders desire to please their customers to retain their competitiveness. It is difficult to implement off-hour deliveries in a typical logistics chain because overall gains are produced but not all parties in the logistics chain benefit equally.

There are also deviant logistics chains in which the three parties are not independent but integrated to some extent. First, in some cases, transport is not provided by a for-hire carrier but by a private carrier. As argued by Holguín-Veras (2009), this form of integration yields economies of scale because the sender/carrier can extract the maximum benefits of off-hour deliveries by switching all or none of the operations to off-hour deliveries. In a second variant, transport occurs between a sender and receiver that are part of the same company. This system also facilitates off-hour deliveries because the sender can force the carrier to decrease transportation costs to compensate for the increased costs experienced as a receiver. In an ideal situation from the off-hour deliveries viewpoint, the three parties are completely integrated. In that case, transport is provided by a carrier that belongs to the same parent company as the sender and receiver. Holguín-Veras (2009) argues that not only economies of scale play a role but also, and more importantly, that the overall benefits can be internalised, which enables cross-subsidisation among carrier, sender and receiver operations. Only one decision maker decides what is best for the entire operation. Holguín-Veras (2009) refers to several retail chains when stating that this is also the reason why most companies that have implemented off-hour delivery operations have private carrier operations. This pattern is confirmed by European pilot studies and tests, which were mostly created by supermarket chains (Delaitre, 2010; Niches, 2006a; Niches, 2006b; Senter Novem, 2008; South London Freight Quality Partnership, 2007, Douglas, 2011). In all of these cases, the sender and receiver are part of the same company and the carrier is a private carrier or offers a competitive price because of strong market competition and large volume at stake.

Volume is a second transport characteristic to consider. In supermarket deliveries, daily volumes are large, which allows trucking companies to consolidate off-hour deliveries, increase truck utilisation, and achieve financially sound operations (Holguín-Veras et al., 2008). Furthermore, sufficient demand for off-hour deliveries allows a transport company to shift work, staff and equipment efficiently (Senter Novem, 2008). The large daily volumes also allow a minimal number of stops during a delivery trip. This system is efficient because only a few receivers must change their operations or infrastructure to fill a complete night shift. A third aspect is the structure of the carrier's customer base. If they have a wide customer base that is also spread over different sectors of the economy, they are less likely to participate in off-hour deliveries because of the coordination challenge (Holguín-Veras et al., 2005). A fourth element is the fleet (or potential fleet) of the carrier. If a delivery can be conducted using silent vehicles or equipment,

it can be much more easily shifted to off-hours (Delaitre, 2010). Finally, the severity of local union regulation of drivers also plays a role (Dekker, 1998; Holguín-Veras et al., 2005).

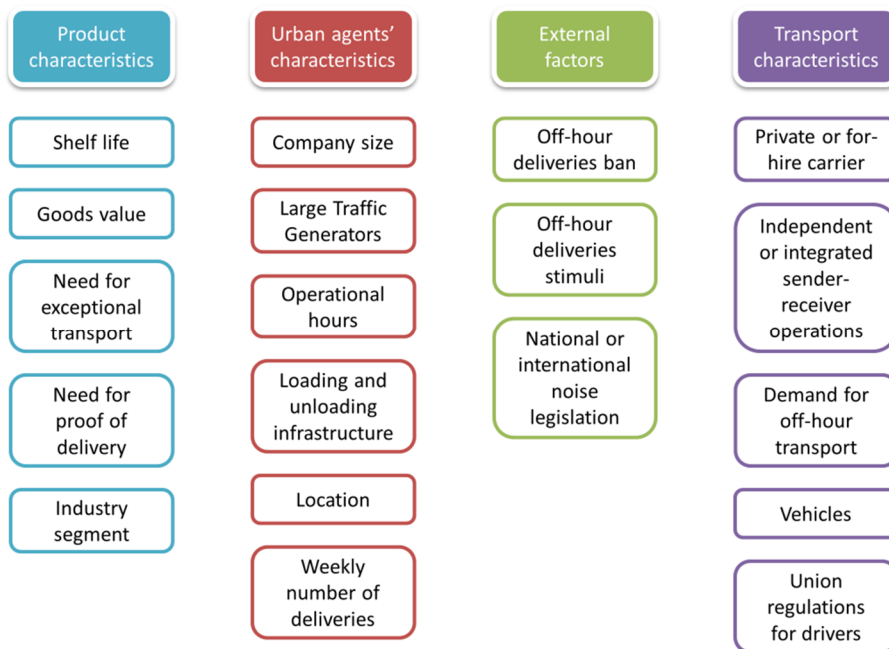
6.3.4 External factors

Factors external to the logistics chain also influence the potential to shift deliveries to off-hours. Most of these factors are policy-related and can be divided into the following two groups: policy measures stimulating off-hour deliveries and policy measures banning them. The most obvious stimulus is a ban on peak-deliveries. For example, in Dublin, large heavy goods vehicles are banned from entering a region of the city centre between 7 am and 7 pm (Niches, 2006a). In London, different rules apply depending on the location of the receiver's premises (Douglas, 2011). Regulation banning day deliveries to Los Angeles was considered; however, following formidable opposition from the business sector, the plan was abandoned (Holguín-Veras et al., 2007). The greatest regulatory forcing of off-hour deliveries is likely in Beijing, China, where the government has mandated that all deliveries be made during off-peak hours (Holguín-Veras et al., 2007).

A less invasive approach is to provide economic incentives aimed at both carriers and receivers. Holguín-Veras et al. (2007 and 2008) modelled the impact of three different policies: a tax deduction provided to receivers in exchange for their commitment to accept off-hour deliveries, time of day tolls with a surcharge for regular hour deliveries that target the carriers and financial rewards, that is, government subsidies, for off-hour travels targeting carriers. The models indicated that there are no significant changes in market share for off-hour deliveries as the toll increases (Holguín-Veras et al., 2007). However, off-hour participation increases with the amount of tax deduction (Holguín-Veras et al., 2008). The analysis also revealed that carrier participation in off-hour deliveries increases with financial rewards (Silas & Holguín-Veras, 2009). Note that not all industry segments react to these policies in the same way. For example, toll differentials statistically significantly affect carriers transporting specific commodities, i.e., food, textiles/clothing, wood/lumber and petroleum (Holguín-Veras et al., 2008). According to Silas & Holguín-Veras (2009), another financial incentive could be imposing additional parking fines on illegally parked carriers. In the Netherlands, a particular type of subsidy scheme was tested. At the end of 1998, the renewed "Decree Retail Trade Environmental Protection" came into force (Dassen et al., 2008). The decree stipulated that the noise emissions generated from loading and unloading goods between 7 pm and 7 am must comply with strict peak noise standards. Given the equipment (both trucks and rolling stock) that was used at that time, businesses could not comply with these strict standards which forced manufacturers to develop innovative concepts and technologies. The Dutch government supported the manufacturers through a long-term subsidy scheme, the Piek-programme. The tests that were executed within the framework of this programme indicated that it is possible to conduct off-hour deliveries without causing noise nuisance to local residents. However, whether the programme actually increased off-hour deliveries was not monitored.

A summary of the findings of this literature review is illustrated in Figure 53.

Figure 53. Summary of the findings of the literature review



Source: Own setup.

6.4 The Flemish Case

The literature on off-hour deliveries can provide some insight into why urban freight flows can or cannot be successfully shifted to off-hours. However, most of this knowledge is based on surveys, models or pilot projects that were initiated as part of studies or governmental subsidy schemes. The literature ignores the many urban deliveries that are already conducted during off-hours. These off-hour deliveries are provided by the managers of private companies striving to maximise their profits. Analysing these profitable flows and the motivation of their initiators and executors would considerably increase our knowledge of this topic. This paper compares the results of a literature review with the real experiences of senders, carriers and receivers already engaged in off-hour deliveries in urban settings. We interviewed the general or logistics managers of 41 companies that are part of different types of supply chains (partly) active during off-hours. The interviews mainly address the Belgian or Benelux departments of multinationals and large Belgian companies. Together, the 41 companies had an annual turnover of nearly € 12 billion in 2012. Table 9 provides an overview of these supply chains and of the type of companies that were interviewed. If possible, we interviewed the sender, carrier and receiver. Because of this diversity, the interviews were semi-structured with feedback loops. We asked the interviewees about the core operations of their company, their role in urban off-hour supply chains and their experiences with off-hour deliveries (the advantages, disadvantages and stumbling blocks). Then, we transcribed each interview and compared what was said to the results of the literature review (summarised in Figure 53). Because the interviews did not follow a rigid structure and were not transcribed immediately afterwards, the number of times a particular indicator was mentioned does not mean anything. The interviewees were not directly asked for their opinion on each indicator. Some respondents might not have mentioned a factor even if it plays a role. However, the interviews revealed new indicators that we did not identify in the literature review. Section 6.5 compares the literature review and the interviews.

Table 9. Overview of the types of supply chains in which the interviewees worked

Retail	Manufacturer	7
	Logistics service provider	4
Dealer networks	Retailer	4
	Logistics service provider	5
Wholesale	Brand specific parts logistics centre	2
	Manufacturer	2
Linen deliveries to hospitals	Logistics service provider	1
	Manufacturer	3
Spare part deliveries to technicians or mechanics	Logistics service provider	3
	Service provider	1
Service depot deliveries	Logistics service provider	1
	Press distributor	1
Press distribution	Logistics service provider	2
	Service provider	2
Document and parcel deliveries	Logistics service provider	4
	Security service provider	1
Other	Distributor	1
	Manufacturer	1
	Logistics service provider	2

Source: Own setup.

6.5 Results and Analysis

6.5.1 Product characteristics

The product characteristic mentioned most often by the interviewees was proof of delivery. Products requiring proof of delivery are not unsuited for off-hour deliveries but many respondents spontaneously noted that this is an important aspect to be addressed. For inbound flows, a retailer does not want unstaffed deliveries because it is essential for his operations to verify that deliveries are complete and undamaged and to sign the delivery note when the goods are delivered. Note, however, that a retail chain usually has enough incoming volume to pay the night staff to receive these deliveries. For other receivers, this is not the case; however, this does not prevent them from receiving deliveries during off-hours when no staff members are present. In most cases, the goods are scanned by the driver to provide proof of delivery and reviewed by the receiver the next morning. Multiple interviewees indicated that this is not a watertight system and that their off-hour deliveries are mainly based on trust. One carrier mentioned that his drivers take pictures as evidence that they left the goods in good condition at the client's premises. In a few other cases, there is no proof of delivery.

The second product characteristic that was mentioned by several interviewees is the risk of theft. The fear is not that the driver will steal goods but that delivering high value goods at night might increase the chance that the transport vehicle is robbed. Nevertheless, current off-hour freight flows also involve high value goods. When asked, most interviewees said that theft has not been a problem; however, a few use anonymous trucks, vans and/or boxes when delivering in theft-sensitive areas.

None of the interviewees referred to the perishability of the goods as a factor in favour of off-hour deliveries. Nevertheless, for press distribution and fresh food deliveries, for example, this directly affects goods delivered during the night or early mornings. For the other supply chains in this study, perishability as such does not affect deliveries; however, all receivers experience some time advantage by receiving during off-hours, which is closely related to perishability. For example, when a car mechanic receives spare parts to repair a clients' car the night after he ordered them, he can provide better service.

The 8 manager interviews do not allow us to distinguish among industry segments that might be better suited to off-hour deliveries than other segments are. Our interviewees work in a wide range of industry segments, and their answers suggest that it is not the industry segment as such determining which freight flows can be shifted to off-hours.

Finally, the fifth product characteristic, namely, the need for exceptional transport, was not mentioned by any interviewee. However, no interviewees were involved in this type of transport. The interviews do not allow us to comment on this indicator. The interviewees did not refer to additional product characteristics.

6.5.2 Urban agent characteristics

Of the six urban agent characteristics identified in the literature, the interviewees only mentioned the location of the urban agent as a decisive factor in whether to participate in off-hour deliveries and clearly emphasised noise nuisance. Several respondents indicated that drop-off locations in residential areas should be avoided. However, the vans of technicians or mechanics functioning as off-hour drop-off locations or newspaper shops, for example, are nearly always parked or located in residential areas while none of the carriers delivering them uses noise adapted vehicles or rolling stock. Furthermore, compared to the findings in the research on location, none of the carriers indicated that the distance to, from or between urban receivers influences willingness to provide off-hour deliveries.

The other five urban agent characteristics identified in the literature were not specifically mentioned by the interviewees. A closer examination of the off-hour volumes turned over by these eight supply chains suggests that company size plays a role. The retail chain manager said he does not deploy employees at night if it is not guaranteed that the incoming volume can cover the extra wage costs. In the seven other cases, the volumes delivered at the individual drop-off points are rather small. However, the transport for all of these deliveries is commissioned by the senders and not by the individual receivers. These senders have a considerable volume of goods to distribute and are not small players in their industry segment. This situation might also explain why the distance from, to and between receivers does not influence the willingness of the carriers to provide off-hour deliveries because the volume they must transport on behalf of one particular sender is large enough. Additionally, although receiver volumes might be low in some cases, the frequency of deliveries is high for all eight supply chains, which suggests that the number of weekly deliveries also plays a role.

Whether a suitable (un)loading infrastructure is already in place at the premises of the urban receiver seems to play a smaller role. At nearly all drop-off locations, specific measures had to be taken after it was decided to shift deliveries to off-hours. These measures varied from identifying a suitable place to leave the deliveries (vans, locker boxes, warehouse, shop, etc.) to determining how to allow access to the driver. Most of these measures involved additional investments, which might explain why in most supply chains the sender and receiver are part of the same company. The previous research suggests that this aspect is a decisive transport characteristic and is addressed in Section 6.5.3.

Nearly all of the receivers in this study were not open during off-hour deliveries, except the supermarket chain depot. The supermarket opened during off-hours after it decided to shift to off-hour deliveries. This order contradicts the idea that receivers that are already open during off-hours are more inclined towards off-hour deliveries. Finally, we did not identify a Belgian example of a Large Traffic Generator accepting off-hour deliveries.

6.5.3 Transport characteristics

The literature revealed five transport characteristics that are important for the success of urban off-hour deliveries. Based on the interviews, however, these characteristics are less important. Not one transport characteristic was mentioned by the interviewees. However, when examining their company operations, it is clear that at least some of these characteristics are relevant. First, the literature states that off-hour deliveries are easier when the sender, carrier and/or receiver are not completely independent but, at least to some extent, integrated. This argument is confirmed by our small sample of types of supply chains. In six of eight supply chains, the senders and receivers are part of the same parent company. As previously mentioned under the urban agent characteristics, this relationship allows firms to support their receivers when investments are needed to make off-hour deliveries possible. Another form of integration occurs when the transport is conducted by a carrier part of or related to the company sending the goods. In the literature, when this was the case, there are considerable economies of scale because the sender/carrier can decide to switch all or none of the operations to off-hours. In our examples, however, only for-hire carriers are

present. Of course, this does not imply that having a private carrier does not make it easier or more profitable to shift deliveries to off-hours, but it does imply that using for-hire carriers is not necessarily a stumbling block.

Additionally, six of eight supply chains in this study involve delivery routes with multiple stops and low drop-off volumes. Each round, however, is driven on a daily basis or on a regular scheme (each time with the same stops). Furthermore, as also mentioned in Section 6.5.2, the volumes of the senders in our examples are sufficiently large that carriers need at least one off-hour shift to provide these deliveries, which means that combining the cargo of multiple clients is unnecessary.

In Belgium, a driver must be paid a higher wage when working a night shift. This rule severely influences the cost-efficiency of off-hour deliveries. However, higher pay also motivates drivers to work night shifts. The carriers that were interviewed said that it is not difficult to find drivers who are willing to work a late, night or early morning shift because of the higher wage and because being on the road during off-hours is less stressful. Finally, although there are strict noise regulations in some Belgian cities, none of the carriers use silent vehicles or equipment.

6.5.4 External factors

Multiple interviewees considered the delivery time windows set by local authorities to be stumbling blocks to off-hour deliveries. In some cities, freight traffic is banned at certain times of the day, usually at night. Time windows are uncommon in Belgium but local governments can implement them as they see fit. The interviewees refer to some cases where local governments introduced time windows after noise nuisance complaints by residents. Not mentioned as a stumbling block is the noise legislation. This omission does not imply that such regulations are not stumbling blocks. Companies must apply for environmental permits which in some cases also incorporate noise. On the other hand, many delivery operations take place on the street and are therefore subject to noise rules. None of the interviewees mentioned stimulating measures.

6.6 Conclusions

Urban freight flows with limited shelf lives and low value destined for a receiver located in a non-residential area and originating from a large sender who is preferably in a close relationship with the receiver and/or carrier are well suited to be shifted to off-hour delivery. This can be concluded based on a literature review of scientific papers on off-hour deliveries and on interviews with the general managers or logistics managers of 41 companies that already do urban off-hour deliveries (senders, receivers and carriers).

Taking the urban freight flow and its characteristics as the starting point of an analysis of potential off-hour deliveries required a new framework to systematically describe and classify these flows. Based on existing and generally accepted evaluation frameworks for urban freight initiatives, we distinguished four types of freight flow characteristics: (i) product characteristics, (ii) urban agent characteristics, (iii) external factors, and (iv) transport characteristics. The factors identified in existing research and interviews could be easily assigned to one of these categories which demonstrates the relevance and completeness of this classification.

Previous research revealed 19 indicators of successful freight flow shifts to off-hours. A limited shelf life, for example, is frequently mentioned as a product characteristic influencing the decision to provide deliveries during off-hours because it saves valuable time. The following four product characteristics are also mentioned: the value of the goods, need for proof of delivery, need for exceptional transport and industry segment. For the urban agent characteristics, we found that receivers are afraid of having to make additional investments to be able to receive off-hour deliveries. Therefore, the existing (un)loading infrastructure, company size and operational hours play a role in the decision to shift deliveries. The following two indicators are also mentioned: the location and number of deliveries per week. The transport characteristics influencing the suitability of shifting an urban freight flow to off-hours are linked to the relationships among senders, receivers and carriers. Usually, receivers and carriers are not contractually bound, which hampers off-hour deliveries. Any situation in which there is a closer relationship between receivers and carriers is favourable to off-hour deliveries, e.g., a private carrier and integrated sender-receiver operations. The demand for off-hour deliveries by receivers, carrier fleet and union regulations also influence the suitability of off-hour deliveries. Finally, there are also factors outside the logistics chain that influence shifting deliveries to off-peak hours. These factors are usually policy related, such as the following three examples: stimulating measures, banning measures and noise legislation.

Not all 19 indicators identified in the literature were confirmed during the semi-structured interviews with the 41 general and logistics managers, who only mentioned three of the indicators. Many of the interviewees consider the need for proof of delivery important when conducting off-hour deliveries. The second indicator they refer to is the value of the goods because they perceive an increased risk of robbery at night. Finally, the location of the receiver is considered important, albeit with a clear focus on the noise nuisance the deliveries might cause. Other indicators were not explicitly mentioned by the interviewees but were described when they explained their roles in the supply chain and experiences with off-hour deliveries, such as company size, shelf life, relationships among senders and private or for-hire carriers and receivers. Finally, indicators, such as operational hours, loading and unloading infrastructure and vehicles were not mentioned because they are less important than was assumed in previous research.

In general, the case study suggests that not all assumed indicators of successful freight flow shifts to off-hours are equally relevant. Despite the fact that the geographical coverage of the case study is limited to a single region, the findings of this paper contribute to the current debate on how to foster off-hour deliveries. First, because the 41 companies are local firms part of international supply chains or local branches of multinational businesses. Second, because the combination of a freight flow perspective and an analysis of existing off-hour deliveries is new in the body of knowledge on the topic. The findings in this paper call for two interesting extensions: a more detailed study of the worldwide urban freight flows that already shifted to the off-hours and a quantitative analysis of the importance of each indicator in the decision to shift to off-hour deliveries. Both will provide policy makers and companies with better insights on how to increase off-hour deliveries.

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7

Who is in favour of off-hour deliveries to Brussels supermarkets? The Multi Actor Multi Criteria analysis (MAMCA) applied to measure overall stakeholder support¹¹

7.1 Introduction

A random journey along major motorways and primary roads in European metropolitan areas during peak driving hours takes an average 14.1% longer than the same journey would take in uncongested conditions (<http://scorecard.inrix.com>). European freight transport is expected to increase by 39% by 2030 (compared with 2006) and passenger transport by 16% (Schade & Krail, 2010), so time losses due to congestion will continue to rise. Off-hour deliveries are widely considered capable of absorbing some of the traffic network congestion at peak hours (Browne, Allen, Anderson & Woodburn, 2006; Holguín-Veras, Polimeni, Cruz, Xu, List, Nordstrom & Haddock, 2005). Today, the proportion of off-hour deliveries is rather low. Allen, Browne, Cherrett & McLeod (2008) reviewed 30 United Kingdom urban freight studies and concluded that, on average, 4% of deliveries in British cities were conducted during the evening, night or early morning (between 7 pm and 6 am), a trend which is confirmed by Schoemaker, Allen, Huschebeck & Monigl (2006), Dominguez, Holguín-Veras, Ibeas & dell'Olio (2012) and Holguín-Veras, Silas, Polimeni & Cruz (2007).

¹¹ Verlinde, S., Macharis, C. (2015). Who is in favour of off-hour deliveries to Brussels supermarkets? The Multi Actor Multi Criteria analysis (MAMCA) applied to measure overall stakeholder support. Manuscript submitted for the *9th International Conference on City Logistics*, 17-19 June 2015, Tenerife, Canary Islands.

