UNIVERSITY OF GOTHENBURG
SCHOOL OF BUSINESS, ECONOMICS AND LAW

Master Degree Project in Logistics and Transport Management

# Bus Rapid Distribution

Cost analysis of an innovative freight distribution model for urban areas

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# Abstract

Freight distribution in cities is a topic of growing importance and innovative solutions are needed in order to make urban logistics more sustainable. However, many projects fail and there are no standards for financial evaluations of such projects ex-ante. In this thesis a model for financial evaluation is developed and tested on the Bus Rapid Distribution (BRD) project that combines the use of a freight bus as a mobile depot with electric cargo bikes for emission free last mile deliveries.

To investigate the cost variables and their implications and to assess the project's financial viability both qualitative and quantitative data have been collected and analyzed.

Findings show that the innovative model is not cost competitive to the conventional model in a base scenario in the city of Gothenburg. In a scaled scenario the innovative model reaches a break-even point at a daily demand exceeding 480 parcels. When different variables are simulated in a sensitivity analysis, the delivery speed has the most impact. For a 30% lower delivery speed for the innovative model a break-even point is never reached, whereas a 30% lower delivery speed for the conventional model shifts the break-even point to a daily demand exceeding 320 parcels. Furthermore, qualitative data show that governance tools and reluctance to change have large impact on the viability of a new model in urban freight distribution. Additional findings are the potentials of the innovative model to reduce negative externalities of urban freight operations.

Conclusively, financial viability is a prerequisite for a successful business model and should be evaluated ex-ante. For the actual implementation of a new model other parameters such as stakeholder involvement and specific city characteristics must also be taken into account.

Keywords:
Parcel distribution, Mobile depot, Electric cargo bike, Freight bus, Cost analysis, Urban logistics, BRD

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# List of abbreviations

| | |
|---|---|
| BESTUFS | Best Urban Freight Solutions |
| B2B | Business-to-business |
| B2C | Business-to-consumer |
| BRD | Bus Rapid Distribution |
| C2C | Customer-to-customer |
| CBA | Cost benefits analysis |
| CEP | Courier, express and parcel |
| CIVITAS | City, Vitality and Sustainability |
| E-CB | Electric Cargo Bike |
| EFV | Electric freight vehicles |
| FREVUE | Freight Electric Vehicles in Urban Europe |
| GHG | Greenhouse gas |
| HUR | Handelns Utvecklingsråd |
| JIT | Just-in-time |
| LTL | Less-than-truckload |
| NOx | Nitrogen oxide |
| NPV | Net present value |
| PPP | Public private partnership |
| SCBA | Social cost benefit analysis |
| SOx | Sulphur oxide |
| STRAIGHTSOL | Strategies and measures for smarter urban freight solutions |
| UCC | Urban consolidation centers |

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# 1 Introduction to Bus Rapid Distribution

The first chapter presents the background, purpose, research questions as well as the delimitations and the employed conceptual framework for this thesis. This chapter also illustrates the outline of all chapters of the thesis in order to provide a clear overview of the structure that this research was built upon.

## 1.1 Introduction

*"Growth is inevitable and desirable, but destruction of community character is not. The question is not whether your part of the world is going to change. The question is how."*
*(Edward T. McMahon, 2001)*

Today, more than half of the world's population lives in cities. In America and Europe the urbanization rate is significantly higher, with 82% of all North Americans and 73% of all Europeans living in city areas. According to the forecasts of the UN (2014), urbanization will continue to grow, and in 2050 66% of the global population is projected to live in cities. This poses great challenges on the sustainable development in urban areas (UN, 2014).

The fact that cities are on the one hand places of high commercial activities and on the other hand sensitive areas where many people live makes considerate urban planning a necessity and a challenge. Freight transport is becoming an area of greater concern and is increasingly on the agenda of city authorities as it is associated with several negative externalities such as noise, air pollution, congestion and traffic accidents. Therefore, decision-makers try to find solutions to reduce and eliminate these negative impacts and they face the difficult task of reconciling the often-contradictive objectives and needs of various stakeholders. Moving towards a sustainable development, economic, environmental and social goals have to be balanced. Especially the first two objectives are often conflicting with each other in the context of urban logistics (Hesse, 2008; Anderson, Allen and Browne, 2005; Com 144 Final, 2011; Quak, 2013; Arvidsson and Browne, 2013).

Nevertheless, the reduction of negative externalities caused by city freight has become an obligatory task. The EU has set itself the goal of completely phasing out conventionally fueled freight vehicles from urban transport by 2050 and of making urban logistics in major urban centers $CO_2$-free by 2030. This is an ambitious goal, but at the same time the prerequisites of forming transport activities more environmental friendly are favorable in cities. The given infrastructure and population density allow for smaller vehicles with limited range and a variety of clean transport options that can fulfill the existing tasks are already available. A main potential in increasing the environmental performance of urban freight transport lies in improving the transfer between incoming long-distance shipments and the last-mile distribution to the final recipient. Avoiding a large number of small individual consignments into inner city areas and instead consolidating flows and optimizing routes is a leverage to increase efficiency here (Com 144 Final, 2011).

## 1.2 Background

In the context of the before mentioned challenges and goals, the interest of academic research in the topic of urban logistics has grown accordingly in recent years. In addition to theoretical elaborations, a variety of practical projects and trials have also been conducted. In trans-sectorial and cross-national initiatives like BESTUFS (Best Urban Freight solutions), CIVITAS (City, Vitality and Sustainability), FREVUE (Freight Electric Vehicles in Urban Europe), STRAIGHTSOL (Strategies and measures for smarter urban freight solutions) new technologies and innovative ideas are tested and evaluated, knowledge is shared and recommendations and best-practices are developed with the common aim to develop more sustainable solutions for urban logistics. However, there is a gap in research concerning economic evaluation models for urban transport projects, which has been identified in the literature review of this thesis. Consequently, no common evaluation method exists. Until now, city innovation projects are most often publicly funded and a majority has failed to create sufficient economies to operate independently. Moreover, these projects are often evaluated only in retrospect in order to analyze the reasons for their failure. Such insights can be beneficial and provide a learning effect for other projects. Nevertheless, finding out beforehand if a new concept is prone to failure due to excessive costs, and where major obstacles in the financial structure of a project might lie, provides many advantages. This is where the outcome of this thesis will make a contribution.

## 1.3 Problem Discussion

The idea for this thesis originates from an innovative project proposal for parcel distribution in Gothenburg, Sweden. The project was developed by Niklas Arvidsson at the School of Business, Economics and Law at the University of Gothenburg and financed by HUR (Handelns Utvecklingsråd), Sweco and Vinnova. The concept comprises the combination of a freight bus operated as a mobile depot for parcel distribution with last mile deliveries performed by small emission free vehicles. From here on, this project will be referred to as Bus Rapid Distribution (BRD). The objective of the project is to make city distribution more environmentally friendly without compromising its economic viability. The research of this thesis will conduct a monetary cost analysis of the BRD project and compare the outcomes to a conventional parcel distribution model where vans complete the full inner city delivery. If, and in which specific execution, the new concept will be implemented cannot yet be said. One prerequisite for its implementation is, however, that the concept can be proven to be at least cost neutral and in the best case financially beneficial.

## 1.4 Purpose

The purpose of this thesis is to develop a cost model that can be used to financially evaluate innovative city logistics projects ex-ante.

This model will further be practically applied to test the economic feasibility of the BRD project and to identify if it is feasible within the given framework compared to conventional distribution method. In addition, a sensitivity analysis is carried out to identify the viability of the BRD in different set ups as well as to identify main cost components to which adaptations that can be made. The purpose is also to conduct a qualitative in-depth analysis of the barriers and potential that such a project entails. Overall, the conclusions and methods used in this thesis can provide support for responsible entities to make informed decisions regarding innovative projects in urban freight, especially concerning the ones involved in the BRD project.

## 1.5 Research questions

The research questions work as a guideline and points of reference throughout the research. They help to focus the research and to give it a general direction in order to reach the intended purpose of this thesis. However, the research questions are formulated in a way so to keep the course of the research open and not exclude any ideas or theories right from the beginning (Collis and Hussey, 2014).

To reach the described purpose of the thesis, the following research questions have been formulated:

RQ1: What cost variables exist in parcel distribution in urban areas and what parameters affect the different variables?

RQ2: How do the cost variables differ between the conventional parcel distribution model and the innovative BRD model?

RQ3: How do the total costs between the conventional and the innovative model differ?

RQ4: How does an increase in demand and changes of certain cost variables affect the calculated total costs?

RQ5: What non-monetary aspects affect the viability of an innovative project in urban freight distribution?

## 1.6 Delimitations

In order to focus this thesis, the following limitations are applied.

First of all, this thesis focuses on the evaluation of the financial feasibility of innovative urban logistics projects. Therefore it does not assess its technological maturity and does not consider what hard- or software is needed to make it viable.

Second, this research project concentrates on goods shipments of the courier, express and parcel industry. This freight segment only makes up a subset of all urban goods transportation, but due to its nature it is particularly well suited for innovative distribution concepts. Courier, express and parcel consignments are limited in size and weight and are usually transported over short distances within cities. Therefore they allow for a large selection of possible last mile transportation modes.

Thirdly, the evaluation tool targets a city distribution setup that combines the use of a mobile depot in connection with small emission free vehicles for the last mile delivery. Other environmentally friendly initiatives, such as the use of hybrid or electric trucks, are undoubtedly also interesting to investigate. However, since this thesis was developed in the context of a project proposal using the before mentioned setup it makes sense to further develop the BRD by using the preexisting experiences, results and data.

In addition, the environmental implications of switching distribution models in urban areas are one, and perhaps the most important, reason behind such a decision. This being said, the purpose of this thesis is not to conduct an analysis of the full environmental consequences of the BRD compared to the conventional model, due to the fact that the monetary viability is the main research focus.

Finally, a cost model for cost analysis is important for all innovative urban freight solutions. However, this research will focus on the mobile depot, such as a freight bus, that is helped by small, emission free last mile vehicles, such as cargo bicycles or electric cargo bicycles.

## 1.7 Conceptual framework and thesis layout

The terms 'urban area' and 'city' are used repeatedly throughout this thesis and are of central importance. It is therefore reasonable to offer a more detailed disambiguation. First of all it should be mentioned that the two terms are used interchangeably in this thesis, even so a distinction can sometimes be found in literature. Also in combination with other words like city/urban logistics, city/urban distribution etc. no difference in meaning is intended. Regarding a definition of the term no explicit determination exists in literature. The OECD refers to areas with at least 50,000 inhabitants and a density of more than 1,500 inhabitant per km$^2$ as a city (Dijkstra and Poelman, 2012). However, in this thesis no such quantitative constraint is made. In the context of this thesis only the characteristics of an 'urban area' or 'city' as a zone with a high density of population, businesses and commercial activities and a sophisticated infrastructural network is of relevance. It is seen as opposite to rural areas that are less densely populated and where often a majority of the economic activities are based on agriculture (UNICEF, 2012).