Existing research on off-hour deliveries reveals that shifting more urban deliveries to off-hours has positive and/or negative impacts for different stakeholders. Freight carriers, for example, would be able to reduce their costs because of time and fuel gains, and they would avoid parking fines (Holguín-Veras, Silas, Polimeni & Cruz, 2008; www.niches-transport.org). Holguín-Veras et al. (2005), on the other hand, demonstrated that receivers are the key decision makers concerning delivery times, and they oppose off-hour deliveries because of the extra costs that they would incur. The average citizen would experience safer traffic, cleaner air and more fluid traffic during peak hours (www.niches-transport.org). However, there is also a concern that off-hour deliveries might disturb the sleep of people living close to the receiver's premises (Douglas, 2011). Together, these observations make it difficult to assess whether it is preferable, in a given situation, to shift deliveries to off-hours.

Multiple trials and pilot programs have aimed to demonstrate that it is at least possible to shift deliveries to off-hours. Following the Dutch PIEK project, many European pilot tests focused on the noise nuisance aspect (SenterNovem, 2008; www.niches-transport.org; Vlaamse Overheid, MOW, Haven- en Waterbeleid, 2011; Douglas, 2011). The focus of pilot programs in New York was economic feasibility (Holguín-Veras, Marquis & Brom, 2012). Despite the great contribution of these programs in quantifying some of the impacts of urban off-hour deliveries, their evaluations still do not provide decisive answers regarding whether to shift to off-hours deliveries because not all of the impacts are usually evaluated, and the pros and cons for different stakeholders are not weighed against each other. To measure support for a shift to off-hour deliveries, pilot programs and trials must be evaluated from the perspective of all stakeholders (Ystmark, Bjorgen & Elvsaa, 2014).

This paper presents Multi Actor Multi Criteria Analysis (MAMCA) (Macharis, 2005) as the appropriate tool for measuring support for urban off-hour deliveries. MAMCA is an extension of the widely used Multi-Criteria Analysis (MCA), and it explicitly includes the goals and objectives of all stakeholders when evaluating a set of alternatives. Section 7.2 further explains the MAMCA methodology. We applied MAMCA to a pilot program that took place in 2014 in Brussels. In Section 7.3, we provide the background to the program. In Section 7.4, we describe how the different steps of MAMCA were applied to the program. Finally, conclusions and possibilities for future research are presented in Section 7.5.

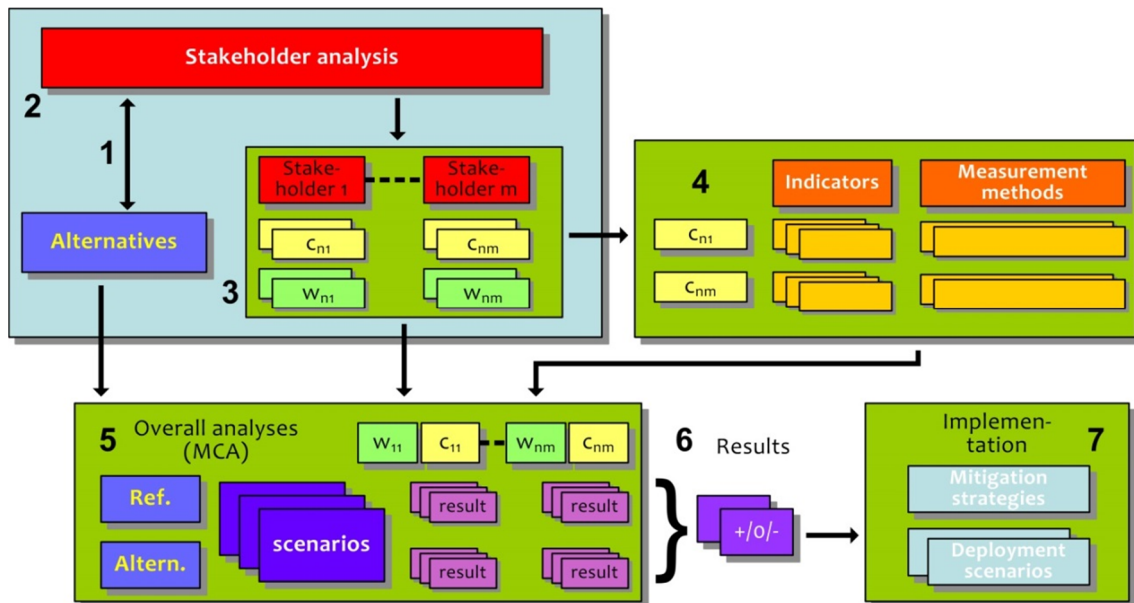
7.2 Multi Actor Multi Criteria Analysis

In this paper, we use Multi Actor Multi Criteria Analysis (MAMCA) to evaluate a shift to off-hour deliveries. This methodology is an extension of the traditional Multi-Criteria Decision Analysis (MCDA) (Fandel and Spronk, 1985; Guitoni and Martel, 1998). MAMCA allows the evaluation of different alternatives (policy measures, business concepts, scenarios, technologies, etc.) by explicitly accounting for the objectives of the stakeholders who are involved in the decision-making process. MAMCA develops a separate value tree for each stakeholder instead of only one value tree for all stakeholders (MCDA). The methodology was developed by Macharis (Macharis 2000, 2005 and 2007) and has been used for many applications, particularly transport-related decision-making problems (for an overview, see Macharis, De Witte and Ampe, 2009).

MAMCA consists of two main phases (Macharis, 2005). The first phase is mainly analytical and gathers all of the information needed to perform the analysis. The second phase is the synthetic or exploitation phase and consists of the actual analysis. These two phases are split into four and three steps, respectively (Macharis et al., 2009), which are depicted in Figure 54. The first step involves defining the problem and determining which alternatives will be evaluated. The second step is a stakeholder analysis to determine all of the relevant stakeholders as well as their objectives. In the third step, the objectives are translated into criteria, and each criterion is given a weight that reflects how important the objective is to the stakeholder. The fourth step links one or more measurable indicators to each criterion. In the fifth step, these indicators, which can be quantitative or qualitative, are used to evaluate the different criteria alternatives. A specific alternative's score on a specific criterion and the weight the stakeholder attributes to that criterion are then aggregated into an evaluation table. Once the table is filled in, any MCDA method can be used to assess the different strategic alternatives (such as AHP, PROMETHEE, MAVI, ELECTRE, MACBETH, etc.) The multi-criteria analysis (MCA) developed in step 5 eventually leads to a classification of the proposed alternatives. More important than the ranking, the MCA reveals the critical stakeholders and their criteria. MAMCA provides a comparison of the different strategic alternatives and provides support for the decision-maker in his final decision by determining which elements have a clearly positive or a clearly negative impact on the sustainability of the considered

alternatives for each stakeholder. The final step of MAMCA translates the results of the analysis into policy recommendations, mitigation strategies and deployment scenarios.

Figure 54. Multi Actor Multi Criteria Analysis (MAMCA)



Source: Macharis, 2007.

7.3 Pilot

In early 2014, for a period of two weeks, the largest Belgian food retailer, which operates 14 supermarkets in the Brussels-Capital Region, shifted at least one of its daily delivery trips to two selected shops to off-hours. Trying to shift a part of its deliveries to off-hours fits the sustainable entrepreneurship vision of the retailer because its management believes that such a shift will decrease costs and at the same time increase traffic safety and decrease the emission of pollutants. In the Brussels-Capital Region, however, retail shops are included on a list of 'regulated installations', which means that they can only be operated with an environmental permit. This permit dictates when deliveries and pick-ups are allowed, and most retail shops in the Region are not allowed to receive deliveries at night. The permits usually state that deliveries should end at 9 pm or 10 pm, and they cannot begin before 6 am or 7 am. For night deliveries to become a common practice, all of the environmental permits would have to be changed, or the legislation implementing them would have to be changed. However, local authorities are not inclined to change the environmental permits or the legislation in general without guaranteeing that local residents are not disturbed.

To facilitate the pilot program, the Environmental Agency of the Brussels-Capital Region decided to allow a temporary exemption to the rules for a period of one week. The exemption led to a two-part trial. During the first week, from Monday to Friday, at least one early morning delivery (between 6 am and 8 am) and at least one late evening delivery (between 8 pm and 10 pm) was carried out. In a normal week, there is usually only one early morning or late evening delivery. During the second pilot week, from Monday to Friday, one of the deliveries that usually take place during the day (between 8 am and 8 pm) was shifted to night (between 10 pm and 6 am). On Saturday, there was at least one early morning delivery during the first week and at least one night time delivery during the second week. On a normal weekday, a shop receives 4 to 5 deliveries per day. The participating retailer took several measures to minimise the noise nuisance for local residents. One shop uses an indoor delivery area, while another uses a covered unloading quay. The quietest diesel trucks were used (Euro 6) as well as quiet trailers with more rubber and fewer steel components. Each shop was also equipped with a silent hand pallet truck, and each driver was provided special training on silent deliveries. The operations at the distribution centre and in the shops did not have to be changed; only the actual transport and the loading and unloading procedure were changed. The retailer already provided night deliveries in other (less densely populated) parts of Belgium and therefore did not need much time to change its operations. The retailer preferred not to communicate in detail about the night delivery pilot program based on previous experiences with night deliveries in other parts of the country because the

management did not want the people living next to the shops to focus on the possible noise impact. The retailer believed that such a focus would influence the number of noise complaints. By request of the Brussels-Capital Region, the retailer agreed to let the communes decide whether dedicated communication was required. As a result, for one shop, flyers made by the administration of the Brussels-Capital Region were placed in the letterboxes of local residents; in the other shop, flyers made by the retailer were distributed at the cash register).

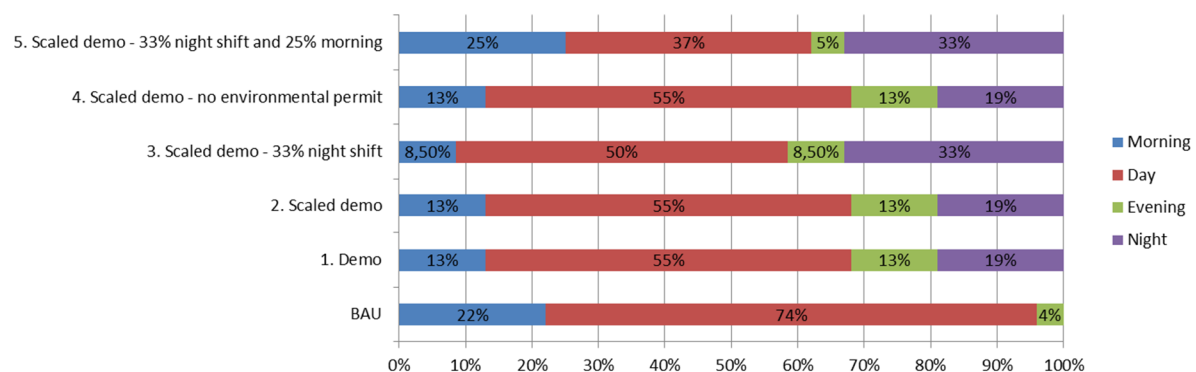
7.4 MAMCA for the Brussels pilot on off-hour deliveries

7.4.1 Step 1: Defining the problem and the alternatives

The first step in the methodology consists of identifying the different alternatives to evaluate. Because the evaluation is based on the outcome of an actual pilot program, our first two scenarios are the pilot itself and the 'business as usual' scenario. Both scenarios cover all deliveries to two shops for a period of two weeks. Four other scenarios were then added, and all of the scenarios simulate that the tested solution would be scaled to the participating retailer's other shops in the Brussels-Capital Region. One scenario simulates that deliveries are equally spread over 24 hours, which would be the preference of the participating retailer and which was not the case during the pilot. Scenario 4 simulates a legislation change whereby retailers would no longer have to apply for a new environmental permit. The final scenario does not simulate an equal spread of the deliveries, but that some of the day and evening deliveries would be shifted to the early mornings. The different scenarios are listed below and shown in Figure 55.

- BAU: 'Business-as-usual' - Normal deliveries to the two shops (74% DD, 4% ED, 22% MD and 0% ND); Euro 5 and Euro 6 vehicles are used.
- Scenario 1 (S1): 'Pilot' - Some of the deliveries to the two shops are shifted to night hours (55% DD, 13% ED, 13% MD and 19% ND); a combination of Euro 6 and CNG are used.
- Scenario (S2): 'Scaled pilot' - Deliveries to 14 shops in Brussels (55% DD, 13% ED, 13% MD and 19% ND); Euro 6 vehicles are used.
- Scenario 3 (S3): 'Scaled pilot – 33% night shift' - Deliveries to 14 shops in Brussels; deliveries are evenly spread over 24 hours (50% DD, 8.5% ED, 8.5% MD and 33% ND); Euro 6 vehicles are used.
- Scenario 4 (S4): 'Scaled pilot – no environmental permit' - Same as S2 but the legislation has been changed so there is no individual adaptation of the environmental permits needed (55% DD, 13% ED, 13% MD and 19% ND); Euro 6 vehicles are used.
- Scenario 5 (S5): 'Scaled pilot – 33% night shift and 25% morning' - Deliveries to 14 shops in Brussels; the majority of the deliveries are carried out during the night and early mornings (37% DD, 5% ED, 25% MD and 33% ND); Euro 6 vehicles are used.

Figure 55. Distribution of the proportion of morning (6am-8am), day (8am-8pm), evening (8pm-10pm) and night (10pm-6am) deliveries in the six MAMCA scenarios



Source: Own setup.

7.4.2 Step 2: Stakeholder analysis

Stakeholders are any group of people, organised or not organised, who share an interest or stake in a particular issue or system (Macharis, Turckin & Lebeau, 2012). The body of literature on urban freight transport and urban distribution leads us to distinguish five main stakeholders for urban freight distribution: Senders, Receivers, LSPs,

(local) Authorities and Citizens. One of the first comprehensive analyses of urban goods movements was conducted by Ogden (1992). He identified three main stakeholders with an active role in urban freight transport: receivers, carriers and forwarders. Other authors addressing the topic of urban freight stakeholders also distinguish among these three stakeholders, although some of them do not consider forwarders/senders and receivers to be separate stakeholders (Taylor, 2005; Witlox, 2006; Quak, 2008; Behrends; 2011). The importance of involving policy makers, decision-makers and local authorities has been recognised in more recent research (Taylor, 2005; Munuzuri, Larraneta, Onieva & Cortes, 2005; Witlox, 2006; Quak, 2008; Behrends, 2011; Russo & Comi, 2011; Lindholm, 2012; Stathopoulos, Valeri & Marcucci, 2011; Ballantyne, Lindholm & Whiteing, 2013; Lindholm & Browne, 2013; Ystmark et al., 2014). Some authors suggest considering 'society' or 'citizens' as a fifth stakeholder (Taylor, 2005; Witlox, 2006; Quak, 2008). Ballantyne et al. (2013) argued that citizens and visitors have an interest in the system of urban freight transport but do not have a direct influence on the system. From that perspective, the authors differentiated between actors and stakeholders and also considered public transport operators, trade associations, commercial organisations and land owners/property owners as passive stakeholders.

The theoretical research on urban off-hour deliveries does not confirm that we should consider the same five stakeholders for urban off-hour deliveries, which is considered a specific type of urban freight distribution. Holguín-Veras et al., (2005) were the first to describe the interactions taking place among the different actors in the case of off-hour deliveries. The authors acknowledged that there are both private and public sector actors, but they focused on private sector stakeholders: shippers, warehouses, receivers, third-party logistics providers (3PLs) and trucking companies. The European research project Niches also approached off-hour deliveries from a stakeholder perspective (www.niches-transport.org). For them, the three key stakeholders are: the city administration, transport operators and shop owners. Although these two references did not consider new stakeholders that do not fit our categories, more insight into which stakeholders are affected by a shift to more off-hour deliveries is necessary to measure the support for such a shift.

Multiple trials and pilots programs have attempted to demonstrate that it is possible to shift deliveries to off-hours. For many of these trials, the before situation was compared with the pilot situation with respect to various quantitative and qualitative indicators. The indicators for which a positive or negative impact was measured can provide us with insight into which stakeholders are affected by a shift to more off-hour urban deliveries.

We reviewed the impact assessments and evaluations of 33 off-hour delivery trials that took place in Europe and North America between 1966 and 2014. In a first stage, these impact assessments and evaluations were retrieved through a systematic keyword search in Web of Science and Google Scholar. The keywords that were used are: 'city logistics night deliveries', 'urban distribution night deliveries', 'off-hour deliveries', 'night-time deliveries' and 'silent deliveries'. Because of the low output, we also performed the same keyword search in Google. After scanning the output for new references, trials and pilot programs, we ended up with 38 references evaluating 33 off-hour delivery trials. It is important to note that these references are mostly reports, papers or even websites or leaflets discussing some aspects of the trial. It is possible that not all of the impacts that were measured were also published. In addition, many of these trials were small scale and short term. Nevertheless, this sample of evaluations and impact assessments is large enough to determine a trend or pattern. The list of trials and references can be found in Annexes A and B.

In total, the 38 references mention 65 different impact indicators that were measured for at least one trial. Some indicators use different measuring units. Impact on fuel consumption, for example, is expressed in percentage terms or in litres per year, per 100 kilometres or per trip. On average, an indicator is measured for 3.60 trials and has an even lower median value of 2. The five most commonly measured indicators are: noise nuisance (complaints by local residents) (24), noise nuisance (noise measurements) (23), driving time (14), fuel consumption (trip) (10) and loading/unloading time (8). These five indicators are then followed by 7 other indicators that were measured for 6 different trials. Table 10 provides an overview. Based on the descriptions of the indicators in the references, we aimed to link each indicator to one or more stakeholders whom it affects. First, it appeared that every indicator that is relevant for one of the other stakeholders could also be relevant for the (local) authorities. Whether it actually is relevant to the authorities depends on the choices the authorities made when deciding on their policy. Furthermore, each government agency also has several policy areas that might attach more or less value to a particular indicator. Second, the stakeholder 'citizens' is a very broad category. Local residents, customers, road users, commuters, and employees are all affected by a shift to more off-hour deliveries, but in different ways. The question then becomes whether the stakeholder 'citizens' should be further subdivided. Third, all of the indicators could be linked to one of

the five stakeholder categories that we defined earlier. However, none of the indicators was specifically defined to address one of the additional stakeholder categories defined by Ballantyne et al. (2013). This lack of specific definition does not mean, however, that off-hour deliveries do not affect these stakeholders. The impact on congestion, for example, is relevant for public transport operators.

Matching the indicators with one or more stakeholders reveals that the five stakeholders are relevant for off-hour urban deliveries. Other than the category 'local authorities', most of the indicators could be linked to the stakeholder 'citizens' (30 indicators, or 46.15%). The fewest indicators could be linked to 'senders' (8 indicators, or 12.31%). For this particular pilot program, the five stakeholders could be narrowed down to three because the retailer acts as sender, receiver and LSP at the same time when delivering to shops from their distribution centres in the vicinity of Brussels.

Table 10. Impact indicators from a review of the impact assessments and evaluations of 33 off-hour delivery trials linked to urban distribution stakeholders

Indicators	Stakeholders						Number of trials where impact was measured
	Senders	Receivers	LSPs	Authorities	Citizens	Other	
1 Noise nuisance (noise measurements)		x			x		23
2 Noise nuisance (complaints of local residents)		x			x		24
3 Total operating expenses	x	x	x				2
4 Fuel consumption (trip)			x				10
5 Fuel consumption (refrigeration)			x				2
6 Driving time			x				14
7 Loading/unloading time			x				8
8 Total time			x				6
9 Waiting time			x				3
10 Distance			x		x		2
11 Efficient use delivery vehicles			x				6
12 Stock replenishment in shop		x					4
13 Load rate delivery vehicles			x				1
14 Type of delivery vehicles			x				6
15 Wage driver			x				6
16 Wage night shift staff receiver		x					2
17 Efficient use night shift staff receiver		x					3
18 Efficient use receiving capacity receiver		x					1
19 Reliability		x					3
20 Efficient use day shift staff receiver		x					5
21 Efficiency shelving receiver		x					2
22 Total efficiency in terms of deployment of manpower	x	x	x				1
23 Delays LSP			x				1
24 Maintenance cost equipment			x				1
25 Order processing sender	x						1
26 Opening hours sender	x						1
27 Frequency of pre-loading	x						1
28 Duration orderpicking	x						1
29 Efficient use sending capacity sender	x						1
30 Ordering behaviour receiver		x					1
31 Difficulties unassisted deliveries			x				1
32 Investment in rolling stock			x				4
33 Investment in shops		x					3
34 Capex total		x	x				4
35 Financial rate or return		x	x				1
36 Support for off-hour deliveries senders/LSPs	x	x					3
37 Support for off-hour deliveries receivers		x					3
38 Safety and accessibility aisles		x			x		3
39 Stock availability		x			x		6
40 Shopping experience		x			x		2
41 Support for off-hour deliveries customers		x			x		1
42 Driver satisfaction			x		x		6
43 Availability of delivery areas			x		x		2
44 Shopkeeper satisfaction		x			x		1
45 Staff shop satisfaction		x			x		3
46 Congestion			x		x		5
47 Air quality					x		1
48 Emission total					x		1
49 CO2					x		6
50 NOx					x		6
51 PM10					x		5
52 HC					x		1
53 Traffic safety					x		5
54 Smell caused by driving vehicles					x		1
55 Smell caused by unloading vehicles					x		1
56 General hindrance caused by driving vehicles					x		1
57 General hindrance caused by unloading vehicles					x		2
58 Impact on external costs (incl. congestion) off-hour deliveries					x		1
59 Impact on external costs (incl. congestion) night deliveries					x		1
60 Impact on external costs (excl. congestion) off-hour deliveries					x		1
61 Impact on external costs (excl. congestion) night deliveries					x		1
62 Support for off-hour deliveries citizens					x		5
63 Living environment					x		1
64 Efficient use of public space					x		1
65 Support for off-hour deliveries local authorities							3
Number of indicators relevant for this stakeholder	8	23	22	65	30	0	
Percentage of indicators relevant for this stakeholder	12.31%	35.38%	33.85%	100.00%	46.15%	0.00%	

Source: Own setup.

7.4.3 Step 3: Defining criteria and allocation of weights to the criteria

Each stakeholder uses his own criteria when assessing the different alternatives. These criteria are linked to this stakeholder's objectives. The first stakeholder is the retailer. He initiated this pilot because he believes he can cut costs and contribute to traffic safety and a better environment by shifting some of the deliveries to the supermarkets

to off-hours without causing extra noise nuisance to local residents. In general, his goal is to provide good customer service in a cost efficient manner without losing sight of the impact of his operations on society. This approach leads to a list of 5 criteria that are based on the lists of criteria for senders, receivers and LSPs that were defined by Macharis, Milan & Verlinde in 2012 within the framework of the European research project STRAIGHTSOL and that were confirmed by the head of the transport department of the retailer. He was not only asked whether he considered these criteria to be the most important, he was also asked to weigh them. The result can be found in Table 11.

The second stakeholder is the authorities of the Brussels-Capital Region. The authorities decide whether shifting deliveries to off-hours will be allowed, paying special attention to the noise impact for local residents. At the same time, the authorities want to provide a sound living environment for citizens and a good business climate for businesses. To make the trial possible, a vast amount of engagement was expected from the local authorities because they had to make an exception to the rules. To establish the criteria and their weights, one representative of the Mobility Department of the Brussels-Capital Region responsible for urban freight transport was interviewed. Her answers were compared with the policy choices that are reflected in the policy documents of the Brussels-Capital Region. The results can be found in Table 11.

The third group are the citizens, who are the people living, working and spending time in Brussels. They want to be able to live their lives as they want in a safe and healthy environment. The trial did not expect engagement from citizens. Nevertheless, their active opposition to a shift to off-hours would make it impossible. The criteria and weights for this stakeholder were based on a Europe-wide survey of 507 unique respondents that was also conducted within the framework of STRAIGHTSOL (Milan, L., Kin, B., Verlinde, S., Macharis, C., 2014). The criteria and weights are shown in Table 11.

Table 11. Stakeholders and their criteria and weights for the off-hour deliveries trial in Brussels

Stakeholder	Criterion	Criterion definition	Weight
Retailer	High level of service	Customer satisfaction, deliveries on time and of the right quantity	30
	Socio-environmental concerns	Positive attitude towards environmental impact	25
	Profitable operations	Making a profit	16.5
	Viability of investment	A positive return on investment	16.5
	Employee satisfaction	Employees are satisfied with their work and working environment	8
	Security	Security of the goods and the drivers; no thieves and no attacks	4
Local authorities	Quality of life	Attractive environment for citizens	58.7
	Network optimisation	Optimal use of existing infrastructure	21.6
	Social and political acceptance	Citizens' support for measures	9.4
	Cost measures	Low costs to implement measures	6.5
	Positive business climate	Attractive environment for companies	3.9
Citizens	Safety	Positive impact on road safety	31
	Emissions	Reduce emissions of CO ₂ , NO _x , PM _{2.5} , PM ₁₀	26.4
	Urban accessibility	Reduce freight transport; less congestion	20.8
	Noise nuisance	Reduce noise nuisance	15.7
	Visual nuisance	Less space occupancy by trucks	6.1

Source: Own setup.

7.4.4 Step 4: Indicators, measurement methods and impact assessment

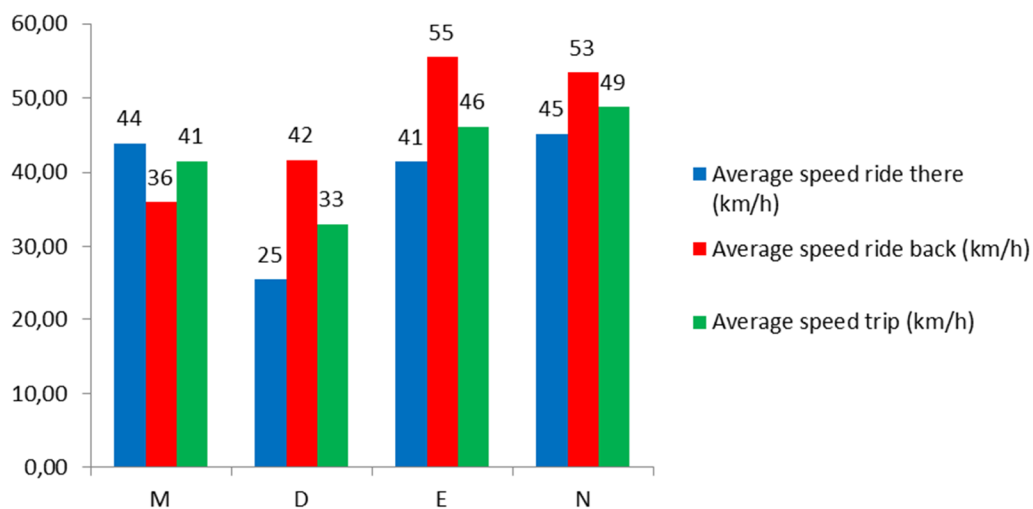
Assessing how well one of the alternatives scores on a certain criterion requires measurable indicators to quantify its impact. Within STRAIGHTSOL, the stakeholder criteria were translated into a set of Key Performance Indicators (KPI) that, in turn, were linked to measurement methods and data needs (Balm, S. & Quak, H., 2012). For the night deliveries pilot in Brussels, the STRAIGHTSOL list of indicators, measurement methods and data needs was used after checking whether all of the criteria were covered by these indicators.

During the pilot program, 46 delivery trips (taking place at different times of the day) were monitored, noise measurements were carried out and stakeholders were interviewed. A distinction was made between early morning trips (arrival at the shop between 6 am and 8 am), day trips (arrival between 8 am and 8 pm), late evening trips (arrival between 8 pm and 10 pm) and night trips (arrival between 10 pm and 6 am). In total, 8, 16, 8 and 14 trips were monitored, respectively. The collected data allowed a mutual comparison between these 4 types of trips. Below, the comparison of the four types of trips is described for the indicators for which the impact could be monitored and measured: average speed, time needed for loading and unloading, fuel consumption, noise nuisance, emission of pollutants and employee satisfaction. Later, we provide a business case analysis (BCA). For the BCA, there is no comparison between types of trips but between the three scenarios: the BAU scenario, the pilot scenario (S1) and the scaled pilot scenario (S2).

Average speed

The drivers who performed the deliveries and trips that were monitored were asked to fill in a logbook. In that logbook, the drivers noted the exact departure time of their trips to and from the shop. In combination with the known mandatory routing between shops and distribution centres, these exact times allowed us to calculate the average speeds during the trips. During the night trips, the average speed reached was 48.75 km/h, which is 48.02% higher than the average speed reached during the day trips (32.94 km/h). The average speed during trips for morning and evening deliveries was somewhere in between because such trips partially take place in congested traffic. Figure 56 clearly shows that in the morning, the trips to the shop were much faster than the trips away from the shop (which took place after 8 am). The opposite holds for evening trips: trips to the shop were driven when the roads were still congested and were therefore rather slow, while the trips away from the shop were much faster. The results show that avoiding congested traffic can lead to significant time gains.

Figure 56. Average speed during early morning (M), day (D), late evening (E) and night trips (N)

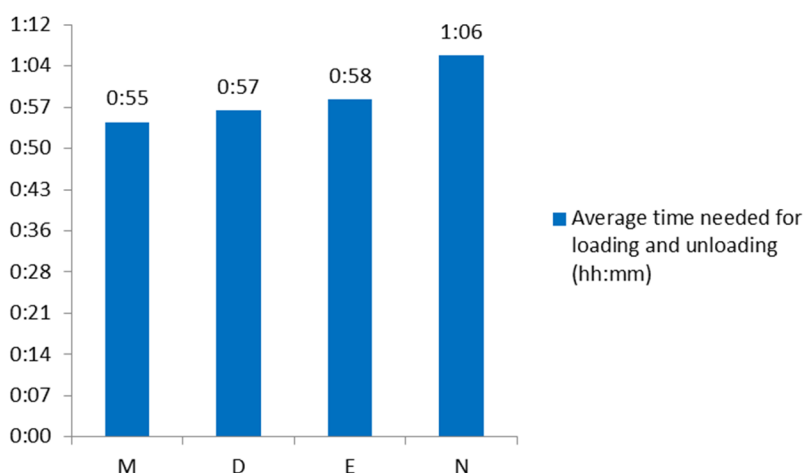


Source: Own setup.

Time needed for loading and unloading

The logbooks also contain the exact starting and finishing time of the loading and unloading operations. The results reveal that the time needed by a driver to unload is also impacted by the time of day the deliveries are carried out. During the night, it took a driver an average 9 minutes, or 16.73% longer than during the day, which can be explained by the fact that there were no staff members present to open the door and help the driver to unload. No significant differences were found between morning, day and evening deliveries. The average time needed for loading and unloading broken down according to the time of day the delivery took places is shown in Figure 57.

Figure 57. Average time needed for loading and unloading during early morning (M), day (D), late evening (E) and night deliveries (N)



Source: Own setup.

Fuel consumption

The drivers were also asked to fill the vehicle fuel tank at departure from and arrival to the distribution centre. Partly because some trips did not leave directly from a distribution centre but from another shop and partly because not all of the drivers followed this directive, we only have reliable data for 26 trips out of a total of 46 monitored trips. Because we only have three morning measurements and three evening measurements, no conclusions can be drawn regarding fuel consumption during these trips. We did observe, however, that the average fuel consumption decreased from 47.64 litres/100 km during day trips to 42.45 litres/100 km during night trips, which corresponds to a savings of 10.89%.

Air quality and climate change

The pilot program was too small scale to measure any impact on air quality or climate change. To nevertheless assess that impact, the common approach is to calculate the impact on the emissions of pollutants such as CO₂, NO_x and PM using primary indicators such as distances driven, average speed, kilometres driven in traffic congestion etc. and emission factors. In this case, there was only a shift to another time of day, whereas the distance driven and the type of vehicle remained the same. Thus, the effect was that the number of congested kilometres decreased, which positively impacted the emission of pollutants.

Noise nuisance

The Brussels-Capital Region has a Noise Abatement Law that defines the maximum noise levels that can be produced while operating a retail shop (or any other 'regulated installation'). The amount of noise allowed depends on where and when (time and day) the noise is produced. To determine the noise produced during the unloading operations at the two pilot sites, an independent acoustic engineering company was asked to perform measurements and analyses. At each pilot site, one night delivery was selected for noise measurement. For a period of four consecutive days, the noise level (LAeq) was measured each second (day and night) at one or several fixed measurement points to determine the ambient noise levels. During the actual night delivery, mobile sound level metres were used to measure the noise levels that were produced during the manoeuvring and unloading.

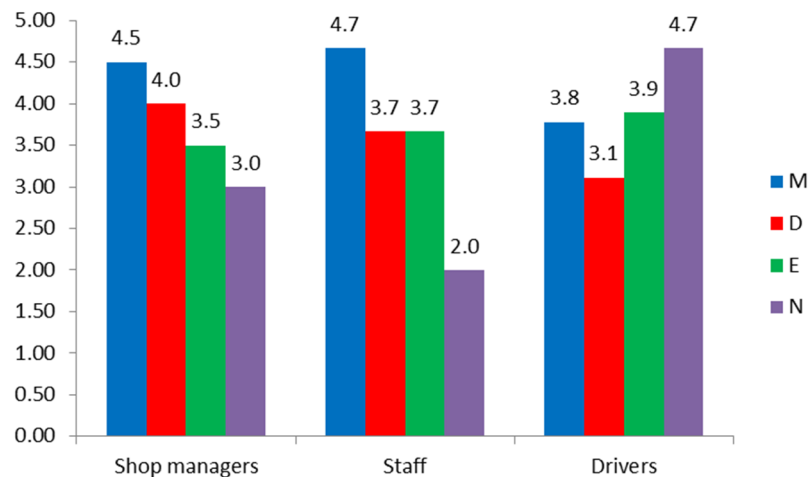
Analysing the obtained data leads to the following conclusions. First, at both pilot sites, the on-site measurements show that the noise produced during both the manoeuvring and the loading and unloading operations (hand pallet, doors slamming, etc.) can hardly be discerned from the ambient noise when measured next to the closest housing unit (at 31 m and 80 m from the loading quay). Second, the threshold of 66 dBA, which by law cannot be exceeded more than ten times in one night time hour, was exceeded twice at the pilot site with the uncovered loading bay and never at the site with the covered loading bay. Third, the average noise levels measured with mobile sound metres immediately beside the truck were within the allowed nightly maximum of 42 dBA. The average noise levels

produced during the manoeuvring towards the loading bays and parking in front of the loading bays, however, exceed the 42 dBA maximum. These noise levels also exceeded the 48 dBA maximum that is allowed during the day, which means that if the Noise Abatement Law is strictly applied, despite the fact that measures were taken to keep the deliveries as silent as possible, the trucks could not manoeuvre legally during the day. It should be noted, however, that this law only applies when the manoeuvring and unloading are conducted on private ground. When such actions take place on public roads, the law does not apply.

Other than the objectively measurable noise levels, a second indicator for noise nuisance is its perception by the local residents. The local residents were informed of the pilot through flyers (in their letterbox or at the cash register of the shop) and were invited to file a complaint if they experienced a noise nuisance because of the pilot test. No complaints were filed. Sixteen close neighbours of both shops were also surveyed on this aspect. None of the interviewees said that they had experienced noise nuisance during the early morning or late evening deliveries (which they were already used to), while two said that they did experience a noise nuisance during the night deliveries, but apparently it was not bad enough to file a complaint.

Employee satisfaction

Shifting deliveries to another time of day has an impact on three types of employees. First, truck drivers must work evenings, nights and/or early mornings. Second, if deliveries are carried out when the shop is not open, shop managers and staff are impacted. All three groups were surveyed, including 11 drivers, 3 staff members and the two shop managers. Of the 11 truck drivers, only nine filled in the survey. They were all asked to score the four types of deliveries on a scale of 1 (strongly negative) to 3 (neutral) to 5 (strongly positive) (with 2 and 4 in between). The average scores were calculated for each of the three groups, and these scores were projected to the business as usual and pilot scenarios. Figure 58 shows the results for employee satisfaction. The results show that the drivers preferred the pilot where the proportion of evening, night and early morning deliveries is higher. The other employees preferred business as usual. In general, managers and staff prefer the early mornings and have their most doubts concerning night deliveries. The reasons they prefer the early mornings concern the fact that there are goods available to put on the shelves early in the morning, but there is also staff available to help the driver unload and tell him where to put the goods. The less positive experience of the managers and staff with night deliveries is linked to how some of the drivers leave the goods in the transit area and do not organise them as the staff would expect. The drivers gave day deliveries an average score of 3.11 and night deliveries an average score of 4.67, with morning and evening deliveries somewhere in between. The drivers clearly preferred night deliveries. The reasons they noted concern with the lack of traffic congestion and that it is easier to manoeuvre their truck. The fact that it is calmer in the transit area of the shop was also mentioned.

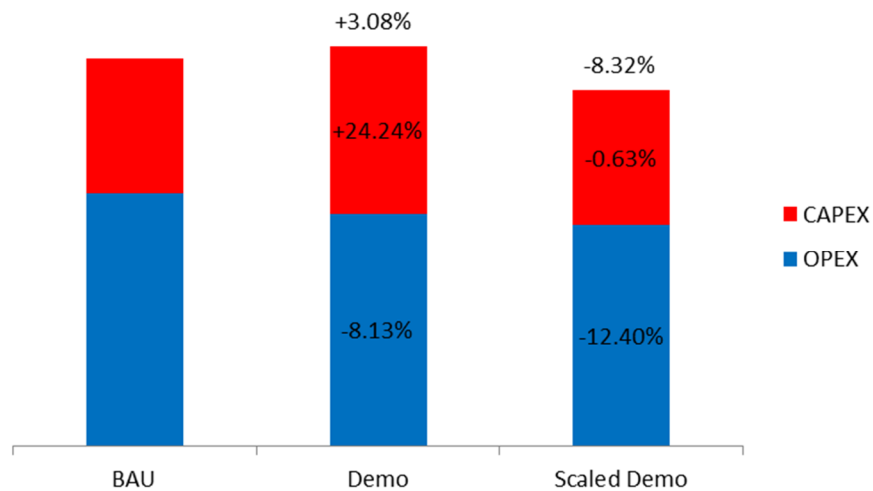
Figure 58. Employee satisfaction of shop managers, staff and drivers

Source: Own setup. Three types of deliveries: early morning (M), day (D), late evening (E) and night deliveries (N). Scale varies from 1 (strongly negative) to 3 (neutral) to 5 (strongly positive).

Business case

Shifting deliveries to off-hours has a significant impact on the retailer's cost structure, while his revenue streams are not impacted (Posthumus, Eris, Balm, Moolenburgh, & Quak, 2014). The retailer must adapt his trucks, trailers, equipment and shops to ensure that deliveries can be carried out as quietly as possible. He also must prepare an application for a new environmental permit, instruct his staff and train the drivers (Posthumus et al., 2014). These costs constitute the capital expenditures (CAPEX) of the shift to off-hour deliveries. This shift also incurs a change in operational expenses (OPEX). The operational expenses include, first, the transport cost, which includes fuel consumption and the labour cost for drivers. Second, there is the labour cost for staff to load and unload the truck at the distribution centre and to unload the truck at the shop. For this pilot, the latter cost was not taken into account because the pilot was too small to identify a significant impact.

When discussing the impact on cost structure, it is not possible to compare one daytime delivery with one early morning, late evening or night delivery. The share of the CAPEX in the total cost of that delivery greatly depends on how efficient the investments are used (both time-wise and scale-wise). Therefore, for the business case analysis, a comparison is made between business as usual (BAU), the pilot (Demo) and a scaled scenario (Scaled Demo). The BAU scenario reflects normal deliveries for the two pilot shops for a period of two weeks: 22% of the deliveries are conducted in the early morning, 74% during the day, 4% in the late evening and none at night. The Demo scenario reflects the pilot as it was carried out, with more off-hour deliveries for the two pilot shops for a period of two weeks: 13% are morning deliveries, 55% are daytime deliveries, 13% are evening deliveries and 19% are night deliveries. The third scenario reflects a fictional scenario: deliveries are evenly spread throughout the day (and night) and are applied to all of the retailer's 14 shops in the Brussels-Capital Region. The analysis reveals that in the Demo scenario, OPEX decreased by 8.13%, and CAPEX increased by 24.24%. In total, during the pilot, costs increased by 3%. When the pilot is scaled, OPEX would still decrease by 11.70%, but the CAPEX would also decrease by 0.63%, which is equivalent to a total decrease of 7.84%. The increase in CAPEX can be explained by the more efficient use of vehicles when deliveries are evenly spread throughout the day on a large sample of shops.

Figure 59. Business case analysis for three scenarios: business as usual, the pilot and the scaled pilot

Source: Own setup.

7.4.5 Step 5: Overall analysis and ranking

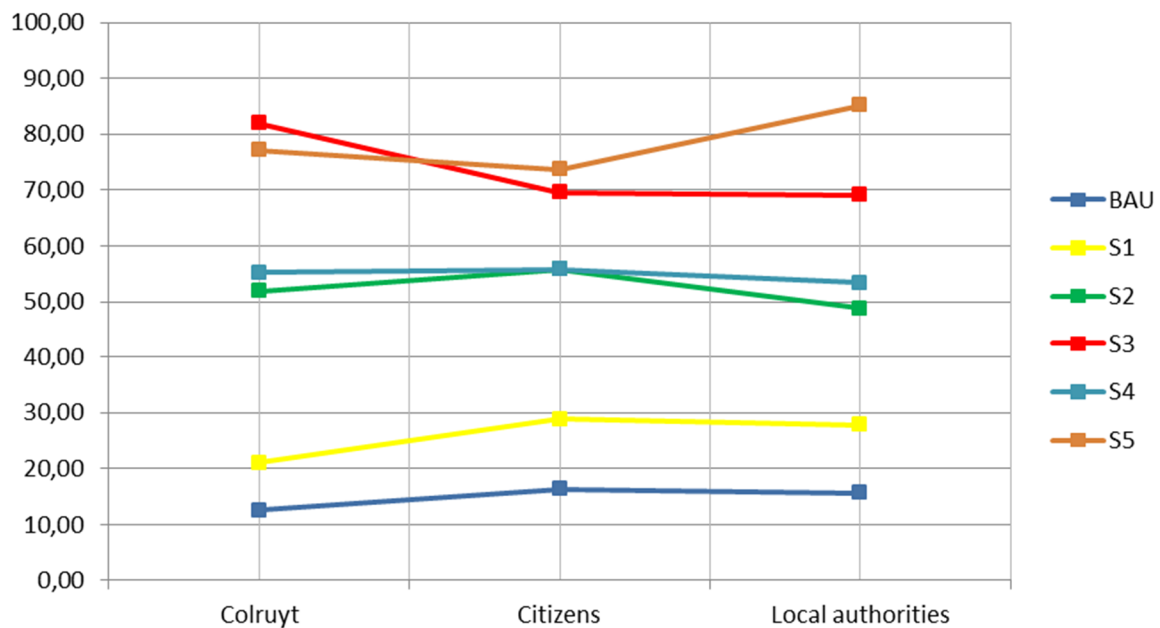
Any multi-criteria decision-analysis (MCDA) method can be used to assess the different strategic alternatives (step 5). In particular, the second generation multi-criteria analysis methods, including the Group Decision Support Methods (GDSSM), are well suited for the MAMCA methodology because they allow the inclusion of the stakeholder concept through each stakeholder's own criteria, weights and preference structure. At the end of the analysis, the different perspectives can be analysed (Macharis, Brans & Mareschal, 1998).