This thesis consists of five chapters. Following the initial introduction into the topic and background of research as well as the definition of purpose, research questions and delimitations in this chapter, this thesis will next continue with the methodology applied and provides a critical reflection of the methods that are used. The subsequent chapter presents a literature review. In this review various topics are covered that are of relevance in the context of the thesis and moreover the summary reveals where a gap exists in current research. Following, the empirical part of this thesis discusses the findings of the research and how they were reached. The thesis ends with a general conclusion and recommendations of prospective future fields of research that can build on this thesis.

# 2 Methodology

In the second chapter, the research attitude and approach employed to conduct this research are presented. The methodology is a study of how the research is done and designed and in what way knowledge is gathered. Moreover, alternative methods as well as method criticism are introduced.

## 2.1 Paradigm

The research paradigm is the philosophical framework chosen by the authors, which guides the research according to their view of the world, involvement, influence and assumptions (Blumberg, Cooper and Schindler, 2011; Collis and Hussey, 2014). There are two main research philosophies that stand against each other on different sides of the research paradigm spectrum. These are positivism and interpretivism.

This research will take into consideration both interpretivistic methods such as sensitivity and qualitative analyses, while at the same time aiming to create a framework that can be used objectively in order to evaluate financial investments in urban logistics projects in a positivistic manner. This research will not include observations or interactions with the objects under research that would color the findings or the research procedures. However, the mere realization that all humans interpret facts and information according to their internal framework and background, makes it likely to conclude that some form of interpretivism will take place in the analysis of the findings of this research. In addition, this research will use existing studies and current operations as a benchmark and aims to develop a new tool for cost measurement, which implies a positivistic approach. This thesis draws conclusions based on outcome of calculations and qualitative aspects, and should therefore, according to Collis and Hussey (2014), be called interpretative since findings are not derived from statistical data. However, the positivistic research philosophy aims for explanation, anticipation, prediction and determination, which are also the aims of this research. Hence, it is clear that this research does not purely follow the positivist or interpretative paradigm, but is rather a weighted combination of the two.

## 2.2 Research classifications

Research must be classified in order to provide a clear structure. By stating one's research classifications, overview and understanding are facilitated. According to Collis and Hussey (2014), there are different basis of classification for a research study.

Purpose: the purpose of the research explains why the research was conducted. The purpose can be to perform a study that is exploratory, descriptive, analytical, explanatory or predictive. In this research, a descriptive and exploratory research is conducted. In order to understand the underlying preconditions and requirements of urban distribution systems and the financially related reasons for failure of new innovation projects, the "what" and "how" questions must be asked and an analysis of the current situation must be formulated. This thesis does not ask the research question "why", however, the conclusions will explain why or why not an innovation project in urban logistics is financially viable. It is therefore argued that this thesis conducts an explanatory research. Additionally, by performing a sensitivity analysis where the cost variables are modified, the question "what if" will also be answered, including a form of predictive research (Collis and Hussey, 2009).

Process: The process of the research determines the way data are collected in order to address the stated research questions. It is possible to collect either qualitative or quantitative data and it is important that the chosen approach complies with the research questions in the best possible way, and many research problems can be solved either through qualitative or quantitative research (Collis and Hussey, 2014; Blumberg, Cooper, and Schindler, 2011). In this research, the analyses as well as the data collection follow a triangular approach. By collecting secondary data through literature reviews and trials in urban logistics the outcome aims to be predictive, however the results will follow a qualitative analysis using interpretative methods. By stating that different cost variables have different sensitivity depending on aspects such as demand and customer density, it would not be possible to conduct a fully positivistic analysis of the secondary data. However, numbers are analyzed and conclusions are drawn depending on the outcomes, and the aim is to create an objective cost analysis model. Therefore a triangular method by combining the two approaches is suitable. Data triangulation where data are collected in both qualitative and quantitative form and from different sources, people, times and places will be conducted in order to broaden the aspects of the empirical study.

Logic: The logic of the research must also be discussed, and the way research moves must be determined. Often, the logic of the research is connected to the intended research paradigm (Blumberg, Cooper, and Schindler, 2011). In this research the logic will be inductive as the aim is to use specific benchmarks as a base for the study in order to create a framework that can be applied in a general context, i.e. inducing general inferences from particular instances.

Outcome: The outcome of a research is important as it, like the purpose, describes the objective of how the findings of the research should be applied to a particular problem or act as a general contribution to increase knowledge (Collis and Hussey, 2009; SAGE, 2006). This research is conducted on the terms of applied research rather than basic research since there is focus on solving an urgent societal, economic and environmental issue related to the triple bottom line. The research conducted serves a specific purpose more than providing additional knowledge as the objective of the research is to develop a model that can be used in specific infrastructure and distribution investment projects, which is why it should be referred to as applied research as opposed to basic research.

## 2.3 Research Process

Previously, the research philosophy has been discussed and there is an obvious link between the research paradigm and the research methodology. Often, a positivist paradigm allows for deductive processes that use methods of research that can predict and explain phenomena, as the other side of the spectrum, interpretivism induces information in order for the researchers to understand phenomena (Collis and Hussey, 2014).

An action research aims to find an effective way of implementing transformation and observe the results of the change. Action research per se has the objective to contribute both to solving an immediate problem and to contribute to science where the research takes place in real situations to solve real-world problems (O'Brien, 2001; Collis and Hussey, 2014). This requires a high level of collaboration with members of the system in order to reach the goals of the research and emphasizes the importance of co-learning to be strongly considered while carrying out the research project. Usually, action research is used in applied research projects in order to investigate an organization and, based on the stated objectives, find new solutions and implement these (Blumberg, Cooper and Schindler, 2011). Action research can be similar to problem-solving consultancy projects when working closely with an organization or client. However, O'Brien (2001) states that action research takes a more holistic approach to problem solving than regular consultancy projects as it emphasizes the importance of scientific study and theoretical development. This approach, combined with the dual objective of action research, allows employment of several different tools, often related to interpretivism and qualitative research methods, such as case studies, interviews, analyses and observations. Researchers often criticize action research due to the fact that it can come too close to consultancy or journalism (Gummesson, 2000). Therefore the term action science is often preferred amongst researchers and even in this case, action science is more descriptive of the performance of the conducted research. Action science follows the definitions of action research and is described as a research that fulfills the two goals of practical problem-solving and contribution to science. Action science also includes a co-learning and co-operational environment where both researcher and client can develop and take a holistic view on investigating a problem while still making the outcomes clear and understandable for everyone (Collis and Hussey, 2014).

This research, as it has been stated, is applied research that aims to contribute to solving a real, societal and academic problem. The nature of this research also takes the shape of an action research to some extent due to the fact that different methods of data collection are used in order to find a solution for a cost analysis model where different variables are considered. However, it should be emphasized that close collaboration with participants in the study has been excluded, as the purpose of this thesis is to investigate cost variables and analyze the financial viability of the BRD, and not to implement it. Therefore the research conducted in this thesis follows action research only partially. Furthermore, the triangular or pluralist paradigm of this research can also be referred to as data triangulation (Flick, 2004).

## 2.4 Data collection

As mentioned, this research aims to collect data of various sources in order to clearly illustrate, from different points of view, the issues that different urban logistics initiatives and investments face. This is done in order to comprehend what cost variables need to be taken into consideration, and investigate what factors affect these variables.

Both primary and secondary data are gathered. Primary data are collected through four in-depth, semi-structured interviews with researchers from different countries and backgrounds related to urban freight. The interviews were recorded and transcribed in order to improve the reliability of the information and to ensure a correct analysis. Table 1 demonstrates the characteristics of these.

| Researcher | University | Length of interview |
|---|---|---|
| **Behrends, Sönke** | Chalmers University, Sweden | 90 min |
| **Browne, Michael** | University of Westminister, UK | 45 min |
| **Heitz, Adeline** | Université Paris Est Sorbonne, France | 35 min |
| **Woxenius, Johan** | University of Gothenburg, Sweden | 30 min |

*Table 1: Interview overview*

Moreover, an online survey created in Google Forms was conducted. 18 professionals from research, public authorities and consultancy with specific knowledge in urban freight distribution partook. The purpose of the online survey was not to derive statistical mass, but rather to obtain a general picture of the perception of different innovative concepts regarding urban freight distribution. The full question catalogue of the in-depth interviews and the results of the online survey can be found in Appendix C.

In addition, primary data were assessed through field studies of current urban distribution operations in the city of Gothenburg with a medium sized CEP transport provider, as well as from informal interviews at industry conferences that allowed the authors to gain further knowledge and better understand the topic under study. Furthermore, e-mail- and personal interviews with parcel operators and vehicle professionals have been performed to clarify information in order to improve the reliability of the research. Secondary data were collected from different, selected sources such as journals, articles, conferences and relevant textbooks, as well as from official institutional information regarding costs and urban city transport operations. Secondary data also serve as input to the cost listings of this research. The databases used to collect secondary data were Emerald, Science Direct and Business Source Premier. From the secondary data a thorough literature review has been conducted where different trials on a global scale in urban logistics are evaluated. The literature review is considered an important part of the empirical research of this thesis and is therefore positioned right before the research findings. To process primary and secondary data in the research findings the online tool Google Maps is used for the distance calculations in the city of Gothenburg and Microsoft Excel is used to perform cost calculations and to develop graphs.

| Method | Data collection | Purpose |
|---|---|---|
| **Interviews** | Qualitative | In-depth knowledge from professionals in the field of urban freight. Project feedback. |
| **Online survey** | Qualitative | Access to opinions on urban freight solutions from professionals in the field of urban freight. |
| **Conference attendance** | Qualitative | Lectures and workshops to gain deeper knowledge. |
| **Excursion** | Qualitative and quantitative | Joining a city CEP transport provider to gain deeper knowledge. |
| **Literature review** | Qualitative and quantitative | Research about previous innovation projects made in the field. |
| **Costs listing** | Quantitative | Compare current monetary costs with the alternative solution. |

*Table 2: Methods and purposes of data collection*

## 2.5 Quality parameters

In scientific research there are two measures of quality that prove if a research and its conclusions are strong enough to stand up to close examination (Raimond, 1993). The first one is reliability, which refers to the fact that the research should result in the same findings and conclusions if it were conducted by another researcher, all other things equal. The other parameter is validity, where it is reviewed to which extent the research and its findings actually investigate and reflect the phenomena intended to be researched in the research question(s) (Blumberg, Cooper and Schindler, 2001; Collis and Hussey, 2009).

This thesis combines positivism and interpretivism and uses triangulation in terms of data collection. It therefore aims at providing as high levels of both reliability and validity as possible in order to provide useful results and conclusions. In terms of reliability, the primary data used for the cost calculations have been thoroughly researched and numbers have been adapted and adjusted according to industry and academic experts. All data collected in this thesis is transparent in order to allow for the highest level of reliability. Furthermore, the secondary data are considered to be reliable as the sources of information are peer reviewed articles in major business- and transport publications and journals. This also allows for an unbiased frame of reference. The authors have carefully controlled both primary and secondary data in order to make sure there are no misunderstandings. In addition, the conclusions drawn from the data are considered reliable as the aim is to represent a large scope of different opinions in the interviews, which assures versified references to the subject in question. This thesis aims at following a positivist pattern by working objectively in identifying and calculating the relevant cost variables for innovation projects in urban distribution without interpretation of these variables. Due to the fact that this thesis uses both interpretivism and positivist paradigms, a higher level of validity is assured. The authors have continuously returned to the research questions and reviewed these throughout the process of the research to improve the validity of the thesis. This assures research accuracy and that appropriate research procedures are employed.

## 2.6 Method Criticism

It is important for researchers in general to take an outside perspective on their own research in order to understand the scope of the research and critically review both the methodology used as well as the findings of the study. This research is no different and although the selected methods have been clearly motivated and rationed, there is always critique to certain decisions that need to be highlighted.

First of all, critique is commonly directed to the paradigm chosen in this research, which is a combination of research paradigms (pragmatism). A more pragmatic research philosophy obstructs the choice of methodology and methods in research and researchers are sometimes advised to carefully reconsider if they should use a mix of paradigms (Collis and Hussey, 2014; Blumberg, Cooper and Schindler, 2001). Additionally, a pragmatic research paradigm often does not offer a clear guideline, which would be the case when one paradigm is followed completely. However, this research embraces the possibility to take into account different ways of approaching research and reality and according to McKerchar (2009) an efficient researcher should possess the flexibility to undertake the appropriate research philosophy depending on the research question and its complexity. The authors of this thesis accordingly argue that using only one paradigm excludes certain input and that the benefits of using methods from both paradigms outweigh the disadvantages of pragmatism.

In terms of the methodology used in conducting the research, it can be criticized that conducting an action research might not be the optimal choice of methodology since this research does not make changes or adjustments based on the outcomes of the study. It is true that this research does not follow the entire process through implementation in the same way as a more consultancy directed action research. However, the result of this research which is the model for cost analyses and the base for calculations can be seen as an outcome, and either way, this thesis follows the method of action research or action science all the way to the implementation stage.

Furthermore, critique can be directed to the use of secondary data, which have certain disadvantages related to it. Some drawbacks can be mentioned as whether some data are enough to cover all data needed to answer the research questions. This can be related to the fact that the secondary data might have been created in a different time and/or environment and it might not provide the specific details that is needed for the research (Blumberg, Cooper and Schindler, 2001). As a defense to this critique, this research aims to map cost factors and implications of conducted trials on urban distribution and thereby develop a model that can be used for financial evaluation for future projects. In addition, the primary data collected in this research serve as important and reliable input and fills the gaps of secondary data.

Finally, it can be said that in general it is important to not just develop a methodology, but to also follow it throughout a research in order for it to be of any use.

# 3 Literature review

The following literature review will investigate existing literature and studies conducted on the topic of new and existing urban logistics solutions and alternatives based on the current problem related to environmental issues and congestion in urban areas. The literature review will provide a framework of urban delivery solutions, their monetary costs, the operational costs of different solutions, the amount of energy consumed by different transport modes, which transport modes that produce the most emissions and what their carrying capacity, advantages and disadvantages are. The review will also include a discussion of the implications of policy regulations and restrictions on urban freight logistics.

The main question, in general terms of ameliorating the operations of urban logistics, is to find a solution that can reduce both negative environmental and social costs that are consequences of urban logistics operations, as well as lowering the all-over distribution costs to make a solution financially viable. Reviewing these areas covers all aspects of sustainability according to the triple bottom line model, i.e. the economic, environmental and social aspects. If the determinative variables can be pointed out, scrutinized and compared in different options, such as urban consolidation centers (UCC), direct deliveries or mobile depots, increased effort is needed in investigating how such a solution in the end can be financially viable in order to be implemented, the sensitivity of these variables and what the sensitivity depends on.

Following in the literature review, aspects and features of urban logistics, alternative solutions in urban freight distribution, innovation management and transport project management will be investigated related to the relevance and influence of these issues on urban logistics and sustainable freight models.

## 3.1 Urban Logistics

### 3.1.1 Characteristics of city logistics

Historically, cities are places where demand and supply of goods meet. Logistics has the function to create the link between these two elements and is therefore an important factor of economic prosperity (Hesse, 2008; Arvidsson and Browne, 2013). Moreover, the efficiency of the logistics system has an impact on economic growth and competitiveness and it influences the lifestyle of the citizens. Therefore logistics activities are vital parts of urban life and a necessity (Hesse, 2008; Anderson, Allen and Browne, 2005; Quak, 2013; Arvidsson and Browne, 2013).

At the same time, urban logistics causes negative externalities and can be perceived as a disturbing element. Air pollution, congestion and noise are negative externalities of urban logistics that are frequently mentioned in literature (De la Calle and Alvarez, 2011; Com 144 Final, 2011; Ehrler and Hebes, 2012; Quak, 2013; Arvidsson, Woxenius and Lammgård, 2013). Freight transport is responsible for a major share of these negative externalities, even though the total number of freight vehicles in urban traffic is much lower than that of private cars (Lindholm, 2013).

Urban logistics influences the economy, society and environment in multiple ways, and different actors have different priorities and goals regarding the impacts that stem from urban logistics operations. Whereas the private sector usually emphasizes economic efficiencies, public authorities have a strong interest in the well-being of the citizens. Therefore, regulations as well as supporting and restricting measures of city authorities often have the aim to improve and secure environmental and social aspects. This can often be in contrast with the aims of private actors (Macharis and Melo, 2011; Arvidsson and Browne, 2013).

There are several specific characteristics that can be attached to the transport of freight in cities. As mentioned, there is a multitude of different stakeholders whose interests and goals often diverge. City councils, retailers, carriers and local citizens are only a few of them. Nevertheless, it is of great importance that the different actors cooperate to create a running system with a good overall outcome (De la Calle and Alvarez, 2011; Ehrler and Hebes, 2012; Riehle, 2012). Looking at the actual transport operations, short distances, short effective driving times and long vehicle downtimes are all features of urban transport. Due to population density in cities, goods recipients are usually concentrated in smaller areas and drivers spend proportionally more time delivering goods than driving the vehicle as opposed to long haul transportation operations (De la Calle and Alvarez, 2011; Riehle, 2012). In addition, labor costs make up a higher proportion of the total costs than in conventional road transport. For the latter, the costs of fuel, depreciation and maintenance are higher (De la Calle and Alvarez, 2011). Moreover, the supply of infrastructure and space restrictions have a big influence on city logistics. Transport consignments in cities are usually carried out in much smaller vehicles with a lower carrying capacity than inter-city trucks. Finding parking space is often a difficult issue and congestion is a typical problem in urban areas where commercial, private and public transport all compete for the same limited space (De la Calle and Alvarez, 2011; Riehle, 2012). In addition, high and increasing rents in city centers result in a greater demand for goods transportation. Retailers use their space at hand for sales activities rather than for storage of goods and therefore a more frequent and sophisticated delivery schedule is needed (VCD, 2006). Lastly, environmental aspects play a major role in urban logistics. Because of the high population density in cities, the number of people directly affected by negative externalities is amplified. The described inefficiencies of urban transport, such as traffic congestions, even intensify the negative impacts. As a result, public authorities often have to regulate urban transport activities more rigorously in order to control the negative externalities (De la Calle and Alvarez, 2011; Ehrler and Hebes, 2012; Riehle, 2012).

### 3.1.2 The courier, express and parcel industry

The courier, express and parcel (CEP) industry plays an important role in urban goods distribution and is characterized by a steady growth. Forecasts predict an annual growth rate of 3.4% within the next five years on a global level. Within the European Union, revenues from the CEP segment were as high as €42.1 billion in 2010. According to Macharis and Melo (2011) more than one third of goods traffic in cities comes from CEP deliveries. It is also an industry in transition, characterized on the one hand by consolidation of the biggest actors on the market, and on the other hand by the emergence of new innovative niche players. Especially regarding the last mile issue in urban centers, many different innovative activities have taken place in the CEP industry during the last years. This segment of urban goods traffic is therefore of great interest in the context of this thesis.

As per definition, CEP can be divided into three different segments. The courier segment is characterized by a point-to-point delivery service that takes place the same day or at a specifically appointed time. The shipment can permanently be tracked and traced as it is accompanied either electronically or personally throughout the delivery process. The express segment is similar but the delivery usually takes place the next day or the day after at a fixed time window. Speed is of high importance but usually there is no direct shipment. The shipment is rather sent through hubs within the CEP provider’s distribution network. Finally, the parcel segment is the most standardized and automated of the three segments. Parcels are limited in their weight and volume and there are no guaranteed delivery times. The transit time is usually within 1-2 days. Consolidation of parcels is common in this segment and there is a strong volume orientation (Ducret, 2014; Esser and Kurte, 2014). However, Ducret (2014) also mentions that the differentiation of the three segments has become somewhat blurry during the last years with the service contents assimilating.

Regarding transport service providers, an increasing process of their convergence and co-evolution can be monitored, especially in city contexts. Ducret (2014) distinguishes between three different types of actors. The first type is the so-called heirs. Heirs are the few traditional, long-term players in the distribution industry that hold a majority of the market shares. In Europe, major players like DHL, UPS or FedEx hold, on average, up to 50% of the market shares for domestic shipments (Salehy and Ryssel, 2011). In the US, the market is even less fragmented, with UPS and FedEx operating 90% of the volume of parcel deliveries (Berman, 2014). The openness of the heirs towards change certainly depends on the individual company, but in general these actors are described to be rather reluctant to change. Liberalization of markets, economic crisis and the emergence of new niche players with innovative concepts have however forced traditional players to adapt to new market conditions. Initially, adaptation was mainly done by subcontracting services, but in recent years increased integration and investments into internal service innovation and vehicle research have been observed (Ducret, 2014). The second type of actors is the new players that are specialized in urban parcel distribution. These actors are usually niche players with a strong focus on service innovation and sustainability. They develop high value services for their customers and are dedicated to find green solutions for last mile problems. Furthermore, they use sophisticated IT tools and innovative logistic organizations to reach these goals. As these new players are usually relatively small and act as subcontractors, their business models are often associated with high risk, especially in financial terms. They are usually highly dependent on their contractors. Another type of actors that falls into this group is e-tailers, such as Amazon, that have expanded their current business model and also become freight forwarders (Ducret, 2014). The third family is other logistics providers. Their traditional business lies more upstream in the supply chain, consisting of large and heavier shipments between business-to-business (B2B) customers. As their business customers increasingly engage in the business-to-consumer (B2C) segment, this group of logistics providers has been forced to adjust their service offer in the same direction. Moreover, some providers have also recognized the field of urban deliveries as a growth market and see it as a possibility to diversify their current business (Ducret, 2014).