The chosen method to carry out all the analyses is the PROMETHEE-GDSS method, which is a powerful extension of the PROMETHEE method (Macharis et al., 1998). This method belongs to the family of outranking methods, which means that the method is based on pairwise comparisons of the scenarios. As an outranking method, PROMETHEE computes a net preference flow that measures how each alternative outranks the other alternatives. The PROMETHEE II method used for this analysis produces a complete ranking of all of the alternatives from best to the worst.

7.4.6 Step 6: Results of the MAMCA

Together, the five previous steps lead to a multi-actor view on the six evaluated alternatives, which is shown in Figure 60. The horizontal axis shows the three stakeholders. For this analysis, the three stakeholders were considered equally important and were therefore given the same weights. The values on the left axis represent the score of a particular alternative under consideration. This score was calculated through the overall analysis and ranking, as described above.

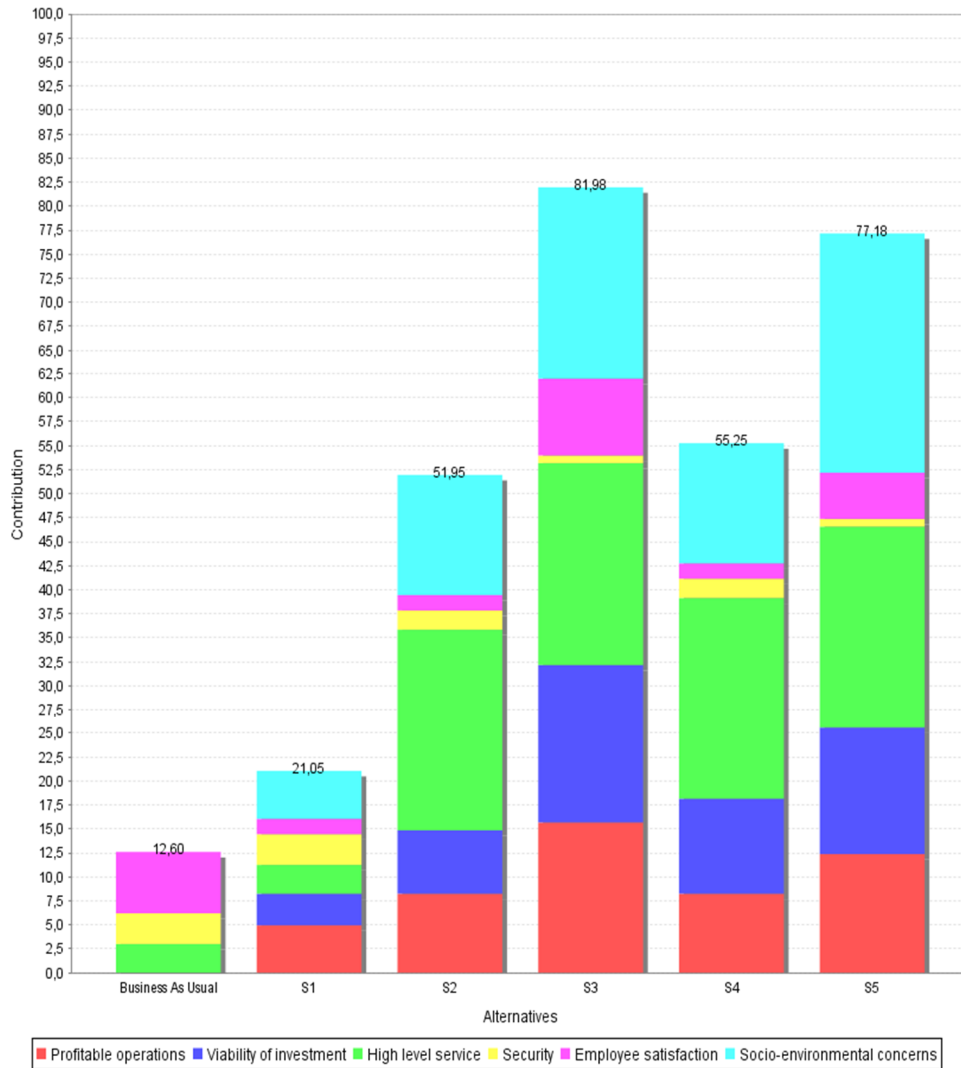
A first conclusion from the MAMCA is that a shift to off-hour deliveries to supermarkets in Brussels should be capable of receiving overall support. All of the stakeholders rank the different scenarios more or less the same, and there are no scenarios that score very high for one stakeholder and very low for another. The graph also shows that for each stakeholder, the alternatives with a high proportion of night deliveries score well.

Figure 60. Multi actor view MAMCA

Source: Own setup.

In addition to the multi-actor view, a mono-actor analysis is performed and visualised via the criteria contribution chart for each stakeholder. This figure shows the contribution of each criterion to each scenario, and it can be read horizontally as well as vertically. The horizontal axis represents the different scenarios, and the vertical axis represents the PROMETHEE II scores of these scenarios given in percentages. One colour is attributed to each criterion: the size of the interval represents the contribution of the criterion for a given scenario. A missing criterion for one scenario means that this criterion scored the lowest compared with the other scenarios. Thus, reading the chart horizontally allows us to compare the value of each criterion: the larger the interval is, the higher the score of the criterion. A vertical interpretation of the chart for each scenario allows us to compare how much a criterion contributes to the overall scenario scores compared with the other criteria: the larger the interval is, the higher its contribution to the scenario score compared with the other criteria. These scores integrate the weights, the stakeholders' preferences and the data-based evaluation of the considered criterion.

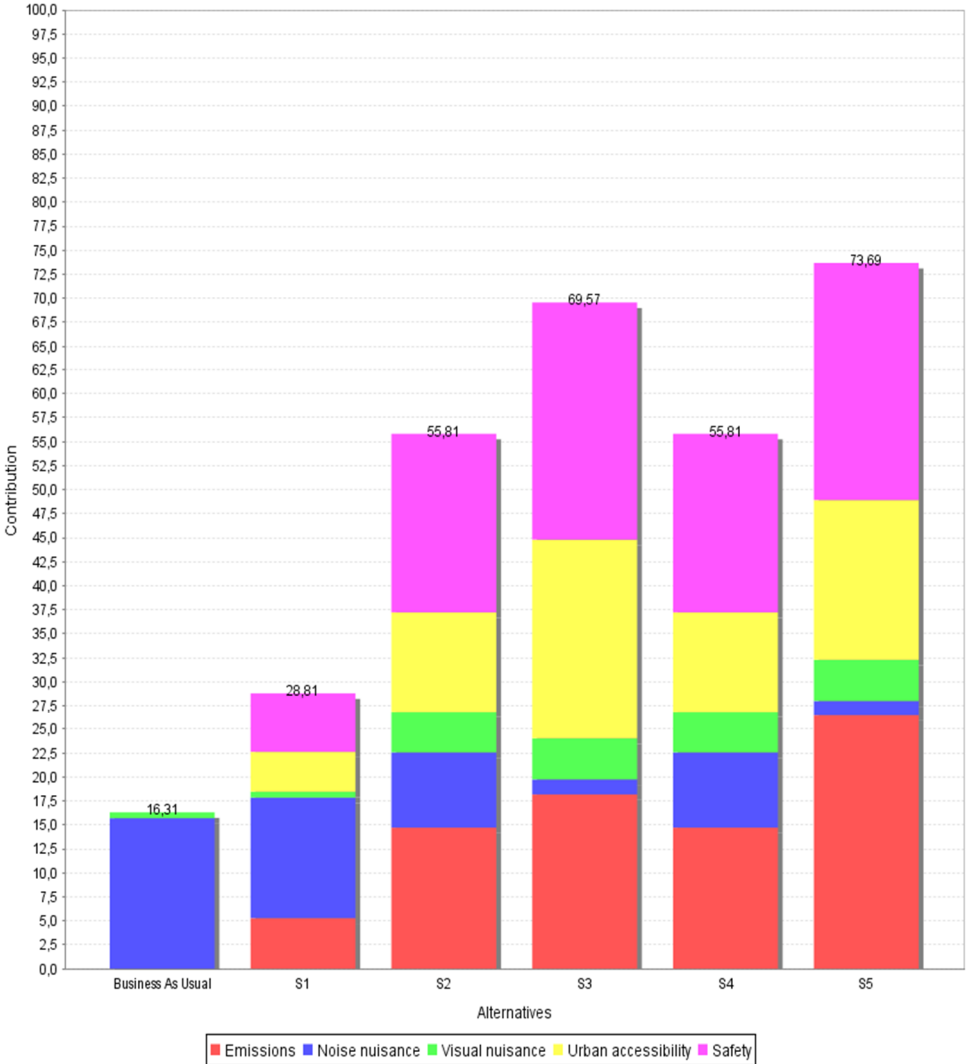
The mono-actor view for the retailer (Figure 61) shows that it is very important to him to be able to implement off-hour deliveries on a large scale. Once that is achieved, he prefers the scenarios with an even spread of deliveries throughout the day. This result is mainly due to the positive impact on three of the retailer's criteria: profitable operations, viability of investment and socio-environmental concerns. Finally, the result also shows that the retailer must take measures to increase employee satisfaction when shifting deliveries to off-hours because this criterion is the only one for which the BAU scores better than the pilot. In his decision on when to deliver to shops, the retailer greatly depends on the opinions of the other two stakeholders. For the environmental permits that determine whether night (and early morning and late evening) deliveries will be allowed, the retailer depends on the local authorities, and the significant weight the retailer attaches to socio-environmental concerns also demonstrates the importance of the opinion of citizens.

Figure 61. Mono actor view MAMCA retailer

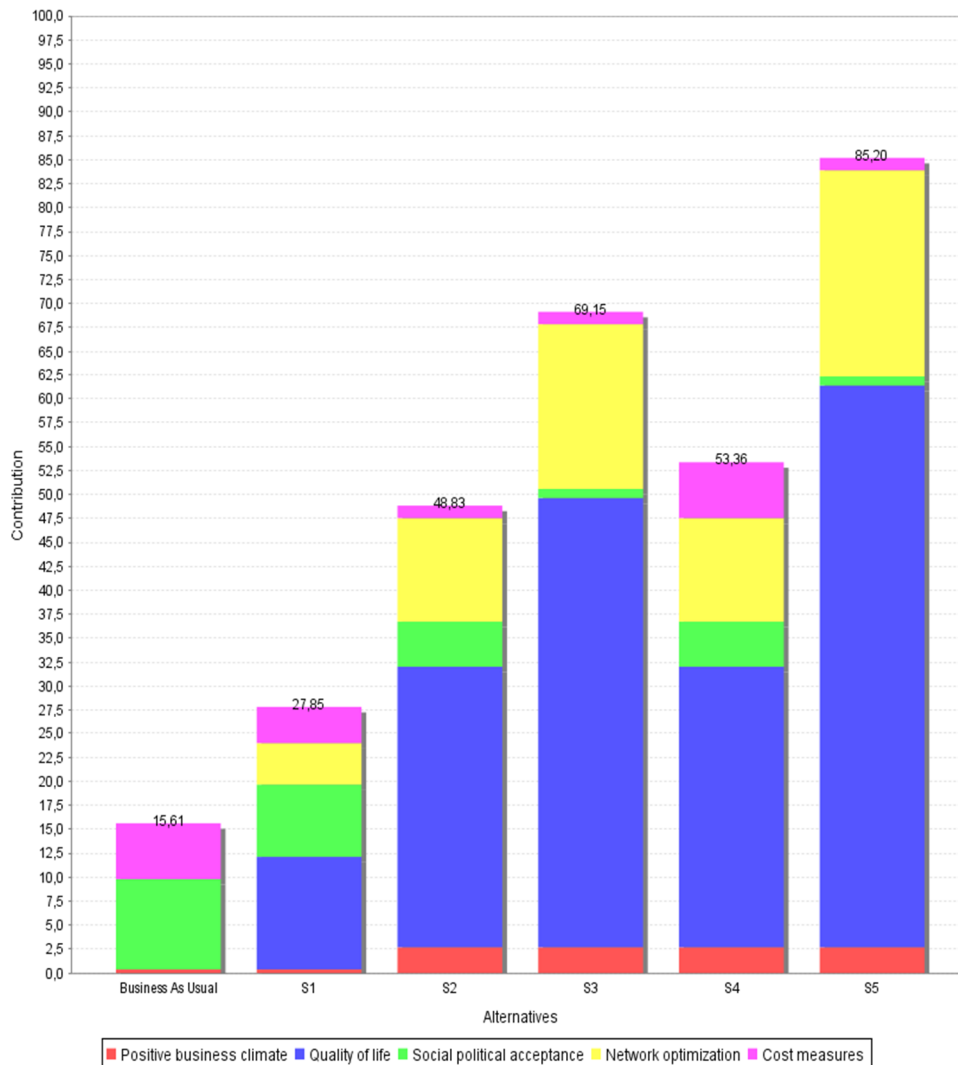
Source: Own setup.

For the citizens, the results show that the bigger the shift of deliveries away from the daytime (8 am-8 pm), the better the scenario scores because of a decrease in emissions, better traffic safety, a decreased contribution to congestion and a positive impact on visual nuisances (Figure 62). The scenario that focuses on morning deliveries (S5) scores the best because of the high average speed the trucks can reach, which directly influences the important criterion of emissions, despite its more negative effect on urban accessibility. Despite their high scores, S3 and S5 do not score well on noise nuisance due to their relatively high proportions of night deliveries. This result illustrates the importance of taking measures to minimise the noise nuisance when carrying out night deliveries despite the relatively low weight attached to this criterion. The importance of taking appropriate measures on noise is also confirmed by the analysis for the local authorities (Figure 63). We observe the same preference for the scenario that focuses on morning deliveries, which can be explained by the significant weight that the local authorities attach to the quality of life of citizens. We also see that social-political acceptance receives the lowest score of the best-scoring scenarios. Because this acceptance is mainly linked to noise nuisance, it is an important aspect. In this case, the criterion of social-political acceptance shows a relatively low weight, especially compared with quality of life. However, if this criterion gains importance, the mono-actor view for the local authorities could be completely different.

Figure 62. Mono actor view MAMCA citizens



Source: Own setup.

Figure 63. Mono actor view MAMCA local authorities

Source: Own setup.

7.4.7 Step 7: Implementation

Implementation is the final step in MAMCA. The analysis shows that it should be possible to implement off-hour deliveries to supermarkets in Brussels. However, the legislative and political situation in Brussels will not allow an immediate shift to off-hours deliveries, particularly because the retailer only wants to do it when there is also political support for the measure. However, the pilot and the results of the analysis did help to put the topic on the political agenda, and in case of implementation, the results could help to identify implementation pathways and additional measures.

7.5 Conclusion

Today, the majority of deliveries in urban areas take place during the day. Shifting some of these deliveries to off-hours would create advantages as well as disadvantages. The literature mentions time gains, fuel gains, disturbed sleep for local residents, increased traffic safety, fewer parking violations, increased operational costs for the receiver, fewer emissions and decreased congestion. This combination of expected impacts makes it difficult to answer the question whether there is overall support for shifting deliveries to off-hours. This difficulty is deepened by the fact that the advantages would mainly be for the LSPs and the citizens, while the receivers and local residents would mainly experience the disadvantages. In addition, support for off-hour deliveries also very much depends on the local situation, which makes the question even more difficult to answer.

This paper reports on the application of Multi Actor Multi Criteria Analysis (MAMCA) to measure the overall support for shifting deliveries to supermarkets in Brussels to off-hours. The analysis was based on data that were collected during a two-week pilot program in two shops of a large Belgian retailer. MAMCA is an extension of the traditional Multi-Criteria Decision Analysis (MCDA) and was chosen because it explicitly takes into account the stakeholders and their objectives by separately developing a value tree for each stakeholder instead of only one overall value tree. The methodology consists of several different steps. Applying it provided increased insight into the stakeholders who are impacted from a shift to off-hours deliveries, their criteria and the importance of these criteria to them. The analysis also demonstrated the actual impact of a shift of food retail deliveries to off-hours in Brussels and answered the question whether there is overall support for such a shift.

A review of the impact assessments of 33 off-hour delivery trials that took place in Europe and North America between 1966 and 2014 revealed the dominance of noise-related indicators, followed by time and fuel consumption indicators. There is much less consensus on the other indicators that must be measured when assessing off-hour deliveries. On average, an indicator is measured for 3.60 trials and has an even lower mean value of 2. When we matched the 65 identified indicators to one or more stakeholders, we observed that the traditional urban distribution stakeholders are also relevant when assessing off-hour deliveries: sender, receiver, LSPs, citizens and (local) authorities. Two remarks can be made. First, it appeared that every indicator that is relevant for one of the other stakeholders is also relevant to the (local) authorities, depending on the policy choices that the authorities have made. Second, especially because of the issue of noise nuisance, it might be better to split the stakeholder group 'citizens' into stakeholder citizens and stakeholder local residents.

During the pilot program, 42 delivery trips (taking place at different times of the day) were monitored, noise measurements were carried out and stakeholders were interviewed. These data allowed a mutual comparison of early morning (6 am-8 am), day (8 am-8 pm), late evening (8 pm-10 pm) and night (10 pm-6 am) deliveries on a set of indicators. A first conclusion to be drawn is that the average speed during the night was nearly 50% higher than during the day. The data also clearly show the impact of traffic congestion: trips to the shops during the early mornings were quite fast, while the trips away from the shop were slow. A second observation is that at night, it took a driver 15% longer to unload. The differences between early morning, day and evening deliveries were not significant. Third, we observed that the average fuel consumption during the day trips was 14% higher than during the night trips. The noise measurements revealed that the noise produced during unloading operations could hardly be discerned from the ambient noise and was well within the Noise Abatement Law of the Brussels-Capital Region. The noise produced during the manoeuvring of the truck, however, exceeded the permissible noise limits. Finally, interviews with different types of employees revealed that drivers had a clear preference for night deliveries, while members of shop staff preferred morning deliveries.

Identifying stakeholders, their criteria and the weights they attach to these criteria combined with the results of a mutual comparison of early morning, day, late evening and night deliveries allowed us to carry out an MAMCA. A first conclusion of the MAMCA is that a shift to off-hour deliveries to supermarkets in Brussels should be capable of receiving overall support. All of the stakeholders ranked the different scenarios more or less the same, and there were no scenarios that scored very high for one stakeholder and very low for another. The graph also shows that the scenarios with a high proportion of night deliveries received a high score. The retailer preferred the scenario with the even spread throughout the day, while the other two stakeholders preferred more morning deliveries. The mono-actor views of the citizens and local authorities revealed that the noise that is produced remains an important aspect if more deliveries will be shifted to the night. The mono-actor view for the retailers revealed that a shift to night deliveries is only interesting for the retailer when he can do it on a large scale. Overall, the main lesson is that there is good potential to shift some deliveries to supermarkets to off-hours.

The findings in this paper show that it would be interesting to apply the MAMCA methodology when evaluating other off-hour urban delivery trials, first because it would provide insight into what the impact of local circumstances is to the overall support for off-hour deliveries and second because multiple analyses would allow more general conclusions to be drawn regarding the overall support for a shift to off-hour deliveries.

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Annex E: Sensitivity analysis MAMCA

Colruyt

The ranking of scenarios for Colruyt is robust. The weights allocated to profitable operations, viability of investment, high level service and employee satisfaction can vary from 0% to 100% without inducing any change in the ranking of the scenarios (Figure 64, Figure 65). Increasing the weight of security more than 49.23% will allow a rank reversal between S5 and S4 (Figure 70). A weight above 39.52% for socio-environmental concerns might lead to prefer S5 as S3 (Figure 71). A rank reversal between S1 and BAU appears when the weight of employee satisfaction is higher than 19.36% (Figure 129).

Figure 64: Stability level 1 - Colruyt (Night deliveries)

Criteria	Min Weight	Value	Max Weight
Profitable operations	0,00%	16,50%	100,00%
Viability of investment	0,00%	16,50%	100,00%
High level service	0,00%	30,00%	100,00%
Security	0,00%	4,00%	49,23%
Employee satisfaction	0,00%	8,00%	100,00%
Socio-environmental concerns	0,00%	25,00%	39,52%

Figure 65: Stability level 6 - Colruyt (Night deliveries)

Criteria	Min Weight	Value	Max Weight
Profitable operations	0,00%	16,50%	100,00%
Viability of investment	0,00%	16,50%	100,00%
High level service	0,00%	30,00%	100,00%
Security	0,00%	4,00%	44,54%
Employee satisfaction	0,00%	8,00%	19,36%
Socio-environmental concerns	0,00%	25,00%	39,52%

Citizens

The ranking of scenarios for the citizens is robust. The weights allocated to visual nuisance, and road safety can vary up to 100% without inducing any change in the ranking of the scenarios (Figure 66, Figure 67). The ranking of the first scenario is mainly affected by the weights allocated to urban accessibility and noise nuisance. Increasing the weight of urban accessibility higher than 34.30% will allow a rank reversal between S5 and S3 (Figure 73). Increasing the weight of noise nuisance above 41.74% will lead to substantial change on the ranking of the scenarios where S2 might be preferred over S5 (Figure 74).