As mentioned, the frontiers that used to distinguish these actors are becoming blurrier. In fact, the CEP industry is characterized by strong consolidation (Salehy and Ryssel, 2011; Ducret, 2014). Horizontally, the heirs and the new players act together in order to create innovative solutions suited to the difficult urban environment. Vertically, traditional parcel shippers and e-commerce logistic providers' work together to create an integrated solution from ordering to final delivery (Ducret, 2014).

The changes that have taken place in the urban CEP industry during the last years can, according to Ducret (2014), be ascribed to three main drivers. The first, and strongest, driver is the retail revolution that has taken place in recent years. Most important here is the emergence and the strong growth of e-commerce which is predicted to proceed in the future (Riehle, 2012; Ducret, 2014). E-commerce has led to a strong increase in B2C deliveries and therefore more urban deliveries. Additionally, traditional retailers expand their service towards multi-channel retailing, with their goods being directly shipped to customers. Moreover retailers are restructuring their upstream supply chain and especially in cities, storage space is sacrificed for retail space. This results in a change of their logistical demand towards more frequent and Just-in-time (JIT) deliveries. This leads to increased volumes of CEP services in cities (Dablanc, 2009; Ducret, 2014).

A second driver of change in the urban CEP industry is that B2B and B2C deliveries are becoming more similar. Final consumers are more demanding today and they have become used to short delivery times. They expect the same high service quality that business customers get. Therefore, the difference between express and ordinary parcel deliveries seems to dwindle. At the same time deliveries to end consumers are more difficult and less efficient in their nature. Failed deliveries are common, and urban constraints, congestions etc. increase the costs of these deliveries. As a consequence, e-commerce and B2C is a growing market with increasing demand and volumes. However, the margins from these deliveries remain small (Salehy and Ryssel, 2011; Ducret, 2014).

As a last driver for change, Ducret (2014) identified the increasing concern and involvement of politics into urban logistics. Growing traffic volumes lead to increased negative externalities that political authorities have to manage. Urban logistics is nowadays on the agenda of most municipalities, and stricter rules and regulations such as low emission zones or congestion charges force the CEP industry to comply and adapt accordingly. In order to continue their business operations, the players often have to find new solutions or team up with e.g. green logistics providers in order to meet the regulations.

In conclusion, the CEP industry is an important and growing segment in urban goods traffic. The change in consumer shopping patterns, like e-commerce, and the reorganization of supply chains by retailers leads to increased volumes of smaller parcel deliveries. At the same time, cities are constrained and regulated environments for goods deliveries. This has led to the emergence of new innovative service providers, which are especially focused on city distribution and sustainability in this context. Traditional players usually have more defensive and cost orientated strategies and try to keep their business as usual free of distortions and therefore they subcontract last mile deliveries in urban areas rather than investing in new, innovative solutions. Thus, their goal is rather to comply with political regulations than to actively find green solutions (Salehy and Ryssel, 2011; Ducret, 2014). As a consequence of the fact that constraints in cities will likely increase in the future, the specific field of urban CEP distribution will undergo further changes, and strong increases in more efficient and emission free last mile solutions can be expected.

## 3.2 Alternative solutions in urban freight distribution

### 3.2.1 Consolidation centers and mobile depots

The way retail has changed has put a lot of strain on urban delivery and freight distribution processes, and unpredictable sales volumes make quick response logistics and inventory management more important than ever in order for companies to maintain a competitive cost structure (Greasley and Assi, 2012). Conclusively, volatile sales and JIT delivery requirements combined with traffic regulations, time windows and increased product mixes indicate considerable challenges to both suppliers and transport operators. Economies of scale are essential to minimize transportation costs and to avoid less-than-truckload (LTL) shipments. LTL shipments can be consolidated into one delivery in order to maximize vehicle utilization rates and cover multiple deliveries within the network with fewer vehicles (Greasley and Assi, 2012). Last mile deliveries pose great challenges on urban distribution networks. Traffic regulations, old, one-directed and narrow streets and congestion can disable the reliability and speed of these deliveries. Pollution, exhaust and $CO_2$ emissions from city deliveries from motor driven vehicles such as trucks and vans is extensive in urban areas and according to Verlinde et al. (2014) the amount of vehicles running on alternative fuels is significantly low, with an average of 5.5% in the EU (Eurostat, 2014a). This brings upon an increased number of cities that will introduce congestion and emission charges to inner city transportation operators, imposing further difficulties in last mile deliveries. Congestion and emission charges thus become cost driven incitements for stakeholders to find new solutions to how to provide last mile transportation services in urban areas (Verlinde et al., 2014).

Many new solutions in terms of depots and inner city distribution alternatives such as outer-city consolidation centers, mobile depots and intermodal combinations have been generated due to the aforementioned strain on urban logistics. Using public transport such as buses or light rail for freight transport is commonly referred to as piggybacking and has been related to several advantages, such as increased vehicle utilization rates and reduced number of freight vehicles on the roads. Trials for alternative urban logistics solutions have been conducted all over the world in high demand cities, and the different options all come with limitations, restrictions, advantages and disadvantages and there is no one-solution-fits-all. This section will investigate alternative transportation modes and innovative depots solutions that have been developed in order to deal with the challenges of urban logistics today.

**Urban Consolidation Centers**

An urban consolidation center is a warehouse that usually works in a hub and spoke system. UCCs are located outside of the inner city area in order to reap the benefits of lower rents and costs compared to more central areas. Deliveries are made to the UCC and freight is then consolidated in order to make all final deliveries more efficient. According to Lin, Chen and Kawamura (2014), there are potential, environmentally related, benefits in employing UCCs when vehicle utilization is optimized through consolidation. Theoretically there are also cost related benefits of using UCCs outside of the city center compared to employing expensive storage at central customers' sites. Apart from last mile deliveries from UCCs, more environmentally friendly vehicles and shorter routing distances, an UCC can provide value added services to its customers such as storage, consignment unpacking and labeling (Browne, Allen and Leonardi, 2011). UCCs are related to institutional success factors such as financial stability and support, leadership and management, an interactive logistics network and engaged stakeholders as well as more operational aspects in terms of spatial coverage, the location of the UCC and the fleet and route management (Panero, Shin and Lopez, 2011). Given these circumstances, an UCC can be both environmentally and economically beneficial compared to a non-consolidated solution. However, the benefits are related the prerequisites of high scale and high customer density, i.e. a larger city with high product demands (Lin, Chen and Kawamura, 2014).

Many UCC projects have estimated to be financially independent on a medium or long-term perspective, however many have failed these goals. Ville, Gonzalez-Feliu and Dablanc (2013) identify a small number of financially responsible UCCs where the UCC manages to balance cost to revenues, such as Padua and Parma in Italy. However, most of the investigated UCCs still receive strong support from the local public authorities. UCCs are sometimes solely seen as an additional step in the supply chain as well as an obstacle when it comes to profit distribution to the various actors of an UCC. Accordingly, Gonzalez-Feliu (2014) found that as a consequence of additional costs and responsibility transfer, most carriers do not gain on passing through an UCC.

**Mobile depots**

Mobile depots have been developed in order to benefit from the cost advantages of having a depot located close to the final customer while at the same time avoiding the high rents and estate costs in central urban areas. Generally, a mobile depot is a larger vehicle that is loaded (usually with CEP-sized consignments) at a warehouse or consolidation center outside of the city to then follow a calculated route through the city. A mobile depot then employs smaller, usually more environmentally friendly, vehicles that perform the last mile deliveries of parcels and consignments from the mobile depot to the customer. The use of a mobile depot could potentially allow for both cost and environmental benefits. The environmental benefits related to consolidated freight and last mile distribution with low-emission vehicles would be acquired, and furthermore the solution does not require any central rent expenses (Browne, Allen and Leonardi, 2011). Verlinde et al. (2014) documented the trial performed by TNT Express in the city of Brussels where a mobile depot was used together with cargo bikes for last mile deliveries. TNT showed successful outcome in terms of integrating the operations into the existing urban transportation network and showed results of reduced $CO_2$ and PM2.5 emissions over the trial. However, Verlinde et al. (2014) conclude that the future employment of the project in Brussels by TNT might be discontinued due to reluctance to switching vehicles as well as the fact that operational costs of the trial were twice as high as the company's regular operations. There are different options for vehicle use in mobile depot operations, where the success of each option in general depends on exogenous circumstances such as city characteristics, scale and project budget.

*Trucks/vans*

The traditional and conventional delivery mode for urban logistics solutions is road transport performed by trucks or vans. In general, road transportation, especially in cities, is one of the most environmentally damaging modes due to the high emissions of $CO_2$ and PM which pollutes not only the local air but also contributes to the greenhouse effect and climate change. Optimized routing software systems, time and size regulations, tolls and taxes and alternative fuels are all examples of actions taken in order to minimize the damage caused by trucks and vans in urban areas (McKinnon, Browne, and Whiteing, 2012). When biofuel and hybrid fuel is used instead of petrol or gas, environmentally friendly trucks and vans become an alternative to conventionally fueled ones. Some disadvantages of alternative fuels such as biofuel or electricity are cost related due to the fact that fossil fuels still cost less than many green fuel alternatives. In addition, the investment costs of introducing a new vehicle fleet can also be substantially high. However, an increasing number of customers begin to value green logistics operations and the usage of low-emission vehicles can improve both company image and sales due to the high level of visibility of labelled trucks and vans in urban areas.

In addition, trucks can be used as mobile depots for inner city distribution combined with low-emission last mile delivery modes, such as bikes. Experiments have been conducted in Germany where companies have focused on using bikes for freight deliveries to reach locations that are difficult to access with other transport modes. In these cases bikes should not replace the current fleet, but rather complement it. In the pilots bikes are used to collect freight from regular trucks that operate as mobile warehouses for further delivery to the final recipient. The delivery bikes do not need to find parking for each stop of delivery in the same way as conventional delivery vehicles do, which saves significant time and is seen as a clear advantage of this model. This system also allows for high utilization rates of the bikes due to the possibility of continuous deliveries along with the mobile depot. Another advantage has been shown as the possibility to shorten routes by riding bikes on limited and one-way streets (Lenz and Riehle, 2013).

*Bus*

One suggestion for urban delivery is to create a bus distribution system. In practice this means that a bus is loaded at a depot, central warehouse or urban consolidation center and then takes a route to deliver packages with last mile delivery options (Dell'Amico and Selini, 2012). Using a freight bus as a mobile depot with alternative last mile distribution modes implies one additional step in the supply chain compared to a traditional truck doing direct deliveries. Something that in turn has additional cost implications to this solution. The most savings when using a freight bus as a mobile depot can be derived from the increased carrying capacity of a specialized freight bus compared to a truck or a van as well as lower loading and off-loading levels. Additional environmental benefits are given if buses run on alternative fuels, such as bio fuel, electricity or hybrid fuel compared to diesel or petroleum driven trucks (Van Mierlo et al., 2003). However, alternatively fuelled vehicles could bring upon extra costs that decrease the likelihood of freight buses being a financially viable alternative for urban freight. Nevertheless, a comparison between urban freight activities performed with a freight bus and with traditional vehicles such as trucks and vans, both in environmental aspects and in cost aspects, is needed to make an evaluation of this distribution alternative.