Figure 66: Stability level 1 - Citizens (Night deliveries)

Criteria	Min Weight	Value	Max Weight
Emissions	15,30%	26,45%	100,00%
Noise nuisance	0,00%	15,70%	41,74%
Visual nuisance	0,00%	6,12%	100,00%
Urban accessibility	0,00%	20,78%	34,30%
Safety	0,00%	30,96%	100,00%

Figure 67: Stability level 6 - Citizens (Night deliveries)

Stability level : 6				
Criteria	Min Weight	Value	Max Weight	
Emissions	15,30%	26,45%	100,00%	■
Noise nuisance	0,00%	15,70%	37,28%	■
Visual nuisance	0,00%	6,12%	100,00%	■
Urban accessibility	0,00%	20,78%	34,30%	■
Safety	0,00%	30,96%	100,00%	■

Local authorities

The ranking of scenarios for the local authorities is robust (Figure 68, Figure 69). The weights allocated to positive business climate, network optimization and quality of life can vary from 0% to 100% without inducing any change in the ranking of the scenarios. Social political acceptance (Figure 75) and cost of the measures (Figure 76) could be critical factors for the scenario preferences as these criteria score respectively the best for BAU and S4. The higher weight allocated to social political acceptance, the higher the score of BAU. When the Brussels-capital would favour this criterion, BAU would become the most preferred scenario. Similarly, the higher weight allocated to the cost measures criterion, the higher the score for S4. A rank reversal between S3 and S4 only appears when the weight of cost measures is allocated as far as 23.68%.

Figure 68: Stability level 1 - Local authorities (Night deliveries)

Stability level : 1				
Criteria	Min Weight	Value	Max Weight	
Positive business climate	0,00%	3,85%	100,00%	■
Quality of life	0,00%	58,67%	100,00%	■
Social political acceptance	0,00%	9,41%	48,91%	■
Network optimization	0,00%	21,60%	100,00%	■
Cost measures	0,00%	6,47%	35,71%	■

Figure 69: Stability level 6 - Local authorities (Night deliveries)

Stability level : 6				
Criteria	Min Weight	Value	Max Weight	
Positive business climate	0,00%	3,85%	100,00%	■
Quality of life	12,74%	58,67%	100,00%	■
Social political acceptance	0,00%	9,41%	35,05%	■
Network optimization	0,00%	21,60%	100,00%	■
Cost measures	0,00%	6,47%	23,68%	■

Figure 70: Evolution of the scores for security - Colruyt (Night deliveries)

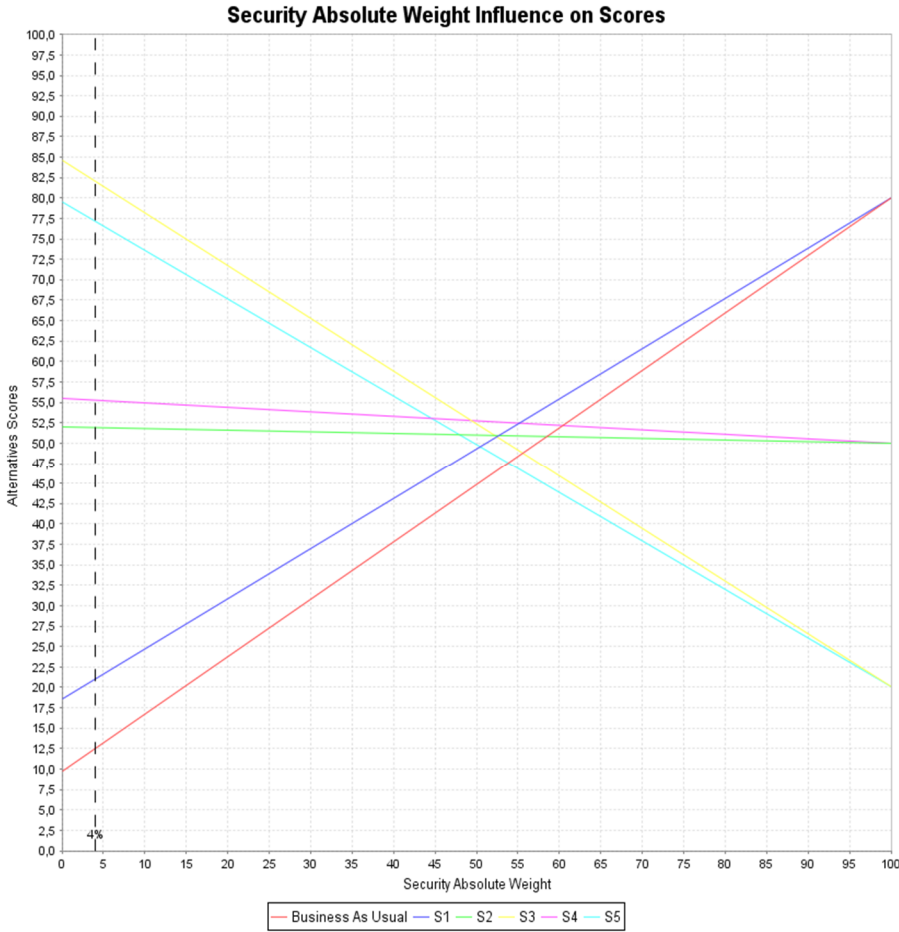


Figure 71: Evolution of the scores for socio-environmental concerns - Colruyt (Night deliveries)

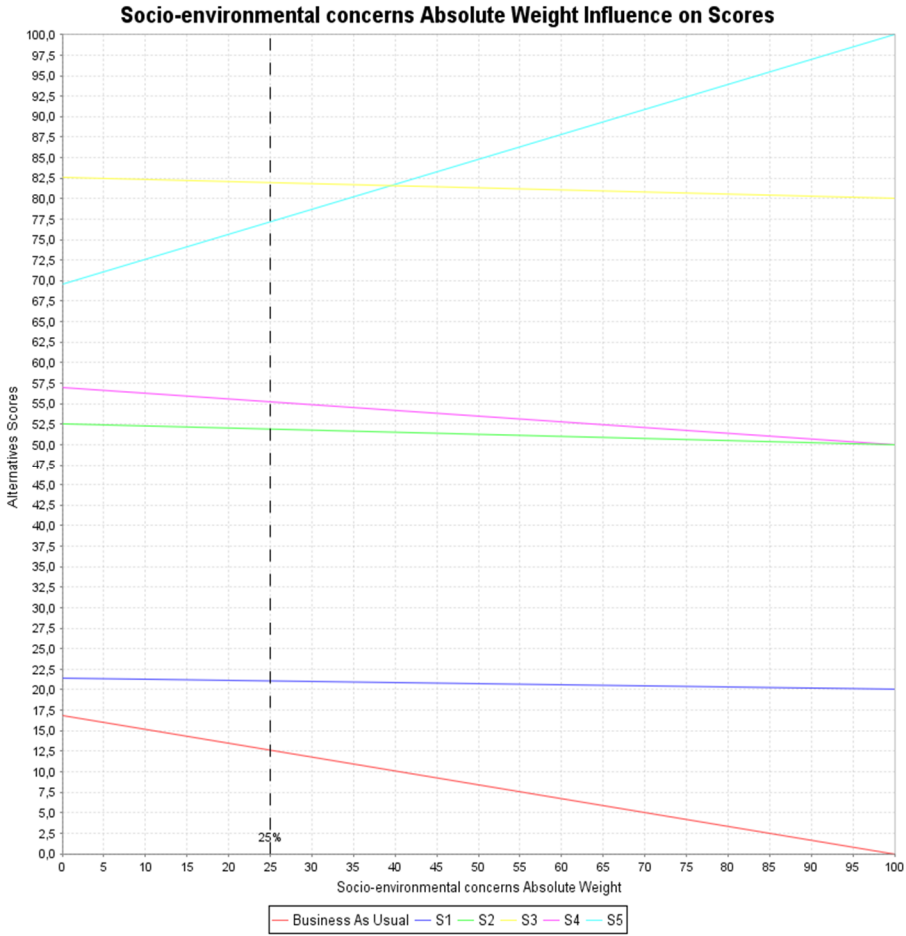


Figure 72: Evolution of the scores for employee satisfaction - Colruyt (Night deliveries)

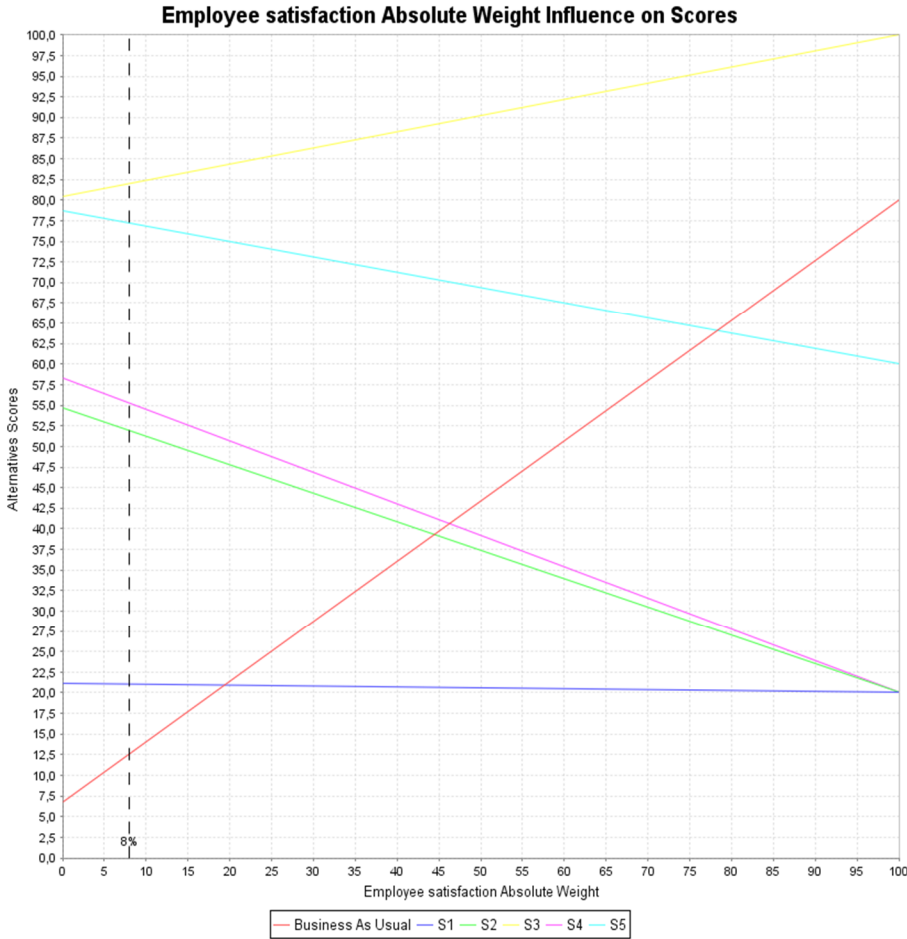


Figure 73: Evolution of the scores for urban accessibility - Citizens (Night deliveries)

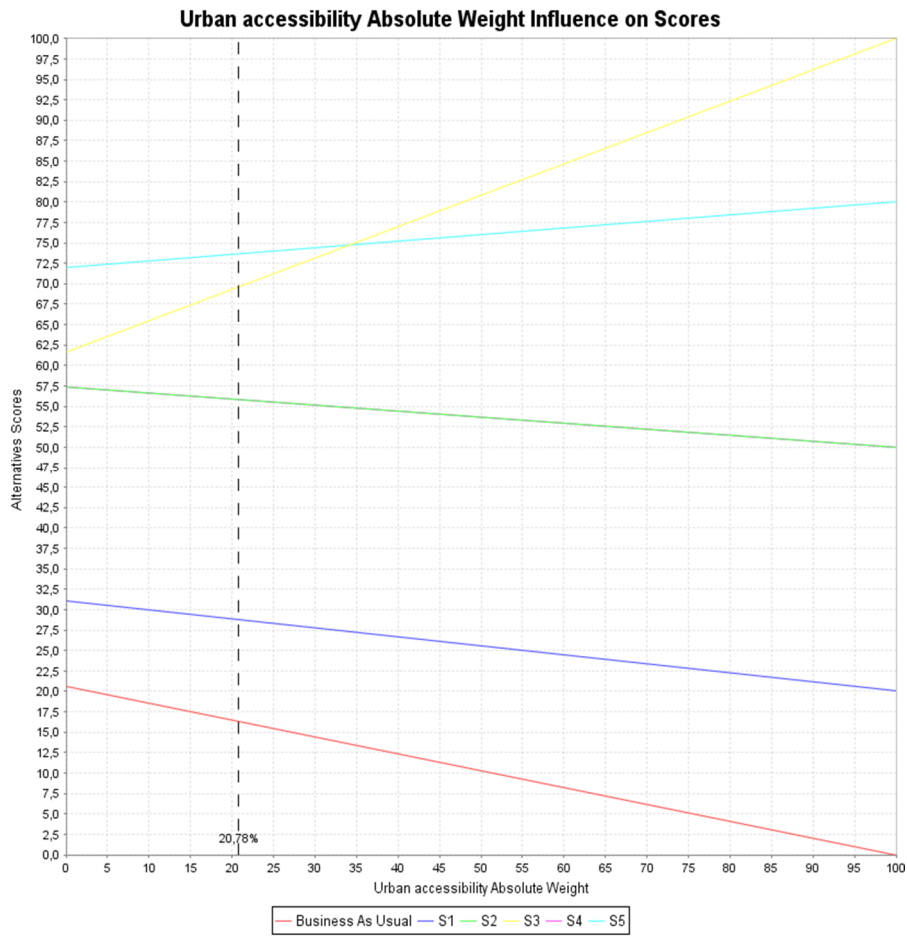


Figure 74: Evolution of the scores for noise nuisance - Citizens (Night deliveries)

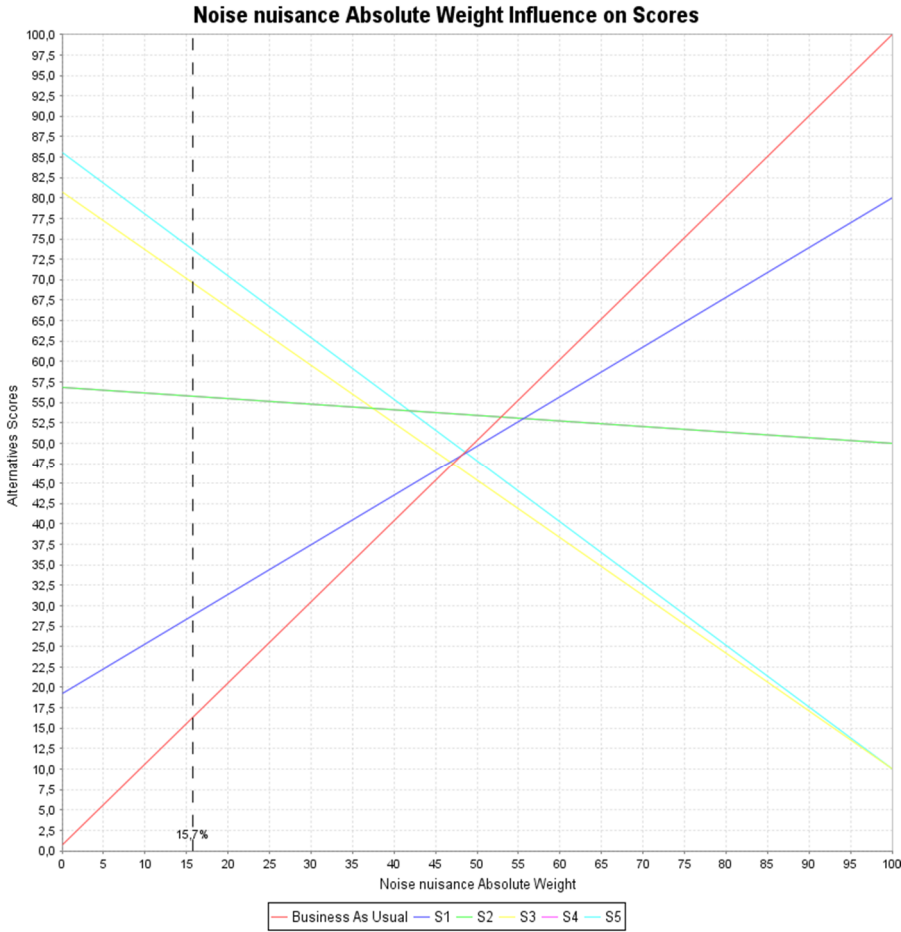


Figure 75: Evolution of the scores for social political acceptance - Local authorities (Night deliveries)

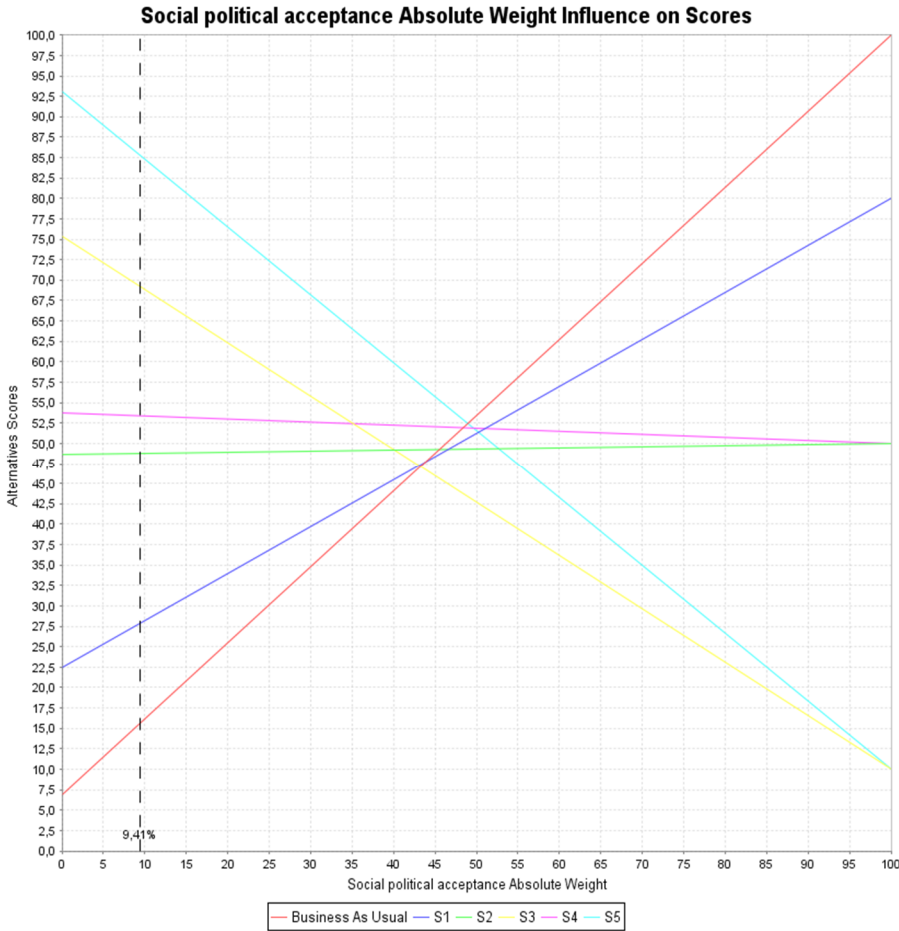
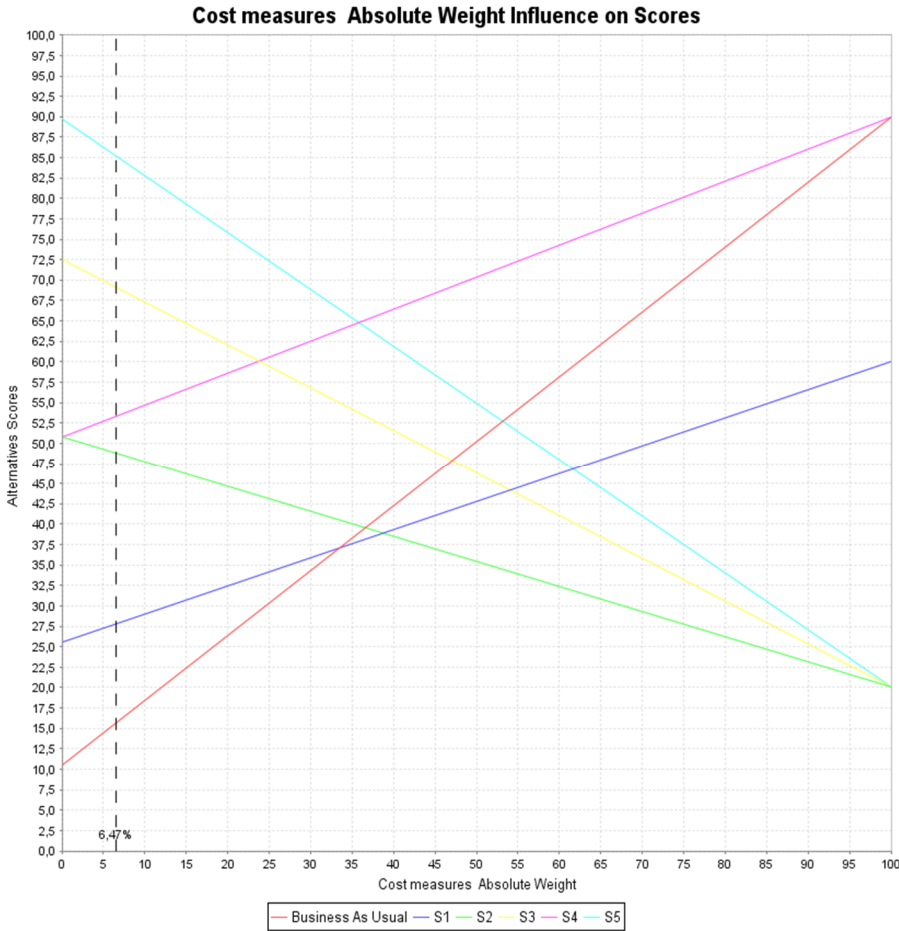


Figure 76: Evolution of the scores for cost measures - Local authorities (Night deliveries)



8

Conclusions, findings and discussion

8.1 Promising but challenging urban freight transport solutions: freight flow consolidation and off-hour deliveries

The observation that urban freight transport is responsible for a considerable part of the negative impacts linked to urban transport in general and the outlook that both the degree of urbanization and the number of urban freight trips will further increase lead to an increase in attention for last-mile transport from commercial as well as public actors. During the last 20 years, a range of initiatives have been researched, tested and implemented to reduce the negative impacts caused by urban freight transport. Two popular and permanently promising urban freight solutions are consolidating urban freight deliveries and shifting them to off-hours. Based on existing research and experiences it is believed that these two solutions can contribute to more sustainable urban freight transport. However, until today, both solutions are applied but not widespread in European cities. In the case of consolidation, there is a unilateral focus on urban consolidation centres of which extensive research into the topic demonstrated that they usually are not economically viable. A shift to more off-hour deliveries, on the other hand, is slowed down by the fear of noise nuisance for local residents and by the usually negative attitude of receivers towards off-hour deliveries.