*Tram/Light Rail*

Another solution to developing urban logistics operations in order to cope with the increasing congestion and climate threat from GHG emissions is presented by Arvidsson and Browne (2013). It is suggested that the existing infrastructure be better used in order to avoid unnecessary investment costs that might hamper a new project. The proposal is to use the existing urban rail system (i.e. piggybacking) in order to make intermodal (rail and road) deliveries more efficient by using trams as mode of delivery (Arvidsson and Browne, 2013). Current examples of cities where trams have been introduced in the urban delivery system include Dresden (Germany), Vienna (Austria), Zürich (Switzerland) and Amsterdam (the Netherlands) where trams serve as cargo modes for freight transport and mobile depots for recycling. In Dresden, the car manufacturer Volkswagen initiated an urban logistics experiment that uses the tram to transport goods to the manufacturing site. The two trams used are each 60 meters long and have a carrying capacity of 60 tons. They would run 16 hours a day, 6 days a week and the results of the implementation showed positive and profitable results compared to road transportation (Regue and Bristol, 2013). However, as shown in BESTUFS (2001) the cost of manufacturing these two specialized trams was high (€3.5 million) and there were difficulties in finding a capable manufacturer. As a solution to this obstacle, Arvidsson (2010) suggests the use of obsolete passenger tramcars for delivery of goods.

Using trams as an urban delivery alternative to conventional transport modes such as trucks and vans have certain environmental advantages due to the fact that trams and light rail can be considered low-emission or even emission-free alternatives. When it comes to congestion, one of the most important issues is that freight transportation cannot interfere with public transportation, which is of high value, something that often happens with road traffic in peak hours (Regue and Bristol, 2013). By using trams, this can be avoided by employing the so-called follow strategy, where the freight tram follows the passenger tram traffic so not to disturb the flow of passenger time schedules (Arvidsson and Browne, 2013).

*River Barge*

Using river barges as an alternative for mobile depots in urban freight solutions has various advantages and disadvantages. First of all, a river barge can carry large freight volumes and thus provides great capacity measures in areas where demand is high. However, natural reasons limit the reach of a river barge in a city, making the last mile delivery from the barge station to the final customer important from a cost perspective. In terms of pollution, a barge delivery solution hardly produces any $CO_2$ emissions on the one hand, but on the other hand waterborne transportation generates both nitrogen oxide (NOx) and sulphur oxide (SOx) emissions that affect the local area significantly (McKinnon, Browne, and Whiteing, 2012). A river barge is only possible where a river is running centrally through a city (such as Paris, Amsterdam, London or Chicago) (Lumsden, 2007). There is also need for different off-loading areas along the central river, something that is likely to have significant costs not only due to the initial investments in case such areas do not already exist, but also because of the high estate prices and rents in central city areas. This is the reason why most urban depots have moved out of the central areas (Taniguchi and Thompson, 2014).

Concluding this section, aspects such as customer density and freight demand volume, time windows and current strain on traffic and congestion to find the best-fit solution must be taken into consideration when evaluating different distribution modes and depots for urban freight distribution. These aspects can make one solution economically viable in one urban area but inefficient in another, depending on the sensitivity of the different variables. This will be further developed in the empirical research and in the analysis of this thesis.

### 3.2.2 Emission free last mile solutions

Last mile delivery and the last mile problem that are often discussed in logistics refer to the last part of a freight delivery process from a warehouse, distribution center or UCC to the final recipient. A lot of attention is paid to last mile solutions due to the fact that it can sometimes be considered the least efficient step in the whole supply chain (McKinnon, Browne, and Whiteing, 2012; Lin, Chen and Kawamura, 2014). Transport operators are often restricted in their last mile operations according to vehicle size and weight restrictions. When large trucks are restricted, transport providers are forced to implement lighter, and thus additional, vehicles into their last mile operations in order to comply with the increase in demand in frequency for goods delivered to urban retailers. In the following, several options for last mile delivery are discussed.

**Bikes, E-Cargo Bikes, Tricycles**

With increasing focus on sustainable freight vehicles in central urban areas, bikes are often suggested as an alternative to trucks and vans for last mile deliveries. Thereby, a new wave of cargo cycles, or E-Cargo Bikes (E-CB), with higher payload than regular bikes are starting to be more and more used. While regular bikes have a capacity of about 25 kg their cargo availability is limited, however, E-CBs can carry cargo of 50-250 kg, making them a much more competitive alternative for actual cargo delivery (Lenz and Riehle, 2013). Electric tricycles can also vary slightly in terms of capacity and scale, however usually the vehicle weighs 110 kg without driver or battery and can carry load up to 180 kg on a load space of 1.5 meters. Tricycles have a travel speed of up to 15 km/h and require overnight charging of batteries (Browne, Allen and Leonardi, 2011). The purchasing prices for electric tricycles or E-CBs can vary greatly, from the lower end of €1,300 - €3,000 for E-CBs up to €6,500 - €10,800 for more advanced models, where the different prices depend on the sophistication and customization of the vehicle (Ecoride, 2015a; Nutzrad.de, 2015; Radkutsche.de, 2015). According to Gruber, Ehrler and Lenz (2013) the major problems in terms of implementing newly developed vehicles in the freight segment are the electric range and the purchasing price.

Findings from urban logistics trials in London have shown significant reduction in environmental impact followed by the replacement of vans by bikes and E-CBs as well as lower stress on traffic lanes and congestion in the inner city (Browne, Leonardi and Allen, 2010). Other findings conclude that the lower payload of the bikes resulted in increased kilometer per package compared to truck or van deliveries.

There are different aspects to consider when it comes to bikes, tricycles and E-CBs. Using cycles for urban freight transport has advantages compared to motor driven vehicles in terms of traffic problems and congestion as well as in terms of costs, delivery speed in inner cities and marketing and brand potential for the transport provider. Bikes also play an important role to better handle increased traffic demands in bigger inner cities and are exempt from vehicle restrictions (Lenz and Riehle, 2013). In London, some transportation providers use E-CBs and other electric vehicles for last mile deliveries in the city center with loading stations located outside of the congestion charge zone. The results of this are reduced $CO_2$ emissions by 62% as well as reduced mileage per package by 52% (Browne, Leonardi and Allen, 2010). Additionally, when it comes to cycle freight as an alternative transport mode, the London example has shown several advantages as well as disadvantages. Purchasing costs as well as taxes and insurance are lower for bikes than for vans and lower operating costs of a bike are significant in order to maintain a competitive pricing model. Other advantages are lower parking costs and no congestion charges for bikes and the environmental impact is significantly lower and less driver training is required for bikes compared to vans, which also has a positive impact on total costs.

In terms of disadvantages of using bicycles as urban freight mode, many non-bike users perceive a high level of insecurity connected to using cycles. Also, many companies relate cycle freight to an increased level of driver fatigue and are thus reluctant to switching transport modes. The most relevant disadvantage is the issue of reduced range, capacity and payload for bikes compared to vans or trucks. This is said to be resolvable by using either secondary city-center hubs as a complement to UCCs, or using vans as mobile depots throughout the city deliveries (Lenz and Riehle, 2013). However, the lack of information available regarding load capacity for bikes and E-CBs might be the reason for these perceptions and technology has actually developed further and E-CBs are now more potent than often believed.

**Segways**

Using segways as an alternative for last mile transportation is less common. Segways can be seen as an alternative version of an E-CB and have similar advantages and disadvantages in terms of pollution, congestion and charging. A segway is a two wheeled, self-balancing transportation vehicle where the “driver” stands on a flat surface between the wheels, holding on to a handle. The segway is battery driven and does not require any pedaling (Rose, 2011). The segway does not require any fossil fuels for charging, only electrical power, and is said to be a zero-emission vehicle, depending also on the source of energy used to charge the segway battery (Heinzmann and Taylor, 2007). The battery is fully charged in 8-10 hours and which consumes 1.04 kWh of energy. A segway can travel 26-39 kilometers on a full battery (Heinzmann and Taylor, 2007). Shaheen, Guzman, and Zhang (2010) conclude that the segway has future potential of developing as a personal transportation mode in urban areas, potentially following a bike-sharing trend, however, no freight solutions is discussed. According to Moore (2006), the segway as a widespread transportation alternative might not be guaranteed due to the fact that it might struggle to overcome some of the natural market hinders for new product and technology introductions.

With the segway being a relatively new phenomenon in transportation, its classification has not been completely clear thus far. In the USA, many states have created a new category for the segway, calling it a “personal mobility device”. This has mostly to do with the fact that without a separate category, the segway most likely would fall into the category of mopeds, which often require specific licenses (Rose, 2011). Because of the fact that the segway must be clearly categorized, and if categorized as a moped, the cost of employing segways as alternative last mile delivery vehicles might increase due to licenses, need for more qualified employees etc. Further on, Rose and Richardson (2009) evaluate the energy savings and sustainability potential of segways as relatively low compared to three-wheeled vehicles and micro- and moped cars. In addition, the segway as an alternative mode does not imply substantial mobility opportunities due to its speed and scale limitations. The segway is supposed to neither increase nor decrease security drastically compared to conventional transport modes (Rose and Richardson, 2009).

In terms of freight capacity, segways can carry about 20-30 kg varying according to the weight of the driver, it is also possible to attach a trailer to a segway to increase cube and weight capacity (Snapp, 2009) and the maximum total weight carried by a segway is 117 kg (Heinzmann and Taylor, 2007). Also, according to Snapp (2009) segways have the disadvantage of still being relatively expensive in terms of initial investments and they are also mainly recommended for warehouse operations and lower impact environments.

**Walking**

Walking is often excluded from calculations and solutions when it comes to solving the last mile delivery problem due to the significant human effort required to produce this service (Edwards, McKinnon and Cullinane, 2009). The option of walking to deliver parcels and shipments might seem outmost costly due to the significantly lower capacity of a person compared to a vehicle. Furthermore, the time implications of one delivery consequentially increase overall delivery costs and amplify the bottleneck of the last mile (Dekker, Bloemhof and Mallidis, 2012). The average person walks in a speed of about 5-6 kilometers per hour and the carrying capacity only stretches to about 10 kg with any weight increase negatively impacting the speed. The only time a human delivery is an option is where the delivery “depot”, or truck, is very close to the receiving destination and human interaction is the only alternative. However, this form of delivery is already the case in many urban CEP delivery processes today where the driver unloads and carries the parcel from the car/van to the recipient.

However, in terms of last mile issues of home deliveries (i.e. B2C), many studies have shown results of respondents being positive towards walking to a pick-up depot to retrieve their goods (McKinnon, Browne and Whiteing, 2012). This has to do with the complications of miscommunications, timing and the hassle of being at home at the time of the delivery. The solution of pick-up centers and collect depots where end customers can walk to collect their goods might be able to solve issues of last mile deliveries in urban areas in the B2C or Customer-to-customer (C2C) segments, however the issue becomes fragmented when larger deliveries in terms of weight and cube in B2B relationships are considered.

The importance of alternative solutions for urban logistics operations has been highlighted above, as well as descriptions of alternatives for last mile delivery modes. Moreover, in order to understand the potential as well as barriers of such implications, it is of value that the underlying complexity of green city logistics projects in different environments and situations is introduced and understood.

### 3.2.3 Green city projects - implications from practice

Numerous experiments towards more environmentally friendly urban transport solutions have been attempted over the last years. However, as there seems to be no lack of innovative ideas but rather of sustainable business models, most of the developed projects have failed to make it over the trial stage (Lindholm, 2013). The high failure rate of innovation projects can be seen as an obstacle when it comes to persuading officials and stakeholders to implement yet new solutions. It is therefore valuable to provide an overview over the different innovation projects and trials that have taken place in the context of green city logistics. By analyzing past experiences, reasons for success and failure can be identified. This leads to an overview of critical topics that have to be kept in mind when designing a new city transport solution. This section shortly summarizes different transport initiatives, reviews and trials about transport projects and draws implications from them to practice.

In a review, Arvidsson and Browne (2013), investigated the reasons for success and failure of four tram projects in Europe. Two of the projects are currently still in use. As mentioned, the so-called “CarGo-Tram” uses the existing tram system to deliver goods for Volkswagen from the distribution center to the factory in Dresden. The project started in 2000 and has run successfully since then, where an equivalent of 60 trucks is saved each day. The limited scope and the small number of actors involved can be seen as a main success factor. In fact Volkswagen is the only customer, which certainly facilitates the organization. In Zürich, a tram project of limited scope has been running since 2003. Along nine stops of the local tram line, citizens can drop of bulk waste in special containers. The containers are then transported away by specially customized, converted old tram wagons for disposal. Even though initial investments for the conversion of the tram were needed, this system now saves significant amounts of fuel, air pollutants and other negative externalities and in addition has achieved to offer a cheaper service. In this case, the availability of infrastructure, the nature of the goods transported and the limited scope can be seen as success factors.

On the other hand, a tram project in Vienna aimed at employing the available space on public tram for commercial goods transport was never implemented. Even though €1.4 million were invested into a pilot, the new system was not able to attract enough private customers to make it financially viable (Ziegler, 2007). Furthermore, a tram project of far bigger range was planned for Amsterdam. When reaching its final scale this project would save a total of 2,500 truck movements of commercial goods within the city each year. However, the project went bankrupt shortly after the implementation in 2008. The estimated costs of this project were €70 million and the inability to collect enough capital was one of the main reasons for failure. Moreover, Arvidsson and Browne (2013) mention politics and discrepancies between the actors involved as obstacles and reasons contributing to the project’s failure.

In their conclusion, Arvidsson and Browne (2013) point out several barriers that can impede the successful operation of cargo trams. First, they mention the complexity of shared use of the tram by passengers and freight. Local authorities usually give preference to passenger transport and therefore it is important that goods traffic does not interfere with this. Second, a too big scale right from the beginning is seen as difficult to approach. Expensive initial infrastructure investments should be avoided and it is important to perform proper cost calculations before the implementation of any new project. Third, a limited radius of action can become a barrier. The existing rail network limits the range of trams and therefore the connecting vehicles for the final delivery stage need to have enough range to reach all customers. As the last two barriers conflicting objects among stakeholders and their involvement is mentioned. A change in the city logistic network should not be seen as a potential threat by already existing providers. Moreover, all stakeholders should participate voluntarily as forcing them into a project usually leads to only limited cooperation and even rejection.

Regué and Bristow (2013) theoretically evaluated the potential viability of a freight tram scheme in Barcelona. They come to the conclusion that in the current situation, no positive financial result could be reached. Nevertheless, they identified three potential success factors in their research. First, to make delivery on public transport viable, the given network infrastructure has to be sufficient. It is therefore important that a high density of customers is located close to the network. The setup of new infrastructure usually leads to high capital investments. This usually impedes the financial viability of new transport solutions even when they run on lower operational cost. Second, cross-docking facilities as locations where the modal shift onto the trams take place are essential. Consolidation centers in proximity to the tram network as well as links to the road and rail infrastructure should already be in place otherwise infrastructure investment with the same problems as above would be the result. Third, there have to be enough demand generators so that the trams can be run with high load factors, in order to increase the operational efficiency. It is the ability to transport more cargo in a single wagon than a truck that usually makes up the advantage in operational costs.

Another comprehensive overview of the implementation of electric freight vehicles (EFV) in urban logistics is provided by the FREVUE study where Nesterova et al. (2013) studied several green city freight initiatives in Europe and identified obstacles and positive examples with the use of EFV. Economically, the high initial investment costs are reported as a possible obstacle. Small transport providers usually have limited finances at hand and focus rather on short term benefits. Moreover, the second-hand value of EFV is not totally clear, which makes operators reluctant to make big investments. On the positive side, the operating costs of these vehicles are usually lower compared to conventionally fuelled vehicles. Additionally, EFVs are often allowed to access city areas that are restricted for conventional vehicle traffic. Due to the better environmental performance they are often favored by politicians and extended hours of operations are also mentioned as a positive aspect. However, one obstacle is the limited loading capacity that such vehicles possess as well as the required charging facilities. In general, concerns about the technical performance of EFVs exist. There is a common perception that the limited range of the vehicles might be problematic, but for distribution activities in urban areas it is usually sufficient. However, in the observed projects several issues with failing batteries, lack of equipment, long charging times and lack of maintenance support have been reported. With reliability being a main issue for transport operators, the technical performance can be seen as a major obstacle. The fact that the development of better technology takes place so quickly is mentioned to be a reason for operators to postpone their investment in innovation. From a social and environmental point of view mainly benefits exists. The reduction of noise and pollution are seen as big improvements and EFV drivers are mostly satisfied with their vehicles. However, it is important to take the source of energy for the environmental evaluation into account, since energy from non-renewable sources weakens the environmental gains. Lastly, the support through local politics is mentioned as important factor. On the one hand, supportive measures can take the form of financial and non-financial promotion of EFV like e.g. purchase subsidies or access to special parking areas. On the other hand this can be restrictions on conventional vehicles such as higher taxes or low emission zones. Politics plays an important role in creating incentives for the use of EFV and can be the reasons why the use of EFVs is more common in some cities than in others (Nesterova et al., 2013). This will be further discussed under the following section "transport project management".

In addition to the extensive project reviews as presented above, there are several other interesting examples of green transport projects. The reasons for their success or failure is shortly illustrated in the following.

In the inner city of Paris, small urban logistic spaces have been set up for innovative operators who perform emission free last mile deliveries. Allowing for these spaces to be used has shown to be financially viable as they take up much less of the high-priced urban space than common UCCs do. Moreover, the city of Paris provides long term funding and support, which ensures the operators security and trust (SUGAR, 2011).

Another example of a successful city project is Binnenstadservice in the Netherlands. The non-profit organization operates consolidation centers in several Dutch cities where it consolidates shipments of the participating, mainly small, retailers in the inner city. From the consolidation centers the goods are shipped with environmentally friendly modes to the recipients. To reach a critical mass of participants, efficient last mile operations are described as a prerequisite. The projects therefore receive governmental funding in the beginning. Moreover, the bottom-up approach leads to high acceptance amongst the participating retailers since they do not pay for the transport service itself. Binnenstadservice offers value added services like collection of packaging material that the retailers can use for a fee. The small-scale approach combined with initial funding, and the high acceptance of the customers can be seen as success factors of this initiative. A critical point is the need for a sufficient mass of customers in order for the concept to work efficiently (Jorna, 2013).

Furthermore, a rather unusual approach of parcel distribution is performed by DHL in Amsterdam where shipments are transported on a rebuilt tourist boat through the canals in the city along with bike delivery people that are connected to the boat via radio and perform the final delivery stage emission free. This transport solution has now been in operation for over 10 years. The success can mainly be attributed to the infrastructure conditions in Amsterdam that are perfectly suited for this solution. On the one hand one quarter of the city is covered by water with a dense network of canals characterizing the city, and the waterways are always in proximity to retailers and other customers. On the other hand, narrow streets and harsh regulations make conventional road transport in the inner city unattractive and painful. In addition, the dialogue and mutual development of the idea between DHL and the city council can be seen as a reason for success (Magnes, 2011).

Finally, in a study for the Frauenhoferinstitut in 2013, 46 city logistic projects in Europe were reviewed. It was concluded that most of the projects are not profitable. The main obstacles discovered are the lack of financial viability and trust among stakeholders. Furthermore, projects that target individual, smaller enterprises as customers make the most sense. Bigger companies usually already have optimized supply solutions in place and therefore no major benefits exist for them (Semmann, 2013).

In conclusion it can be seen that numerous small and big obstacles and success factors influence the success of green city logistic projects. There are several recurring topics. First, the monetary side is of high importance. Many projects have failed after the initial subsidies stopped. In order for a project to be successful, a proper financial model and preliminary cost calculations are paramount. Even though some public authorities financially support environmentally friendly projects initially, a positive cost model has to be in place to guarantee long-term success. Ex-ante calculations with positive results can also help to convince additional stakeholders to cooperate in the project. Stakeholder involvement is another key success factor. Projects where different actors were forced to participate, sometimes even against their own objectives, have not been successful. It is thus essential to create solutions that are beneficial for all affected stakeholders in order to avoid project resistance. Lastly, no one city is like the other. Green city logistics projects can only be successful if they are tailored to the specific needs and characteristics of the city and certain prerequisites are already in place. It has to be carefully evaluated, if a project really is beneficial and if the potential gains are high enough to justify the needed initial capital investments. From a local authority perspective, environmental and social benefits are of especially high importance and if such benefits and gains are great enough, higher monetary costs can sometimes be justified.

In the next sections some ideas of how innovative projects can be better planned and managed are presented.

## 3.3 Innovation management

### 3.3.1 System Innovation

"System innovations are defined as large-scale transformations in the way that societal functions such as transportation, communication, housing, feeding, are fulfilled" (Elzen, Geels and Green, 2004, p.19).

A system innovation is a transformation process that leads from one socio-technical system into another (Geels, 2005).

The notion of a socio-technical system indicates that development and innovation is not only about technological artefacts. In a comprehensive literature review, Geels (2005) explores different theories about system innovation over various academic disciplines. He concludes that most theories only focus on a few aspects in isolation but there is a lack of integration of the different perspectives. He argues that system innovation is more comprehensive. A successful transformation requires the interaction of technological artefacts with human agents, social structures and organizations. Each individual element is important, but has in itself not enough power to lead to actual transition.

A socio-technical regime consists of different groups of actors that interact with each other. These groups are usually guided by self-interest and they take actions that aim to improve their own situation. As the different groups are interconnected, changes in one group can influence the situation of another group and the interaction is therefore referred to as dynamic.