The overall purpose of this dissertation is to identify feasible, consensual and successful applications of these two urban freight transport solutions. A twofold approach was adopted: (i) reassessing the generally accepted logic behind consolidation and shifting to off-hour deliveries as well as their impact and (ii) evaluating both concepts and/or innovative applications from the perspective of all stakeholders. The first approach was adopted to get beyond traditional solutions and stumbling blocks; the second originated from the observation that many authors call to involve all stakeholders when implementing urban freight measures but that traditional evaluation methods are not developed from that perspective. This gave rise to the following three research questions for this dissertation:

RQ1: How to consolidate urban freight flows in a way that it contributes to long-term sustainable urban goods distribution?

RQ2: How to shift urban deliveries to off-hours in a way that it contributes to long-term sustainable urban goods distribution?

RQ3: How to include stakeholders in the evaluation of urban freight concepts and applications?

The main body of this dissertation consisted of two main parts which can be linked to the first two research questions: the first part dealt with urban freight consolidation (Chapters 2-4) while the second part discussed shifting deliveries to off-hours (Chapters 5-7). The next section will synthesize the findings of the different chapters that contribute to answering the dissertation's first two research questions. The third research question is addressed across the two main parts by Chapters 4, 5 and 7 in which MAMCA (i.e. an evaluation method that was developed to include the stakeholder point of view) was applied. Based on the experiences from the three MAMCA evaluations done during this research, the next section will also formulate an answer to the third research question.

8.2 Findings

8.2.1 How to consolidate urban freight flows in a way that it contributes to long-term sustainable urban goods distribution?

Consolidating several small shipments destined for the same urban area in a single vehicle reduces the number of kilometres and therefore the negative impacts of urban freight transport. The question at stake is which consolidation approach to take when aiming for long-term sustainable urban freight transport. Today, the most applied solution is an urban consolidation centre (UCC) which is a warehouse where goods destined for an urban area are transhipped on UCC vehicles and then transported into the city. Previous research, however, clearly shows that most of these UCCs are not economically viable (Browne et al., 2005; van Duin, 2009). They remain popular, however, because of the supposed societal and environmental benefits linked to a decrease in the number of freight vehicle kilometres. The first contribution of this thesis to answering the first research question consists of analysing to what extent a UCC really contributes to decreasing the negative impact of urban freight transport by quantitatively reviewing 93 UCC impact assessments (**Chapter 2**). Below, the findings of **Chapter 2** are summarized on the basis of four sub research questions.

1. What is the impact of implementing a UCC on the number of urban freight vehicle kilometres?

Three quarter of the 93 UCC impact assessments we systematically reviewed quantified the impact of implementing a UCC on the number of urban freight kilometres. According to these assessments implementing a UCC has a positive impact on the number of urban freight vehicle kilometres: a decrease was observed by 79% of the ex-ante assessments and by all of the ex-post assessments. The median value of the measured impact on freight kilometres for the consolidated volume is -27% with a first quartile value of -53% and a third quartile value of -12%. A few assessments also measured the impact on freight kilometres for total urban freight traffic. For those assessments the median value is -1% with a first quartile value on -7% and a third quartile value of +3%.

2. What is the impact of implementing a UCC on loading rate, emissions, fuel consumption and number of freight vehicle journeys?

Despite the fact that one of the main motivations to start a UCC usually is to decrease the number of freight kilometres one quarter of the reviewed assessments did not quantify this impact. There are other impacts that are, to some extent at least, indicative for the impact on distance travelled. That is why impact on loading rate, emissions, fuel consumption and number of freight vehicle journeys were also recorded in our database. Again, not all reviewed assessments mention every impact. To be sure that our findings are based on a representative sample, we only discussed the impacts that were assessed by at least 10% of the assessments. We cannot take position on the impact of implementing a UCC on urban freight vehicle loading rates, for example since only 7 out of 93 impact assessments quantified this impact. All ex-post assessments observed a positive impact on freight vehicle journeys and on CO₂, CO, NO_x and PM₁₀ emissions and 93% observed a positive impact on energy consumption. For the ex-ante assessments, the picture is more diverse. All or nearly all impact assessments measured a decrease in air pollution (NO_x, CO and PM₁₀) whereas only half of them measured a decrease in greenhouse gas emissions (CO₂). Two third of the impact assessments measured a decreased energy consumption and less than half (44%) measured a decrease in the number of freight vehicle journeys.

3. Which UCC characteristics influence whether the impact of a UCC is assessed positive or negative?

The observation that some UCCs aim to attract urban receivers as their clients (and not only LSPs or shippers) and the fact that there is a growing interest to use alternatively powered vehicles that are usually smaller than the ones used before the UCC was implemented motivated our review of UCC impact assessments since it might increase the number of urban freight kilometres instead of decreasing it. Using Fisher's exact test we did not find a statistically significant relation between the type of UCC vehicle or UCC customer and the assessed impact which means that whether the impact on urban freight kilometres of implementing a UCC was positive or negative was not influenced by the type of vehicle used or by the type of customer. However, the box plot showing the distribution of the impact on freight kilometres whilst differentiating between receivers as customers or other actors as customers shows a considerable difference in median value suggesting that the type of UCC customer does affect how big the impact of the UCC is. The box plot showing the relation between fuel type of UCC vehicles and impact of a UCC reveals that when traditionally fuelled vehicles are used the number of freight trips decreases considerably. That decrease is doubtful when UCC vehicles are alternatively powered.

4. Which impact assessment characteristics influence whether the impact of a UCC is assessed positive or negative?

For all impact assessment that (partially) explained the methodology that was used it was recorded whether or not the assessment was (partly) based on (i) real-time measurements/observations, (ii) estimations, (iii) calculations using impact factors and/or (iv) urban freight modelling. These subcategories were not decided on in advance, they were developed during the data extraction based on the observed methods and the level of detail in the reviewed publications. Using real data and using urban freight modelling suggests a more thorough approach compared to using estimations and calculations with (estimated) impact factors. Using Fisher's exact test we found a statistically significant relation between a positive impact on the number of freight kilometres for the consolidated volume and the use of urban freight modelling and the use of real data. When these more thorough approaches were used it is less likely that the impact assessment measured a positive impact. When real data were used, 66.67% of the impact assessments measured a decrease in the distances travelled whereas all impact assessments measured a decrease when no real data were used. When some modelling was used to assess the impact, 77.78% of the assessments measured a decrease in the distances travelled whereas all impact assessments measured a decrease when no modelling was used. Using a threshold of 0.05 Fisher's exact test suggests that there is not a statistically significant relation between a measured decrease in the number of freight kilometres for the consolidated volume and whether or not the publication explains the assessment method used.

The observation that it is difficult to find a viable business model for UCCs and that the impact on freight kilometres for total urban freight traffic is limited leads to question whether there exist alternative consolidation oriented urban freight transport solutions. The second contribution of this thesis to answering the first research question consists of a review of existing classifications of urban freight measures for consolidation oriented solutions and of a scan of urban freight transport practice for already implemented examples of alternative urban freight consolidation (Chapter 3). Below, the findings of Chapter 3 are summarized on the basis of two sub research questions.

5. How did the position of urban freight consolidation evolve within the research domain of urban freight transport?

Reviewing classifications of urban freight measures revealed that within the literature and research on urban freight transport consolidation is not considered as a stand-alone concept (Browne et al., 2007; Munuzuri et al., 2005; Russo & Comi, 2009; Quak, 2008). In each of these classifications the different measures that aim to better consolidate urban freight flows are spread over multiple categories mainly because the break down into categories is not based on the final goal of the suggested actions but on their impact. Reviewing a number of European research projects on urban freight transport revealed that one particular consolidation oriented measure (i.e. implementing a UCC) has been receiving considerable research attention whereas other consolidation oriented measures were only treated superficially. Furthermore, although reducing the negative impacts of urban freight operations gained in importance, the more recent the research project, the less attention it pays to alternative consolidation concepts. COST 21, for example, dates back from 1999

and identified 56 theoretically feasible measures of which 13 are, at least to some extent, consolidation oriented. Civitas which is the most recent European research project that was reviewed (dd. April 2011), on the other hand, considered UCCs as a separate type of urban freight measures but did not test or implement any other consolidation oriented concept.

6. What would be a suitable classification system for consolidation-oriented tools, measures and initiatives?

We developed a classification system for consolidation-oriented tools, measures and initiatives by analysing existing examples of freight consolidation (whether applied on an urban scale or on a larger scale). The first and most important distinction to be made is based on how the existing inefficiencies are tackled: by working a way around them or by addressing the root causes. The most important reason for urban freight inefficiencies is the fact that retailers and carriers are not obliged to confer and cooperate because of the lack of contractual obligations between them. The first type of consolidation oriented measures avoids empty urban kilometres by adding an additional transshipment point to the supply chain. We called them physical consolidation concepts. It can be a traditional UCC on the outskirts of the city centre in which the local government plays a key role or any other additional transshipment point. The second type of measures is characterised by receivers and/or carriers changing their behaviour. We called them behavioural consolidation concepts. When these concepts require behavioural change of only one type of stakeholder, we called them horizontal behavioural consolidation concepts. When vertical consultation and cooperation within the supply chain is needed, we called them vertical behavioural consolidation concepts. The case examples confirmed that the main stakeholders to be addressed with these behavioural consolidation concepts are carriers and receivers.

The third contribution of this thesis to answering the first research question consists of evaluating one example of an alternative consolidation oriented solution. A Mobile Depot is a trailer fitted with a loading dock, warehousing facilities and an office. It can be used as a mobile inner city base from where last-mile deliveries and first-mile pick-ups are done with electrically supported cyclocargos. In **Chapter 4**, the impact of and stakeholder support for using a Mobile Depot for inner city express deliveries was assessed. Below, the findings of **Chapter 4** are summarized on the basis of two sub research questions.

7. What was the impact of the three month Mobile Depot trial of TNT Express in Brussels?

TNT Express used a Mobile Depot for a period of three months (May 2013 – August 2013) to do their pick-ups and deliveries of parcels and documents in postal code areas 1030, 1040 and 1210 in the city-centre of Brussels. Regular TNT Express deliveries and pick-ups are carried out from their depot at the Brussels freight airport by van. During the pilot, the Mobile Depot was loaded with all deliveries destined for the pilot area at the depot and then driven to a predefined central location. From there, the final deliveries were carried out by four electrically driven cyclocargos. TNT succeeded in integrating the concept in their operational structure in Brussels. Even though the punctuality dropped from 95% to 88%, there were no complaints by senders or receivers about this new way of working. Emissions of pollutants dropped significantly, from 24% for CO₂ up to 99% for PM_{2.5} emissions. The number of diesel kilometres decreased from 1291 van kilometres per week to 141 weekly truck kilometres. It remains unsure, however, whether and how TNT can further operationalize the Mobile Depot. Dispatch riders prefer working from their own depot instead of from the Mobile Depot. Planners of TNT also prefer to work with vans, mainly because the Mobile Depot solution is more expensive. Apart from the investment cost, which was partly covered by the European Commission through the STRAIGHTSOL project, operations during the demonstrations were 2 times more expensive than the regular operations.

8. Would there be stakeholder support for possible future Mobile Depot scenarios in Brussels?

To be able to fully assess whether the Mobile Depot concept can face the future with confidence we compared stakeholder support for business as usual (BAU), the TNT Express Mobile Depot trial in Brussels and five possible future Mobile Depot scenarios by means of Multi Actor Multi Criteria Analysis (MAMCA). Based on this analysis it can be concluded that the objectives of commercial stakeholders (i.e. TNT Express, shippers and receivers) are fairly well addressed by BAU while the objectives of public

stakeholders (i.e. citizens and local authorities) are better addressed by the Mobile Depot scenarios. Overall, the pilot as it was carried out does not score well for any of the stakeholders. The future scenarios differ from BAU, the pilot and each other in the capacity at which one or more Mobile Depots are used (0%, 40% and 90%), whether Brussels has a congestion charging scheme (0.00, 1.00 or 2.40 € per km) and whether the Mobile Depot is used for TNT Express deliveries and pick-ups exclusively or also for parcel and document deliveries and pick-ups of other express service providers. The congestion charge scenarios (with one Mobile Depot used at 90% of its capacity) best address the combined objectives of all stakeholders. The scenario with the best chance of a consensus, however, is the scenario where nothing is changed to the pilot except that the Mobile Depot is used at 90% of its capacity instead of at 40%. A further analysis of the individual stakeholders shows that the viability of investment and profitable operations criteria of TNT Express have to be met better for the Mobile Depot concept to become really interesting. The analysis of the scenarios shows that this can be done by using the Mobile Depot at full capacity and by increasing the drop density. The MAMCA also showed that when using the Mobile Depot, TNT Express does create benefits for the other stakeholders for which it is not compensated. Internalising the external costs could do that for example.

8.2.2 How to shift urban deliveries to off-hours in a way that it contributes to long-term sustainable urban goods distribution?

Off-hour deliveries are deliveries taking place outside regular business hours when there is no or little traffic congestion. Shifting deliveries to off-hours takes away vehicles from peak-hour traffic. At the same time, transport operations are not slowed down by peak-hour traffic. Despite these benefits, it appears difficult to induce such a shift because of the negative attitude of receivers towards off-hour deliveries (Holguin-Veras et al., 2012) and the possible noise nuisance for local residents (Douglas, 2011). The question at stake is how to shift urban deliveries to off-hours in a way that all stakeholders perceive the advantages of the shift to be greater than the disadvantages. The first contribution of this thesis to answering the second research question consists of identifying urban off-hour delivery stakeholders and evaluating Belgian stakeholder support for urban off-hour deliveries by means of MAMCA (Chapter 5). Below the findings of Chapter 5 are summarized on the basis of two sub research questions.

1. Which stakeholders are affected by a shift to urban off-hour deliveries?

Traditionally, in urban freight transport, two types of stakeholders are distinguished: public and commercial stakeholders. Most authors addressing the topic of urban freight stakeholders identify three main commercial stakeholders: receivers, logistics service providers and senders and two main public stakeholders: local authorities and citizens (See for example Ogden, 1992; Munuzuri et al., 2005; Taniguchi & Tamagawa, 2005; Taylor, 2005; Witlox, 2006; Quak, 2008; Behrends, 2011; Russo & Comi, 2011; Stathopoulos et al., 2011; Lindholm, 2012; MDS Transmodal Limited, 2012; Ballantyne et al., 2013; Lindholm & Browne, 2013; Ystmark Bjerkan et al., 2014). In our research into stakeholder support for urban off-hour deliveries in Belgian cities we identified four slightly different stakeholder groups based on mutually divergent and coinciding objectives of the traditional stakeholder groups when it concerns off-hour deliveries. First, we considered receivers to be a main stakeholder since their attitude is a decisive success factor for a shift to off-hour deliveries (Holguin-Veras et al., 2005). In the second stakeholder group we grouped carriers and logistics service providers together with suppliers and transshipment points since their objective coincide when it concerns urban off-hour deliveries. We called this group 'transport sector'. The third stakeholder group, which we called society a whole, comprises both the local authorities and the people living, working and spending leisure time in the urban space as their objectives also coincide when it concerns urban off-hour deliveries. Finally, we identified truck drivers and employees working in shops, at the port, in distribution centres etc. as a separate stakeholder because the working environment of these employees considerably changes when deliveries are shifted to off-hours. As part of the evaluation of off-hour deliveries to Brussels supermarkets, we reviewed the impact assessments of 33 off-hour delivery trials that took place in Europe and North America between 1966 and 2014. This review revealed the dominance of noise-related indicators, followed by time and fuel consumption indicators. There is much less consensus on the other indicators that must be measured when assessing off-hour deliveries. When we matched the 65 identified indicators to one or more stakeholders, we observed that the traditional urban distribution stakeholders are also relevant when assessing off-hour deliveries: sender, receiver, LSPs, citizens and (local)

authorities. Two remarks can be made. First, it appeared that every indicator that is relevant for one of the other stakeholders is also relevant to the (local) authorities, depending on the policy choices that the authorities have made. Second, especially because of the issue of noise nuisance, it might be better to split the stakeholder group 'citizens' into stakeholder citizens and stakeholder local residents.

2. Would there be stakeholder support for possible future off-hour delivery scenarios in Belgium?

We used MAMCA to evaluate stakeholder support for a shift to more urban off-hour deliveries in Belgium. Eighteen representatives of the four stakeholder groups we identified were asked to list their objectives, to allocate weights to these objectives and to score five off-hour scenarios on a scale of -2 to +2 for each objective. The scenarios put up for evaluation represent extreme situations: all deliveries take place during the day (7am – 7pm), during the night with or without noise standards and a subsidy scheme for the development of silent equipment (7pm – 7am), in the evening (7pm – 11pm) or in the early morning (3am – 7am). MAMCA led to conclude that stakeholder support for a shift to off-hour deliveries is rather low. Employees prefer deliveries to be carried out by day because they feel that a shift to another time of day would be bad for their health, social life and safety which are their three most important criteria. Receivers also prefer day deliveries because they think it is cheaper, safer and preferred by their employees. They do think, however, that a shift to night deliveries would create a more attractive urban environment. As opposed to employees and receivers, the transport sector prefers night deliveries mainly because they feel that such a shift would reduce costs which is their most important objective. Finally, stakeholder group society also prefers night deliveries but only when there would be noise standards and a subsidy scheme to develop silent trucks, trailers and rolling stock. The mono-actor analysis for this stakeholder revealed that off-hour deliveries are considered to be negative for noise nuisance and the social component, but considered positive for traffic safety, emission of pollutants, congestion and visual nuisance and the efficiency of urban distribution.

The majority of urban deliveries take place by day. However, about 4 to 14% of deliveries already take place during off-hours (Allen et al., 2008) and they don't seem to be hindered by the traditional stumbling blocks for off-hour deliveries. The second contribution of this thesis to answering the second research question consists of analysing existing off-hour deliveries to identify freight flows that are particularly suited to be shifted to off-hours (**Chapter 6**). To facilitate this analysis, a framework to systematically describe and classify types of freight flows was developed. Below the findings of **Chapter 6** are summarized on the basis of two sub research questions

3. What would be a suitable framework to systematically describe and classify types of freight flows?

Several authors have developed a framework or model to structure and capture all aspects of (urban) freight transport. As such, these frameworks and models are not fit to systematically describe and classify urban freight flows. However, because they address urban freight transport, they all touch upon aspects that can be linked to urban freight flows. We used the existing frameworks and models as starting point to identify components that characterize urban freight flows: (i) product characteristics, (ii) urban agent characteristics, (iii) external factors, and (iv) transport characteristics.