As an outcome of the extensive literature review, Geels (2005) developed a conceptual framework for system innovations that combines theories from technological, evolutionary and sociological economics. This is a multi-level perspective that consists of three interrelated layers.

The meso-level is made up by the existing socio-technical regime and is characterized by a high stability. The current system might not be the best solution available but the current society is built around it. Infrastructure has been developed for this system and large investments have been made to enforce the current state. The characteristic of high stability is often referred to as a lock-in situation in that no disruptive innovation or change can be expected, and the actors rather invest in incremental innovations to improve and optimize the current system. There exist many rules and regulations and this level is highly structured and coordinated.

Below the meso-level is the micro-level of technological niches. These niches are supposed to be safe places where experiments can be performed and where radical innovations are developed. The developed innovations cannot yet compete in the existing system and marketplace. There are no rules, structure or coordination on this level. The innovations have the potential to solve existing problems and the niches can be seen as places where a learning process takes place.

The top layer is the macro-level, which consists of the wider external environment and socio-technical landscape. It represents society as a whole, its values, concerns and aspects like demographics, environmental problems and resource scarcity form this level. This level is the most structured of the three. It cannot be influenced willingly by the actors involved but rather develops over a long time.

According to the multi-level perspective, innovation takes place through the linkage between the processes on the different levels. As mentioned, radical innovations that are developed in niches are not strong enough to compete with an existing regime. Different innovations rather have to sum up and mutually reinforce each other to become competitive on the meso-level. A real transition from one socio-technical regime into another is only possible if the existing regime starts to become unstable and problems can no longer be solved by only gradual changes.

Geels (2005) describes four phases of a transition process, also referred to as a multi-level perspective that have been tested and verified through various case studies. Initially innovations emerge in an existing context but no expansive application exists for them. They solve a specific problem and have only niche applications (e.g. cars for racing). Thereafter, the novelties become more technically specified and new functions are developed. In the third phase, a wider diffusion of the new technology takes place and starts to compete with the existing regime. Finally the old regime is replaced by the new technology and a wide transformation takes place. This is when a new stable socio-technical regime has developed around which society is built.

A comprehensive transition theory on a broad level is also described by Elzen, Geels and Green (2004) in “System innovation and the transition to sustainability”. The authors illustrate system innovation that is far more complex and broad than single innovations. According to Elzen, Geels and Green (2004) incremental, isolated innovations are only system optimizations that have the potential to gain improvements in environmental efficiency but for real system innovation, a far bigger step is needed. The field of transport illustrates an example where partial fixes can help to solve numerous problems, but on the long-term a transition into a new system is needed.

This transition theory builds further on the theory of Geels (2005) that system innovation is a multi-actor process that takes place on different levels. Transition is characterized as co-evolutionary development. First, this means that changes have to take place on the supply as well as on the demand side. Second, transitions mean large and deep changes in the current structures and elements of the existing regimes. Third, as mentioned, they involve various actors that are interrelated. And fourth, they take place over a very long period of time and a timeframe of one generation (ca. 25 years) is mentioned.

The authors describe transition management as “deliberate attempt to work towards a transition which is believed to be a more sustainable solution” (Elzen, Geels and Green, 2004, p.143).

However, they also note that real management of transition is not truly possible as such transitions are far too complex and autonomous and there are too many actors involved for anyone to attain a complete overview. It is nevertheless possible to steer transitions in a certain direction and to speed them up through the use of the right tools. For this purpose, the authors describe a modulation philosophy of transition management, which makes use of bottom-up initiatives and uses ongoing dynamics in society to push the transition towards the sustainable goal. They recommend a two-sided approach of putting pressure on the existing regime through harsher regulations and of stimulating niche development at the same time. This differs from today's way of doing policies. A change is not only needed in the economic framework, e.g. taxes, but the mindset of people also has to change. That is, the macro landscape has to alter in order to reach a transition of the existing regime.

Transition management is therefore rather process oriented. It is not focused on a certain outcome but it is rather the process of reaching the sustainable vision that matters. It consists of content and process objectives, but learning itself is rated as an important objective and innovation experiments are seen as learning by doing. Failures are not necessarily perceived as negative outcome but as an opportunity to learn. Short-term and long-term goals are back casted from the long-term vision and are seen as a mean to reach this vision.

The described process of system innovation and transition management is comprehensive and reasonable on an academic level. However, if critically reflected, it is at doubt whether it is suitable in praxis. First there is the notion that transitions are described as processes that take place and have to be managed over a very long time period of several decades. Certainly a long-term vision is desirable and beneficial but it is doubtful whether a clear path can be followed for such a long time. In democratic societies governments usually change a few times during this time period and different political parties involved often have opposing goals. However, here, agreement of all involved actors, i.e. politics, society, industry etc. is an important precondition. The beliefs in the macro landscape have to change in order for one regime to be able to change and adapt into another. Not only politics but also societies are more heterogeneous today and have become melting pots of different cultural backgrounds and therefore a bottom-up approach as suggested by Elzen, Geels and Green (2004) could turn out to be difficult to achieve. Furthermore, the notion of innovations as experiments in the transition process must be seen from a critical point of view. They are described by Elzen, Geels and Green (2004) as learning-by-doing tools, where failure is not necessarily negative but can contribute in the process of increased understanding and knowledge development. However, today's world is characterized by a strong orientation towards short-term goals and benefits. The idea of learning for its own sake is not strongly positioned in society. Therefore it is doubtful whether innovation projects that do not deliver the desired outcome in terms of measurable benefits are accepted on a broad level. On the contrary, the review of different urban logistic projects has shown that failed initiatives discourage and hinder the implementation of other innovative ideas.

It can therefore be argued that innovations as the incremental steps towards long-term sustainability should be carefully planned, and positive outcome is important. Only learning is not enough. Therefore, the next section describes one way to plan innovation projects in order to maximize their probability of becoming successful.

### 3.3.2 Managing Innovation projects

When reviewing the literature it becomes apparent that there is no lack in innovative ideas and new technologies for urban transport logistics. It is also clear that only a small percentage of these ideas is operationalized and even fewer projects are economically sustainable. In his paper about business model innovation, Chesbrough (2010) recognizes the difficulty of capturing value from innovative ideas. He states that a new technology itself has no value but needs to be commercialized. This commercialization takes place through business models, and the use of different business models for the same innovative idea can generate different results. According to Chesbrough and Rosenbloom (2002) a business model has several functions. First of all it describes the value that is created for the user by the new offering. Secondly it identifies a market segment for the offer and specifies how the revenue generation mechanism works. Moreover it should describe what a value chain looks like that is needed to produce the offer and where the company is positioned within the value network. Finally, a business model should describe profit potential and the cost structure as well as a competitive strategy of how an advantage over competitors is created. Chesbrough (2010) notes that the mere construction and development of a business model helps to acquire a better understanding of the underlying processes of new ideas. As one barrier for innovations, Chesbrough (2010) mentions that the required change is often perceived as being disruptive and therefore new business models are likely to face resistance.

One of the best-known tools for creating and developing business models is Osterwalder's (2004) business model canvas. It is a visual template that can be used to design a business model. In nine building blocks the business activities of a company are described that together form the business model. Osterwalder's (2004) building blocks are similar to the business model functions described by Chesbrough and Rosenbloom (2002) and are summarized into four broader categories. First, at the heart of the business model lies the value proposition. That is a description of what pains can be relieved or what benefits can be gained from the new business idea. Second, the area called 'customers' describes the targeted customer segment, through which (distribution) channels this takes place and what the relationship to the customers is. Third, 'infrastructure' comprises the key activities that have to be performed to create the value propositions, the key resources that are needed therefore and the partner network required. Fourth, the area 'finances' covers the cost structure and the revenue mechanism of the business model. The overview makes possible trade-offs apparent and therefore helps companies to align their processes and resources.

Discovery-driven planning as introduced by McGrath and MacMillan (1995) is a dynamic tool that is especially useful for innovation projects with many unknown factors. In contrast to conventional projects, where data and experience from similar past projects can be used to predict the future outcomes of a new initiative quite precisely, this is not the case for innovation projects. Here, many unknown variables exist and many assumptions often have to be made. McGrath and MacMillan (1995) describe four planning errors that are often made in this context. First, even when sufficient hard data are lacking, companies often treat assumptions as key facts once some main decisions have been made. Second, even if all the required hard data are acquired the underlying assumptions are not tested and the project proceeds as if the assumptions were true. Third, companies might possess all the data to assert that a good business opportunity exists but nonetheless make erroneous estimates of their own abilities to implement the innovation. Finally, assuming a static environment, innovation projects might fail if key variables change over time and the initial data cease to be valid. It is obvious that new innovative projects are prone to errors and therefore the discovery-driven planning process suggests the use of different documents in order to avoid them. The 'reverse income statement' helps to model the project's economic assumptions. As the name implies the financial modelling of a project does not start with revenue estimation and arrives at a profit prediction but instead works the other way round. As an outset the required profits are stated based on the revenues required and on the maximum allowed costs to reach that profit goal. By concentrating on profitability right from the beginning, a high discipline on revenues and costs is imposed. Another document is the 'pro forma operations specs'. This is a description of all the activities that are needed to produce a product or service. The focus is not to build a precise and accurate model but rather to find a reasonable model that is refined as more information becomes clear and assumptions can be removed. This model of required operations makes it possible to see the costs of the new venture and basic data for the distinct activities are often already available. Furthermore, the specification can help to recognize major flaws in the business model or even project rejection due to unachieved viability. It might also become apparent what the most sensitive assumptions are that might lead to the failure of the project and therefore have to be monitored with special care. To provide an overview of all the uncertainties, McGrath and MacMillan (1995) suggest a 'key assumption checklist'. This list is used to make sure that all the assumptions made are discussed and checked while the project evolves. Finally, the 'milestone planning chart' determines at which project milestones different assumptions are tested. In contrary to conventional time-based meeting plans, not specific dates but events are the trigger here. New investments are only realized if the results from previous milestones suggest that the risk is justified. It is important to note that the described documents are not static but have to be adapted when new data are introduced. Furthermore it is recommended to formally designate a person who is responsible for checking and updating the assumptions in an iterative process. In general, discovery-driven planning acknowledges the dynamic and uncertainties of innovation projects. It is focused on explicitly stating the unknowns of a project and gradually turning them into knowledge as a project evolves. The uncertainties that might cause a project to fail are made visible and can therefore be managed explicitly. Discovery-driven planning is therefore a useful planning tool for innovation projects.

This chapter has shown that planning and implementing new ideas is a challenging task. Some general tools and methods have been presented that can support the innovation process. The next part will look specifically at the management of transport projects and how they can be financed and evaluated.