4. Which urban freight flows are more suited to be shifted to off-hours?

To identify which urban freight flows are more suited to be shifted to off-hours, we reviewed the literature on urban off-hour deliveries and we interviewed 41 general and logistics managers of companies that are already involved in off-hour deliveries. We could extract 19 indicators of successful freight flows shifts to off-hours from the literature. A limited shelf life, for example, was frequently mentioned as a product characteristic influencing the decision to provide deliveries during off-hours because it saves valuable time. The following four product characteristics were also mentioned: the value of the goods, need for proof of delivery, need for exceptional transport and industry segment. For the urban agent characteristics, we found that receivers are afraid of having to make additional investments to be able to receive off-hour deliveries. Therefore, the existing (un)loading infrastructure, company size and operational hours play a role in the decision to shift deliveries. The following two indicators are also mentioned: the location and number of deliveries per week. The transport characteristics influencing the suitability of shifting an urban freight flow to off-hours are linked to the relationships among senders, receivers and carriers. Usually, receivers and carriers are not contractually bound, which hampers off-hour

deliveries. Any situation in which there is a closer relationship between receivers and carriers is favourable to off-hour deliveries, e.g., a private carrier and integrated sender-receiver operations. The demand for off-hour deliveries by receivers, carrier fleet and union regulations also influence the suitability of off-hour deliveries. Finally, there are also factors outside the logistics chain that influence shifting deliveries to off-peak hours. These factors are usually policy related, such as the following three examples: stimulating measures, banning measures and noise legislation. Only three of the 19 indicators identified from the literature were also mentioned during the interviews. Many of the interviewees considered the need for proof of delivery important when conducting off-hour deliveries. The second indicator they referred to is the value of the goods because they perceive an increased risk of robbery at night. Finally, the location of the receiver was considered important, albeit with a clear focus on the noise nuisance the deliveries might cause. Other indicators were not explicitly mentioned by the interviewees but were described when they explained their roles in the supply chain and experiences with off-hour deliveries, such as company size, shelf life, relationships among senders and private or for-hire carriers and receivers. Finally, indicators, such as operational hours, loading and unloading infrastructure and vehicles were not mentioned because they are less important than was assumed in previous research.

The third contribution of this thesis to answering the second research question consists of evaluating one example of a shift to off-hour deliveries. In **Chapter 7**, the impact of and stakeholder support for a shift of Brussels supermarket deliveries to off-hours was evaluated. Below, the findings of **Chapter 7** are summarized on the basis of two sub research questions.

5. What was the impact of the four week off-hour deliveries trial to Brussels supermarkets?

A large Belgian retailer shifted at least one delivery per day to two supermarkets in Brussels to off-hours for a period of two weeks. During the pilot program, 42 delivery trips (taking place at different times of the day) were monitored, noise measurements were carried out and stakeholders were interviewed. These data allowed a mutual comparison of early morning (6 am-8 am), day (8 am-8 pm), late evening (8 pm-10 pm) and night (10 pm-6 am) deliveries on a set of indicators. A first conclusion to be drawn is that the average speed during the night was nearly 50% higher than during the day. The data also clearly show the impact of traffic congestion: trips to the shops during the early mornings were quite fast, while the trips away from the shop were slow. A second observation is that at night, it took a driver 15% longer to unload. The differences between early morning, day and evening deliveries were not significant. Third, we observed that the average fuel consumption during the day trips was 14% higher than during the night trips. The noise measurements revealed that the noise produced during unloading operations could hardly be discerned from the ambient noise and was well within the Noise Abatement Law of the Brussels-Capital Region. The noise produced during the manoeuvring of the truck, however, exceeded the permissible noise limits. Finally, interviews with different types of employees revealed that drivers had a clear preference for night deliveries, while members of shop staff preferred morning deliveries.

6. Would there be stakeholder support for shifting Brussels supermarket deliveries to off-hours?

Identifying stakeholders, their criteria and the weights they attach to these criteria combined with the results of a mutual comparison of early morning, day, late evening and night deliveries allowed us to carry out a MAMCA. A first conclusion is that a shift to off-hour deliveries to supermarkets in Brussels should be capable of receiving overall support. All of the stakeholders ranked the different scenarios more or less the same, and there were no scenarios that scored very high for one stakeholder and very low for another. The graph also shows that the scenarios with a high proportion of night deliveries received a high score. The retailer preferred the scenario with the even spread throughout the day, while the other two stakeholders preferred more morning deliveries. The mono-actor views of the citizens and local authorities revealed that the noise that is produced remains an important aspect if more deliveries will be shifted to the night. The mono-actor view for the retailers revealed that a shift to night deliveries is only interesting for the retailer when he can do it on a large scale. Overall, the main lesson is that there is good potential to shift some deliveries to supermarkets to off-hours.

8.2.3 How to include stakeholders in the evaluation of urban freight concepts and applications?

Evaluating measures and solutions allows to gain knowledge and new insights which supports deliberate decisions on whether to implement a measure or solution, proceed with it, adjust it or just stop it. For transport related projects commonly used evaluation methods are: private investment analysis (PAI), cost effectiveness analysis (CEA), economic-effects analysis (EEA), business model analysis (BMA), social cost-benefit analysis (SCBA), the multi-criteria decision analysis (MCDA) and the Multi Actor Multi Criteria Analysis (MAMCA) (Macharis et al., 2009; Osterwalder & Pigneur, 2010). The first four only take into account economic criteria for the analysis whereas the latter three also make it possible to include societal and environmental criteria in the evaluation. MAMCA differs from the other evaluation methods by explicitly accounting for the objectives of the stakeholders who are involved in and/or affected by the decision-making process. The methodology was developed by Macharis (2000, 2005 and 2007) and is an extension of the traditional MCDA (Fandel & Spronk, 1985; Guitoni & Martel, 1998). MAMCA develops a separate value tree for each stakeholder instead of only one value tree for all stakeholders. The method has been applied to evaluate various transport-related decision making problems (for an overview, see Macharis et al., 2009). The fact that so many different stakeholders with often conflicting objectives are involved in urban freight transport suggested that MAMCA would also be a suitable evaluation method for urban freight transport projects and that the stakeholder perspective would offer added value to urban freight transport research. Until now, however, the method was not applied in this field.

In the research for this dissertation MAMCA was applied three times. First, to evaluate whether there would be support for a shift to urban off-hour deliveries in Belgian cities. A MAMCA was done combining the views of four main stakeholders based on the outcome of interviews with 18 stakeholder representatives and evaluating five rather general off-hour scenarios. The second MAMCA also evaluated stakeholder support for a shift to off-hour deliveries but compared more detailed scenarios on a shift of one large retailer's supermarket deliveries in Brussels. The data that were collected during a two week pilot program in two supermarkets provided input for this MAMCA. Finally, MAMCA was also used to evaluate a larger-scale implementation of the Mobile Depot concept that was tested in Brussels by TNT Express for a period of three months. Again, the data that were collected during this pilot were used as input.

MAMCA consists of seven steps. In the fifth step, any MCDA can be used to evaluate the different strategic alternatives (Macharis et al., 2009). Especially the second generation multi-criteria analysis methods (the Group Decision Support Methods (GDSM)) such as PROMETHEE, the Analytical Hierarchy Process (AHP) method and ELECTRE are well suited because they can incorporate the multi-stakeholder concept (Macharis et al., 2009). In our research we used the AHP method and the PROMETHEE-GDSS method, which is a powerful extension of the PROMETHEE method. The MCDAs were done by someone more experienced in MCDA (Annelies Heemeryck and Ellen van Hoeck for the research on stakeholder support for off-hour deliveries in Belgian cities and Lauriane Milan for the research on stakeholder support for the MD and for a shift to off-hour supermarket deliveries). For all three MAMCAs in this dissertation I was responsible for the other six steps the method consists of. Based on that work and the evaluation results, there are four aspects of MAMCA confirming that this is a suitable way to include stakeholders when evaluating urban freight transport projects.

First, MAMCA transfers the idea that it is important that public and commercial urban freight stakeholders confer and co-operate (Browne et al., 2003; OECD, 2003) into an evaluation method. The evaluation methods that primarily evaluate from an economic perspective focus on commercial urban freight stakeholders. MCDAs and SCBAs combine the point of views of public and commercial stakeholders by evaluating on a range of indicators of which some are primarily important to public stakeholders. However, they use a top-down approach. It is the evaluator who decides which aspects are assessed and which are not. MAMCA, especially in the way it was used in this research takes a bottom-up approach by asking the stakeholders which criteria they use to evaluate an urban freight transport measure. Each time, a representative group of stakeholders were presented a list of criteria which was based on the literature on the topic and, for the Mobile Depot and for the off-hour deliveries to supermarkets, on prior consultations with representatives of that stakeholder group. They were asked if, according to them, criteria had to be added to that list. The majority did not want to add criteria, however. Only for the evaluation of a shift to off-hour deliveries in Belgian cities, some interviewees chose to add additional criteria.

Second, the method thoroughly incorporates the perspective of all stakeholders since it consists of a series of MCDAs, one for each stakeholder, which are then brought together. As long as all relevant stakeholders are listed at the start of the evaluation, the method provides the opportunity to all consider them equally important. Applying the method once again confirmed that the different stakeholders and their points of view are addressed extensively by the existing research. However, different authors identify different stakeholders depending on the perspective of their publication (e.g. economic or not) or the type of measure under consideration (See Section 1.2 on p. - 7 -). And even for one specific type of measure, the stakeholders to take into consideration can differ. When evaluating stakeholder support for more off-hour deliveries in Belgian cities, we considered employees to be a separate stakeholder group since it was expected that a shift to off-hour deliveries would considerably change their working conditions. The results of the analysis proved us right. The multi-actor view of the MAMCA (Figure 51) shows that the point of view of the employees is very different from the point of view of the other stakeholders. When evaluating shifting supermarket deliveries to off-hours, we did not consider employees to be a separate stakeholder group despite the fact that it also concerns off-hour deliveries in a Belgian city. This was motivated by the fact that it concerns supermarket deliveries: operations in the distribution centres of the retailer do not have to be changed to allow off-hour deliveries, deliveries in the shop can be done unattendedly and interviews with individual truck drivers had revealed that some of them prefer off-hour deliveries because it causes them less stress. That is why, in this particular case, it sufficed to incorporate the point of view of employees in the point of view of their employer as the criterion: 'employee satisfaction'.

Third, MAMCA also incorporates the idea that it is not necessary that a successful measure only has positive impacts. According to Ystmark Bjerkan et al. (2014) it suffices that each stakeholder perceives the advantages of a measure to be greater than its disadvantages. Two of the MAMCAs we did were fed by the results of a before-after impact assessment of an urban freight transport pilot. Both assessments identified positive and negative impacts. The assessment of the Mobile Depot, for example, revealed a positive impact on the number of urban freight diesel kilometres but a negative impact on the operational costs (See Section 4.5.4 on p. - 77 -). These results make it difficult to judge whether implementing a Mobile Depot, overall, is a good idea. MAMCA captures this idea of comparing advantages and disadvantages for each stakeholder by expecting them to allocate weights to their criteria and by taking these weights into account when evaluating the alternatives for the separate stakeholders.

In MAMCA, any MCDA method can be used for the evaluation which eventually leads to a classification of the evaluated alternatives (Macharis et al., 2009). More important than the ranking, however, is to identify the critical stakeholders and to gain insight in what are the main stumbling blocks for the different alternatives (Macharis et al., 2009). However, because of the ranking, the different visualisations of MAMCA results (or MCDA results) invite to consider the highest ranked alternative as the best alternative. We tried to counter that issue by no longer including an overall ranking in the multi-actor views (Hadavi & Macharis, 2015). The visualisation of the results of the MAMCA to measure stakeholder support for off-hour deliveries in Belgian cities (analysis done in 2009) still depict an overall ranking (See Figure 51) whereas the visualisations of the other two MAMCAs (analyses done in 2014) do not anymore (See Figure 20 and Figure 60).

Fourth, opposite to SCBA, how a certain scenario scores on a certain indicator does not have to be expressed in monetary terms. Furthermore, since MAMCA is an extension of MCDA, it also allows the inclusion of qualitative criteria (Macharis et al., 2009). Mainly because of the public stakeholders in the field of urban freight transport it can be difficult to quantify all indicators. What is, for example, the value or quantified impact of decreased visual nuisance? Second, when an analysis is based on a short-running pilot, it can be difficult to accurately quantify long-term impacts, even if the indicator as such would permit it. A two-week pilot on off-hour deliveries to supermarkets, for example, would not observe a statistically significant impact on traffic safety because the sample of monitored trips is too small.

Applying MAMCA to urban freight transport measures has not only confirmed that the evaluation method is suited to include stakeholders when evaluating this type of measures but has also led to additional insights. First, the weights stakeholders attach to their criteria do not always completely capture their attitude towards the different alternatives. Sometimes stakeholders prefer to keep things as they are because the alternatives score worse than BAU on one particular indicator. This one criterion is their driver for change. In the mono-actor view for TNT Express (Figure 21), for example, we see that the lower toll scenario (S3) receives a relatively high overall score just under the score BAU receives. Based on these results, you could expect that this scenario is not very far from being a valuable

option for TNT Express and might even be better than BAU if it scored slightly better on any of TNT Express' criteria. However, interviews with TNT Express revealed that they would not be inclined to implement an MD if operational costs were higher compared to BAU, irrespective of the impact of implementing an MD on their other criteria.

A second observation is that stakeholder groups often are less coherent than they seem. The overall goal of local policy makers, for example, would be to provide the best living and working conditions possible. However, there are different aspects to that objective and depending on which political party is in power or which administration is asked, different weights would be attributed to these different aspects. The MAMCA evaluating stakeholder support for off-hour deliveries to supermarkets, for example, revealed that despite the fact that, in general, the off-hour scenarios score better than BAU for the stakeholder 'local authorities', the Environmental Department of the Brussels-Capital Region is against a shift because of the possible noise nuisance for local residents. Something similar was observed for the stakeholder 'employees'. For the MAMCA evaluating support for a shift to off-hour deliveries in Belgian cities, we interviewed unions of which we can assume that they represent employees. It appeared that they are very negative attitude towards more night work for drivers. For the other MAMCA on off-hour deliveries the drivers themselves indicated that they prefer off-hour deliveries and night work because there is much less stress involved for them and the drivers we interviewed were not only drivers who already work at night. This confirms one of the lessons learned by Holguin-Veras et al. (2014) that the attitudes expressed by the interviewed or surveyed stakeholders are likely to present only a portion of the whole stakeholder group.

A third observation is that there is no conclusive list of urban freight transport stakeholders that is always applicable. Which stakeholders to take into account highly depends on the type of solution that is evaluated and on local context. Despite the similar context (Belgium and Brussels) and only two types of solutions (consolidation and off-hour deliveries), we distinguished different stakeholder groups for the three stakeholder support evaluations in this PhD research. For the Mobile Depot demonstration, we identified five different stakeholder groups: the traditional three supply chain stakeholders on the one hand (shippers, transport operators and receivers) and citizens and local authorities on the other hand. We chose to separate citizens and local authorities because local authorities are supposed to defend the interests of both their citizens and companies located in their city when taking decisions. Furthermore, they also have interests of their own which are not always directly related to urban freight transport but have to be kept in mind, e.g. the feasibility and cost of enforcing a measure. Also the two MAMCAs on off-hour deliveries consider different stakeholder groups. The MAMCA evaluating support for a shift to off-hour deliveries in Belgian cities does not distinguish between local authorities and citizens and considers society as a whole. The alternatives in this MAMCA are rather general and do not imply government intervention which is why we assumed objectives of different types of urban space users and the governments to be very similar. This was also confirmed afterwards when mutually comparing the input of the different representatives of this stakeholder group. We did consider 'employees' to be a separate stakeholder group because a structural shift in Belgium to off-hour deliveries would impact their working conditions. In the final MAMCA, only three stakeholder groups were considered. The retailer integrates sender-carrier-receiver operations which means he is the only supply chain stakeholder. For the same reason as for the Mobile Depot demonstration, local authorities and citizens were regarded as separate stakeholder groups. Finally, employees were not regarded as a separate stakeholder group because earlier experiences with off-hour supermarket deliveries demonstrated that some drivers are in demand for more off-hour trips. However, employee satisfaction was integrated in the objectives of the retailer. For all three evaluations, the followed approach to identify stakeholders was similar and based on a thorough literature review, a detailed definition of the different alternatives and discussions with local actors. The three examples in this PhD thesis demonstrate that there is no generic list of urban freight transport stakeholders, even if the local conditions or proposed solutions are similar. The overview of stakeholders cited in Chapter 1 (See Section 1.2 on p. - 7 -) is very useful though as an overview of possible stakeholders to consider. Based on the results of this PhD research, I would suggest adjusting this list of possible urban freight stakeholders. First, the results of the MAMCA on shifting supermarket deliveries to off-hours exposed the possible need to differentiate between local residents and citizens in general since they can experience a completely different impact from the same solution. Second, the existing list of urban freight transport stakeholders does not mention employees while in some cases it is important to also take into account their point of view.

8.3 Discussion

The previous section listed the outcomes of this PhD research into feasible, consensual and successful applications of urban freight flow consolidation and urban off-hour deliveries. This section will explain how these findings contribute to urban freight transport research and what they mean for public policy in this field. To conclude, the most important limitations of the study will be described together with future research opportunities this research gave rise to.

8.3.1 Contribution to urban freight transport research

A considerable part of the research into urban freight transport consists of evaluations of real-life tests of urban freight transport solutions to gain insight in whether they are valuable solutions (See for example van Rooijen & Quak, 2010; Holguín-Veras et al., 2011; Leonardi et al., 2012). This PhD research assessed the impact of two innovative pilots on a selection of indicators that are commonly used in this field of research. The first assessment revealed that using a Mobile Depot at 40% of its capacity for the deliveries and pick-ups of one express service provider in an area of just over 12 square kilometres in Brussels decreases the amount of emitted pollutants and the number of diesel kilometres but doubles the operational costs for the express service provider. The second assessment observed considerable time and fuel savings, and therefore also a decrease in the emission of pollutants, when supermarket deliveries to two shops in Brussels were shifted to off-hours. The same assessment also revealed that truck drivers prefer off-hour deliveries and that members of shop staff prefer morning deliveries. Noise measurements which were carried out by an independent acoustic engineering company demonstrated that the evaluated unloading operations do not cause noise nuisance to local residents but also the noise produced by manoeuvring trucks is not within the Noise Abatement Law of the Brussels-Capital Region, even by day. Both pilots were innovative and relevant for urban freight transport research. The Mobile Depot was a new concept developed by TNT Express and implemented for the first time in Brussels. In the research into off-hour deliveries, multiple pilots were launched and evaluated earlier. However, several of them were not evaluated on such a broad set of indicators (See for example Niches, 2006; Freight Transport Association, 2009) and despite the fact that the fundamental tenets seem to be of general value, research results cannot just be transferred from one city to another because of specific local conditions (Holguin-Veras et al., 2014).

The second contribution to the research field of urban freight transport is that this PhD research introduced the concept of stakeholder involvement in the evaluation of urban freight transport solutions. From 2003 on, several authors have been pointing out that for an urban freight initiative to be successful, public and commercial stakeholders should confer and co-operate (Browne et al., 2003; OECD, 2003). Despite the fact that this idea has been put into practice with, for example, Public-Private Partnerships for UCCs (e.g. UCCs of Bristol, Stockholm and Padua) or Freight Quality Partnerships (Allen et al. (2010) identified 87 in the UK), it had not been transferred to the evaluation of urban freight transport measures. In this PhD research we used MAMCA which is an evaluation tool that explicitly includes the goals and objectives of all stakeholders. So far, the method had not been applied in the field of urban freight transport research. The method does not only evaluate from the perspective of the different stakeholders, it also incorporates the idea that it is not necessary to find solutions that only have positive impacts but that it suffices that the balance between positive and negative impacts skews towards the positive for each stakeholder separately (Ystmark Bjerkan et al., 2014). This is achieved by asking stakeholders to allocate weights to their criteria and by taking these weights into account when evaluating the different alternatives. Despite the fact that this is not the focus of my PhD research, using MAMCA also provided added value to the research into evaluation methods by pointing out that there can be one criterion that is considered as a driver for change which is not always captured by how stakeholders allocated weights to their criteria.

Third, this research shifted the focus from a UCC as the only solution to come to consolidation of urban freight flows to a range of other possible consolidation approaches. Combining freight into fewer vehicles to increase loading rates of freight vehicles driving around in cities is one of the basic principles of coming to a more sustainable urban freight transport system. However, over time, this evolved in a unilateral focus on UCCs. Also other consolidation oriented measures exist, but these have not been receiving much attention so far. The contribution of this research is that it identified all types of possible consolidation oriented measures by developing a framework to classify them and linked these types to existing (urban and non-urban) real-life examples to demonstrate that they are feasible. Widening the focus on all possible consolidation oriented measures did not originate from an aversion of

UCCs but from the observation that there are only a few UCCs that can be considered successful and from the suspicion that not all UCCs have a positive environmental and societal impact. Since the latter was not yet evaluated in a systematic way in the research into UCCs, this is a fourth contribution of this PhD research concluding that based on the available impact assessment we have to conclude that implementing a UCC has a positive impact on the number of urban freight vehicle kilometres. However, this impact might have to partially put down to the lack of high-quality data that cover the entire urban freight spectrum.

Fifth, a freight flow perspective was taken at the question on how to shift more urban freight flows to off-hours. Off-hour delivery research in the United States of America proved that off-hour deliveries are more efficient for the economy and looked at which government incentives could help removing this market failure (Holguín-Veras et al., 2014). In European research, a different approach is taken. There is a (difficult to quantify) demand for more off-hour deliveries, but this demand cannot always be met because of the existing regulations (e.g. noise abatement laws or time access restrictions). Case by case pilots are used to answer the question whether, in a very specific setting, it would be possible to somewhat relax these regulations without causing extra nuisance to local residents. In practice, it means that most pilots that were launched concerned super market deliveries because supermarkets receive multiple deliveries a day and they are often located in residential areas (See for example: Douglas, 2011; Niches 2006; Dassen et al., 2008; Vlaamse Overheid, MOW, Haven- en Waterbeleid, 2011). Starting from the observation that other types of European urban deliveries are already carried out during off-hours and that various pilots demonstrated that when silent equipment is used, noise nuisance can be circumvented, our research widened the perspective by identifying which freight flows are more suitable to be shifted to off-hours than other and why. The results of the American research were incorporated by identifying freight flows for which the identified market failures are less dominant. Finally, since this freight flow perspective had never been taken before there was no existing approach to categorize urban freight flows and describe them in a structured way. The framework that was developed can be useful for other urban freight transport research that wants to take an urban freight flow perspective.

8.3.2 Policy implications and implications for private urban freight actors

Every change in urban freight transport operations impacts the two types of urban freight transport stakeholders (i.e. commercial and public stakeholders). From an economic perspective, supply chains are made as efficient as possible. To reduce costs goods are often not produced where they are consumed causing an increasing demand for transport, including first- and last-mile transport. This transport also comes with negative side effects. We partially count on market forces to organise this transport as efficient as possible. However, there are commercial stakeholder characteristics and mutual interactions that lead to market failure. The lack of contractual obligations between retailer and carrier (Stichting Leve De Stad, 2005) and the low market power of carriers (Holguín-Veras et al., 2014), for example, lead to inefficiencies which confront public stakeholders with additional and unnecessary negative impacts. Local authorities tend to take measures to counter these impacts. Research revealed, however, that both public measures and private solutions do not always have the desired societal and environmental outcome and might even have the opposite effect. Sathaye, Harley & Madanat (2010), for example, question the positive environmental effects of rescheduling deliveries to off-hours. Also time-access restrictions and heavy freight vehicle bans were found to increase freight traffic externalities (Quak & de Koster, 2009; Quereshi, Taniguchi & Yamada, 2012; Holguín-Veras, Cruz & Ban, 2013; Groothedde, Rustenburg & Uil, 2003). The research for the impact of implementing UCCs on the number of urban freight vehicles that is part of this dissertation revealed that not all impact assessments observed a positive effect and that the impact for the entire urban freight traffic system is limited (See **Chapter 2**). It shows that policy makers have to be careful when taking urban freight transport measures and have to be sure that there is enough insight in the various impacts of these measures.

8.3.2.1 Policy implications

The work carried out for this PhD dissertation contributes to that insight which gives rise to the following policy implications:

- **There is a need for high-quality data that cover the entire urban freight spectrum and that are collected periodically.** This need was already expressed in other research (See for example Lindholm, 2012) and was confirmed during the research into the impact of implementing UCCs on the number of urban freight vehicle kilometres (See **Chapter 2**). Being responsible for the data collection for both the

Mobile Depot pilot and the off-hour deliveries pilot in Brussels, I also personally experienced the lack of publicly available urban freight transport data whereby it is not possible to measure real impacts (without huge investments in data collection) but forces to calculate impacts based on derived indicators and variables. Striving for a more efficient urban freight transport system from an urban perspective requires the enabling of evaluating the impact of changes to that system on an urban scale.

- **Evaluating alternatives from a multi-stakeholder perspective generates new insights and exposes possible stumbling blocks.** Implementing urban freight measures will involve some sort of evaluation (be it ex-ante or ex-post, extensive or not). In their decision to implement a certain measure, local policy makers will aim to reconcile the objectives of commercial and public stakeholders since they want to keep their city as attractive as possible by providing a good business climate and favourable living conditions. In this PhD research, MAMCA was used to evaluate urban freight alternatives from a multi-stakeholder perspective which gave insight in the overall stakeholder support for a certain alternative as well as in the possible stumbling blocks for individual stakeholder groups.
- **Implementing a UCC is not the only urban freight measure leading to better consolidated freight flows.** There seems to be a trend among local policy makers in the type of urban freight measure they prefer. Ten to fifteen years ago, there was a focus on UCCs and all types of access restrictions (European Commission, 2009; MDS Transmodal, 2012). Today, there seems to be renewed interest in UCCs and much attention for off-hour deliveries. Finding trends in urban freight transport policy making was not within the scope of this PhD research, but a look at the policy papers and freight plans of the three Belgium regional governments (the country where I live) supports this idea. Two out of three literally refer to UCCs and off-hour deliveries as the preferential measures to come to more sustainable urban freight transport in Belgium (Gouvernement wallon, 2014; Weyts 2014). In the third region, the Brussels-Capital Region, the two measures are part of a set of feasible measures explained in a dedicated freight plan (Brussel Mobiliteit, 2013). This PhD research identified other measures (apart from implementing a UCC) that can also lead to better consolidated urban freight flows, e.g. cooperation between different logistics service providers. In a context where it seems difficult to find a viable business model for UCCs and where the urban scale impact of a UCC can be questioned these findings urge local policy makers to keep an open mind.
- **There is need for dedicated and integrated policy making on off-hour deliveries.** Today, in Europe, there is an unbalanced focus on the noise impact of off-hour deliveries. Partially justified since noise nuisance severely decreases quality of life. Analysing deliveries that already take place during off-hours revealed however that it can be put in practice, even in different industries (**Chapter 6**). The pilot in Brussels (**Chapter 7**) confirmed the results of other off-hour delivery pilots: there is an economic benefit to off-hour deliveries and when measures are taken to avoid noise nuisance for local residents, there are little or no complaints. There can be stakeholder support for a shift to off-hour deliveries. To further explore that stakeholder support, there is need for dedicated and integrated policy making. Noise measurements in Brussels revealed that the noise produced by manoeuvring trucks is not within the Noise Abatement Law of the Brussels-Capital Region, even by day. Today, this law is used to prohibit off-hour deliveries in Brussels while it was not designed from that perspective. Furthermore, a shift to off-hour deliveries has many other impacts (both positive and negative) which are now more or less ignored by policy makers. A more integrated approach would allow to shift policy making on this topic away from allowing or prohibiting off-hour deliveries just based on noise impact. The impact, for example, on traffic safety and truck drivers still is not fully explored because analyses are based on small-scale pilots.

This thesis pays attention to two types of urban freight transport measures (i.e. consolidation and off-hour deliveries) by exploring how they can be applied in a sustainable way. It is clear that these are not the only two possible measures (**Chapter 3**). Urban freight transport policy making should keep an open mind about all types of measures since not all measures can be successfully applied in all types of cities. Furthermore, the two measures in this thesis address the symptoms of an increasing demand for urban freight transport. The thesis did not pay attention to measures or mechanisms that influence the demand for urban freight transport (e.g. spatial planning).

8.3.2.1 Implications for private urban freight actors

The work carried out for this PhD dissertation gives rise to the following implications for urban freight actors:

- **Higher loading rates and fewer freight vehicle kilometres can be achieved by collaboration across and along supply chains.** Supply chain actors constantly search for efficiency gains in both door-to-door and last-mile operations. Higher loading rates and fewer freight vehicle kilometres would allow them to save on fuel and wage costs. Fragmentation, however, is apparent in long-haul transport, and despite policy support and public investments to foster inter-modality, modal shift and cargo consolidation, load factors on long-haul routes have stalled at roughly 50% for the last decade (Doherty & Hoyle, 2009). Furthermore, the last mile is the least consolidated leg, though it often accounts for the largest parts of the costs. The rising popularity of e-commerce may further fragment deliveries as different deliveries by different shippers are made to the same delivery address by different underutilized vehicles. This PhD research demonstrates that, also in the last mile, shipments can be consolidated through horizontal and vertical collaboration across and along supply chains.
- **Shifting deliveries to off-hours is attractive because it saves time and fuel.** The off-hour delivery pilot evaluated in this dissertation originated from the wish of two Belgian retailers to shift some deliveries to their supermarkets in Brussels to off-hours which is not authorized today. To them, the pilot confirmed that shifting deliveries would save time and fuel. Research by Holquin-Veras et al. (2005) revealed that not all last mile supply chain actors are convinced that such a shift is attractive and that, if bans on off-hour deliveries in European cities were lifted, the share of off-hour deliveries would not increase significantly. This PhD research confirms that there are significant gains to be made in the retail sector. Second, the research also identifies specific freight flows that could economically benefit from a shift to off-hour deliveries based on existing literature and on interviews with general and logistics managers of companies that are already involved in off-hour deliveries. Important indicators for a successful shift to off-hour deliveries are the need for proof of delivery, value of the goods, location of the receiver, company size, shelf life of the goods and the relationships among senders, private or for-hire carriers and receivers.
- **There is a need for high-quality urban freight data and private actors would also benefit from contributing to that.** The need for high-quality urban freight data was already expressed in other research (See for example Lindholm, 2012) and was confirmed during the research into the impact of implementing UCCs on the number of urban freight vehicle kilometres (See **Chapter 2**). To evaluate new concepts, researchers do not only need data that provide insight in the societal and environmental impact of the concept but they also need data to characterize the concept and to evaluate economic impact. These data are usually owned by private urban freight actors and they are reluctant to share these data. The two pilot evaluations in this dissertation confirm that insight in the economic impact of a certain solution allows evaluators to really take into account the objectives of private stakeholders and to make public stakeholders aware of feasible solutions and important stumbling blocks for private actors.

8.3.3 Limitations and further research

This PhD research identified sustainable ways to consolidate urban freight flows and to shift urban deliveries to off-hours. While the previous sections summarized findings and implications of the study this section will discuss its limitations and constraints as well as future research options.

The first type of limitation constrains the generalizability of the findings of this research. In **Chapter 3**, for example, the identification of examples of alternative consolidation concepts did not aim to be comprehensive. Due to time and resource constraints, the research was limited to listing a few examples to demonstrate the feasibility of the consolidation concept and to further explain how it works. In **Chapter 6**, the analysis of types of freight flows that are better suited to be shifted to off-hours is partly based on a case study. When doing the interviews, there was never an aim to cover all supply chains that are already involved in off-hour deliveries. Adding up that the geographical scope of the case study was limited to Flanders (which is one of the three Belgian regions). Furthermore, because the interviews did not follow a rigid structure (the interviewees were not literally asked for their opinion on each of the indicators that were identified in the literature) and were not recorded or transcribed immediately afterwards, the number of times a particular indicator was mentioned in the transcriptions of the interviews does not mean anything. A more structured interview approach would have led to better research results. A first future research option would be to further explore the entire spectrum of alternative urban consolidation concepts and existing urban off-hour deliveries to identify the most feasible solutions and to determine the proportion of urban freight flows these solutions would apply to and the social-economic impact be if these solutions were actually implemented? In both cases, a first ex-ante assessment could eventually lead to innovative pilot programs and to new

ex-post assessments. Especially for the consolidation-oriented solutions, there would also be value in reviewing more in detail in which supply chains this type of measures was already implemented (both in an urban and non-urban setting) since both vertical and horizontal collaboration have been gaining in importance since the manuscript on alternative consolidation concepts was published.

The results of **Chapters 4** and **7** build on two small-scale pilots. Despite the fact that these pilots were set up with great care, both had their limitations. Each concept was tested together with only one commercial initiative taking stakeholder, in only one city (i.e. Brussels) and for a limited period of time. For the pilot on off-hour deliveries it was originally planned to have an additional retailer in the program but this retailer could not deliver what was agreed upon due to internal restructuring. For the two sites of the remaining retailer, it proved difficult to get an environmental permit to do off-hour deliveries. To facilitate the pilot program, the Environmental Agency of the Brussels-Capital Region decided to allow a temporary exemption to the rules for a period of one week. Obtaining this exemption took so much time that the available time frame only allowed a trial period of two weeks for each site (one with night deliveries and one with early morning and late evening deliveries within the existing environmental permit). However, the before-after impact assessments confirm results of other off-hour delivery trials so it can be assumed that this limitation did not affect the results of these assessments. The Mobile Depot pilot was done with the express service provider who developed and owned it. Because this concept was so innovative, it is difficult to assess whether it would have led to other outcomes when the pilot was done with another express service provider. Both pilots ran in Brussels. Specific characteristics of Brussels make it difficult to judge the transferability to other cities, e.g. the maximum noise levels set by the Noise Abatement Law or the population and business density in (which influences the drop density of the express service provider).

One avenue for further research would be to replicate these promising applications in an even more suited setting. In case of the Mobile Depot, MAMCA revealed that the concept can become interesting when the trailer is used at its full capacity, when drop density is high and when external costs are internalised. It would be interesting to test the Mobile Depot in such a setting and evaluate its impacts and its possible future. Such a pilot has been planned as part of the European H2020 project CITYLAB. In case of the shift of supermarket deliveries to off-hours, MAMCA revealed that, in Brussels, there is a good potential for such a shift. The evaluated pilot only involved one retailer and two of his sites and focussed on supermarket deliveries. A more extensive pilot covering a wider variety of types of shops and deliveries would provide more insight in the advantages and disadvantages. Similar pilots were set up for the other two Belgian regions. It would be valuable to confront and combine the results of the different pilots to come to a more generic conclusion. Apart from testing similar solutions in different settings to learn more about their advantages and disadvantages, it would also be interesting to explore the relation between urban planning, logistics sprawl and urban characteristics on the one hand and how well urban freight transport concepts function on the other hand.

The second type of limitation is linked to data availability. The analysis of UCC impact assessments was limited to the 93 impact assessments we were able to identify (See **Chapter 2**). There are more impact assessments, but some of them could not be consulted because they are not publicly available or not published in English. There probably also is a predominance of schemes that received some kind of European funding as the EC tends to require a thorough publicly available impact assessment in return for their support. For the same reason, it can also be expected that the share of schemes involving environmentally friendly vehicles is overrated in our sample.

To assess the impact of the pilots (**Chapters 4** and **7**), before-after comparisons were made on a number of relevant indicators. Many of these impacts had to be derived and calculated based on the impact on other 'supportive' indicators. This is partly due to the fact that the pilots were small-scale which was explained in a previous paragraph. Because of the small-scale some impacts (e.g. on congestion or on emission of pollutants) could not be measured and had to be derived. The other reason is that periodically collected data on urban freight transport are not (publicly) available. Within the scope of a pilot program, it is often too expensive to do the necessary measurements or counts. All of this resulted in modelled, calculated and derived impacts which are, despite the fact that they were determined with great care, never as precise as real measurements.

To be able to feed an evaluation tool with established impacts, there is need for reliable data. Reviewing the state-of-the-art on urban freight data collection was not part of the research aims of this dissertation, however, the research work that was carried out confirmed that there is a lack of data. It prevents us to evaluate the urban-scale impact of

pilots and implementations or to build reliable models that can predict that impact. My experience learned that one of the reasons that it is difficult to get access to the necessary data is that, today, local governments do not collect dedicated freight data and that because of the many stakeholders, different people, companies or institutions have to be involved. Therefore, one avenue for further research would be to identify feasible data collection methods for urban freight, especially because in our digitalised society, many data are collected anyway but underused.

Third, existing research into urban freight transport solutions mainly focusses on freight flows to and from shops located in urban areas. Other freight flows like those to and from offices, hospitals and people's homes, for example, or waste and reverse flows are less addressed. The different chapters in my dissertation also focus on the traditionally researched freight flows (e.g. Chapter 7) or do not differentiate between different types of freight flows (Chapters 2, 3 and 5). On the other hand, Chapter 4 explicitly evaluates the use of a Mobile Depot for express deliveries and pick-ups to and from any type of urban premises (and not only retail outlets). In Chapter 6, I explicitly aim to broaden the perspective for off-hour deliveries from a freight flow perspective. However, it would be valuable to further explore the potential of freight flow consolidation and off-hour deliveries for other important but less studied freight flows (offices, construction sites, hospitals, home deliveries, reverse flows, waste flows, etc.).

The fourth type of limitation is the difficulty to involve stakeholders in the evaluation of urban freight transport measures. In line with the call of several authors to involve urban freight stakeholders in the urban freight decision making process, we chose to also take that multi-stakeholder perspective to evaluate possible urban freight solutions. We selected MAMCA for that which is an existing evaluation methodology that was never applied to urban freight transport before. **Chapters 4, 5 and 7** use MAMCA to evaluate and mutually compare urban freight transport alternatives. The three MAMCAs are largely ex-ante assessments; most of the evaluated alternatives were not implemented or tested (except for BAU and the pilot). The input for the indicators (step 4 of MAMCA) was based on before-after assessments of the pilots, on interviews with relevant stakeholders and on own reading of the (future) situation based on literature and trends. The limitations of the before-after assessments were explained in a previous paragraph. Concerning the interviews, in some cases, the number of respondents was rather low. For the first MAMCA of the Mobile Depot, the mono-actor view for citizens (See Figure 24) was partly based on measured impacts and partly based on 12 interviews asking citizens for the expected impact of a scenario. Despite the fact that 57 people were personally asked to take part in the survey, it proved very difficult to motivate people. Most of them answered that they could not relate to the topic and were unqualified to answer the questions. The second MAMCA of a shift to off-hour deliveries in Belgian cities was completely based on 18 interviews with representatives of the different stakeholder groups. Despite the fact that the interviewees (e.g. leaders of trade groups, unions, associations of cities, etc.) represented a considerable constituency this low number of interviews might have influenced the results since my later research revealed conflicting opinions in what is considered to be one stakeholder group. The drivers I interviewed, for example, indicated that they prefer off-hour deliveries whereas the unions were completely against. For the third MAMCA of a shift of supermarket deliveries to off-hours, 16 local residents were found willing to be surveyed on whether the pilot caused them any additional noise nuisance. Again this number might seem rather low, but the assessments used in the MAMCA are based on a combination of these results, the noise measurements and the complete lack of complaints filed. Doing a sensitivity analysis on the results of the evaluation is part of MAMCA. Despite the fact that these analyses were not included in the manuscripts of which this PhD consists, sensitivity analyses were carried out both on the weights that were allocated to the criteria of the stakeholders and on the outcome of the analysis. They showed that even when stakeholders would have attributed different weights to their criteria, the ranking of scenarios would not have changed. One possible way to deal with this limitation in further research would be to introduce crowdsourcing in MAMCA by asking an (online) community to define their objectives, attribute weights and evaluate alternatives. A second option would be to use the living lab concept to develop innovative urban freight solutions together with stakeholders and to not only ask them to participate in developing a new solution but also in evaluating it.

Applying MAMCA confirmed that it is well suited to evaluate urban freight transport measures since it reveals whether there is overall stakeholder support for a measure and what the stumbling blocks are for individual stakeholder groups. Applying the method to similar applications in other settings or other countries and applying the method to other urban freight measures would contribute to urban freight transport research. Within this PhD research, MAMCA was only used to compare alternatives that are all variations to one type of measure and that require initiative of a private actor. It could prove valuable to decision makers to use the method to mutually

compare different types of measures and solutions within the same urban setting. Not only to provide insight in which measure would receive overall stakeholder support but also in which private solutions would be worthy of government support and in the impact of different types of government intervention for private stakeholders.

Applying the method also suggests that the weights stakeholders attribute to their criteria do not always completely capture their attitude towards the different alternatives since there appeared to be criteria on which they wanted the alternative to score better than BAU before even considering changing their behaviour. Possible future research could consist of reviewing other MAMCAs to see whether this effect also occurred and if so, finding a way to incorporate this into the methodology since it would provide additional information to decision makers. In that respect, it might also be useful to research how other scenarios can be compared to BAU more easily in MAMCA visualisations. Decision makers use the outcome of the evaluation to decide whether they want to take action to move away from BAU or not (and what that action should consist of). The visualisations used in this research treat BAU as any other alternative scenario (See for example Figure 49 and Figure 23). Would it be possible to visualise BAU as a reference scenario to which the other scenarios can be compared? Possible ideas are to visualise BAU as a horizontal line with the other lines representing the alternatives swirling around it in the first type of visualisation and to keep the height of every part of the stacked column representing BAU equal while the value depicted in the other columns is relative to that in the second type of visualisation.

The three MAMCAs also revealed that stakeholder groups often are less coherent than they seem and that different opinions and attitudes occur in what is considered as one single stakeholder group in literature. This was also one of the lessons learned from the off-hour delivery trial that was done in New York (Holguin-Veras et al., 2014). Despite the fact that the different stakeholder groups already received a considerable amount of attention in current research, future research might want to focus on these differences which might lead to sub-stakeholder groups or more detailed stakeholder groups. Furthermore, different contexts and different solutions give rise to new stakeholders and/or new combinations of stakeholders into one stakeholder group requiring on-going attention for urban freight transport stakeholders.

In this dissertation (and also in other applications), MAMCA approaches the alternatives that have to be evaluated in a rather passive way: they are identified and described very early in the process and are kept fixed for the remainder of the evaluation process. The results of the evaluation are then used to identify the main stumbling blocks for each of the alternatives and each of the stakeholders and to learn in what respect an alternative has to be changed to overcome these stumbling blocks. A possible avenue for further research would be to test whether MAMCA can also be used to quantify the change that is needed. In case of the Mobile Depot, for example, we concluded that mainly TNT Express itself has two main stumbling blocks for implementing this solution: operations are not profitable and return on investment is not high enough. It could have been useful to use MAMCA to calculate how much more profitable operations would have to be or how much more viable investments would have to be before any of the other scenarios would score higher than business as usual for TNT Express.

Finally, the decision to apply MAMCA in the field of urban freight transport evolved from the notion that it is important to involve all stakeholders in the decision making process on which approach to take in this field. We have seen that the method can give stakeholders insight in whether other stakeholders would support a certain measure or not. Sometimes this insight is based on factual and more objective assessments like measurements, calculations or modelling; in other cases it is based on interviews or surveys which are more subjective assessments. Further research might want to explore whether the method can be used as part of a consultation process between the different stakeholders to help them understand each other's point of view (e.g. in a workshop) and also whether the method can be used to confront beliefs of certain stakeholder groups with actual measured outcomes. A first MAMCA might be done based on what they believe would be the impact of the different alternatives and afterwards be compared to a MAMCA that is fed by established impacts of the same alternatives.

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