## 3.4 Transport project management

### 3.4.1 Financing of transport projects

When it comes to transportation and urban logistics projects, conflicts often arise between the private and public actors involved due to conflicting priorities among stakeholders. In order to compromise between different stakeholders, government interventions and market regulations often interfere to guide the market to a more sustainable agreement (Gonzalez-Feliu, 2008). Since the 1990's public authorities have been the most active parties in the development of urban logistics solutions. However, from 2004 and onward private stakeholders have also become more and more engaged (Gonzalez-Feliu, Taniguchi and Faivre d'Arcier, 2014).

Despite of the growth of interest and engagement in urban logistics solutions most projects improvements and innovations are ended or turned down as a consequence of the investment situation and the financing mechanisms. When it comes to financing an urban transportation project there is always a great width of different stakeholders with different interest. In addition, the free-rider problem, where actors who did not pay for their consumption but can still enjoy it because of someone else's investment, is a recurring risk factor and can impede new investments. Regarding logistics projects financing, Gonzalez-Feliu, Taniguchi and Faivre d'Arcier (2014) claim there to be three modes of financing. The first funding structure is all-private, meaning that a private actor such as a logistics provider sets up its own distribution center, invests in better routing software or less polluting vehicles. The second funding structure is all-public, which can take different forms.

*Delegation* is when a public authority funds the initial investments and allows a private actor to use the infrastructure to provide their services and the user covers some or all of the operational costs. Examples are e.g. public transport or urban distribution logistics terminals. Another all public measure in terms of financing logistics or transport projects are *subsidies* which means economic aid that is not refunded to the public authority. Subsidies are used in order to create a function that would not have been financed or sustained by market forces and are commonly applied in many cases. Subsidies can be made from governments to local authorities or to other stakeholders to invest in infrastructure, investments in green vehicles or green technology (Gonzalez-Feliu, Taniguchi and Faivre d'Arcier, 2014). The third funding model is a combination called *public-private partnership* (PPP). A PPP is one of the most common strategies in general transportation projects such as public transport, and is becoming more frequently observed also in urban freight logistics. A mixed investment is made where public funds are used to pay for certain global costs and the private user pays for the remainder of the project, or vice versa. Subsidies can also be viewed as a PPP where the public authority covers some of the private actors' investment costs by enabling a subsidy.

The most common forms of public funding are subsidies and low cost "giveaways" of older existing facilities. Another important function provided by the public authorities are to introduce regulations and legislations to enforce a preferred delivery consolidation system. Regulations can be restrictive to impede or rewarding to reinforce (Ville, Gonzalez-Feliu and Dablanc, 2013). Gonzalez-Feliu, Taniguchi and Faivre D'Arcier (2014) find that nodal facilities such as UCCs, proximity delivery and reception points and other delivery bay related systems are most suited for a successful PPP in terms of sharing costs and risks of such a project.

The reason why a public organ would invest in logistics and distribution projects relies on the collective utility gained from an existing infrastructure or green vehicles. In order for collective utility to be demonstrated and thus justified, the project and investment must be proven socio-economically viable for the public investor. The result of a cost benefit analysis (CBA) where benefits such as economic, environmental, cultural, social, societal, etc. are quantified is then used to determine if it makes sense for the public actor to invest in the project (Hayashi and Morisugi, 2000). Often, public authorities are the main funding body to support UCC initiations due to the socio-economical value they provide (Ville, Gonzalez-Feliu and Dablanc, 2013). In addition, the reason for public intervention in urban transport projects is often due to subventions consisting of local authorities covering the high real estate expenditures for UCCs (Dablanc, 2007). However, an urban logistics solution must not only be socio-economically viable, but also fully economically viable (Ville, Gonzalez-Feliu and Dablanc, 2013). An UCC might not be sufficient to prove a project economically sustainable as profit and break even numbers must also be calculated and demonstrated.

*Drivers of PPPs*

Lowndes and Sullivan (2004) list three main drivers of PPPs. The first driver relates to *efficiency gains* by better use of resources and resource leverage and increased access to innovation. Secondly, multi-agency partnerships allow for *better integration* of dispersed private actors and service providers so that heterogeneous local needs can be satisfied. The third driver has to do with the *accountability for public services*, meaning that a successful PPP has the power to increase the public's trust in the local politics. In their study of different PPPs in various European cities, Lindholm and Browne (2013) found that most partnerships were of rather low cost nature where the main funding comes from the local authorities. In those cases the costs of meetings and networking were considered. However, there are also PPPs where the undertaken initiatives would not have been possible without a collaborative funding and a coordinated partnership. However, PPP projects are usually of most interest when a financial CBA is negative, but a social cost-benefit analysis is positive. This is because such a scenario does not create incentive enough for private actors to fund a transportation project while at the same time the social benefits are highly valued by public authorities (APAS, 1996).

*Success factors of PPPs*

There are many aspects that need to be in place for a PPP to be successful. First of all a clear understanding and a common ground for all the stakeholders involved in an urban transport project in a PPP is essential to achieve the sustainability goals (Lindholm and Browne, 2013). A successful PPP should be lead and chaired in a non-bias direction. Structure and organized leadership are also essential, both for keeping PPPs together and to help private sector participants justify the time invested by clearly demonstrating productive outcomes (Lindholm and Browne, 2013). In 2007, Allen and Eichhorn studied the BESTUFS II project and found that policy makers were recommended to clearly communicate the required level of engagement, the best time-usage and to maintain an engagement to the private sector. According to Allen and Eichhorn (2007), these measures within a PPP should succeed in enabling an integrated transport plan.

Moreover, Lindholm and Browne (2013) state that a relevant mix of stakeholders participating in a PPP is essential for its success and development. An example from Gothenburg, Sweden, where a “Local freight network” was initiated after 2009, focused on board-crossing collaboration and cooperation. The partnership includes interested stakeholders and participants from different areas of interest in the city’s infrastructure that participate on a voluntary basis. Participants in the project are actors such as inner-city trade associations, shopping center representatives, real estate and property owners, transport associations, transport operators, vehicle industry, university and various city representatives such as the city planning authority and the public transport authority. According to Banister (2008), in order to accomplish the goal of a sustainable city all major stakeholders need to be involved in the PPP.

Another important success factor for these PPP’s to work and be efficient is that all partners and participants need to be willing to transfer and share information (Lindholm and Browne, 2013; Marsden and Stead, 2011). However, information sharing and collaborations are not always easy to achieve due to sometimes existing history of reluctance of private and public sectors working together. It can take time to create a long-term sustainable PPP relationship, which would give the best benefits for all parties involved. The critical aspect of the delivery and the development of outcome is not only important in terms of accounting, it is also necessary in order to maximize the possibility of identifying where policy can have the most impact and thus make the PPP effective. According to Lindholm and Browne (2013), a strong management is a key element for a prosperous PPP. A PPP should be able to form urban freight policies and its local development based on input from the participants from both the private and public sectors. When there is clear communication and information sharing, all parties develop a better understanding for the other actors’ businesses and operations.

PPPs do not eliminate the traditional role of public bodies to regulate the transport market in inner-cities, but a partnership can help public authorities to better form the regulations according to different requirements of different stakeholders affected by urban logistics projects. PPPs also benefit private stakeholders in that these are exposed to information regarding other stakeholders and on-going projects of which they then would be able to adjust to.

### 3.4.2 Evaluation of transport projects

Even though a gap in research of ex-ante evaluation models is identified through the literature review, there are certain frameworks that can be used as benchmarks when developing this field. The UN (2003) noted that transport projects have an impact on economy, environment and society, but are in today's world mainly restricted by limited budgets. Therefore thorough evaluation of financial implications of new transport projects is of specific importance.

This section therefore considers several methods and parameters that have to be taken into account for the appraisal of such projects.

The UN (2003) has developed a framework for appraisal of different transport projects. Before starting with actual calculations, several prerequisites should be in place. First of all it is important that all required data are available in order to define the current situation and to model future scenarios. The quality of the data is crucial as it directly influences the quality and reliability of the evaluation result. Moreover, all parameter values that are needed for the calculations should be in place. This can be in the case of a cost-benefit analysis e.g. the discount rates, operating period for a project or its starting and ending year. Furthermore, attention has to be paid to the specific transport project itself. It has to be clearly defined with all details like costs, responsibility for implementation or design and location details readily available. The scope as well as the system boundaries should be selected appropriately. It is also important to find a suitable selection of scenarios that reflect reality and lie somewhere in between the current solution and the engineering ideal. Project definition is considered to be a dynamic process where changes can be made if the project does not turn out to be viable. These adjustments could be e.g. a more basic specification at a lower cost or a staged implementation where more functions are added over time. Finally, it is necessary that the project definition is up to date and conforms to recent developments. Only if these preconditions are fulfilled, a meaningful result can be obtained.

The UN (2003) suggests the use of a CBA to compare the impacts of different transport projects against each other and with a do-minimum scenario, which describes the state that would be in place if none of the projects would be implemented. The do-minimum scenario implies that the current situation is continued and only minor investments are performed to uphold the current system.

A rough distinction between two types of costs is made, the investment costs and the operating costs. The former are mainly for planning and construction of a new transport project, this can be investments in new infrastructure for instance. The latter are costs for operating which can be time-dependent or distance-dependent. Time-dependent costs are fixed amounts that do not change with the kilometers travelled. It comprises repair and maintenance costs as well as the time-share of depreciation. In contrast, distance-related operating cost increase along with the kilometers travelled. This category includes fuel and lubricant costs, overhead, administrative costs, and the distance-share of depreciation. Furthermore demand and revenues might also change as consequence of a new project implementation. In the CBA the monetary benefits and cost of each year over the whole time-horizon of the project are opposed to each other. It is important to note that the value streams can vary each year. The first years in particular generate more costs whereas revenue streams are generated later on. As the value of money is different now and in the future a discount rate is used to determine the present value of a project. The net present values (NPV) of the different scenarios can be compared and usually the alternative with the highest NPV would be chosen. However the UN (2003) notes that there are also other than economic impacts to consider which are the potential gains or losses for the society and environment. Therefore also non-monetary items like reduction in noise levels, GHGs and congestions should be taken into account. This can be done by estimating their impacts and assigning monetary values according to agreed standards. Essentially, in the end it is always the task of the decision-maker to decide on the most appropriate solution, taking into account the specific circumstances and limited resources.

A financial analysis can show if a project is self-sustaining over its expected lifetime. However, the UN (2003) clarifies that is also important to critically monitor what the underlying sensitive assumptions of a project are, that have an important influence on its outcome. Therefore a sensitivity evaluation should be made regarding the uncertainties of the various costs, conditions and scenarios and eventually recalculated with various data sets. Finally, even if a project shows an overall positive result in the end, some of the involved entities might still suffer a loss. This has to be taken into account and the specific impacts have to be evaluated.

The framework of the UN gives a good general guideline for the evaluation of transport projects. However, it lacks a description of specific variables that have to be taken into account when specifically looking at innovations in the context of urban logistics. Gonzalez-Feliu (2014) has created a social cost benefit analysis (SCBA) to assess urban rail logistics. In specific he evaluated a possible scenario of a freight tram that would transport goods from the periphery of Paris into the inner city, where small emission free vehicles would perform the final leg. He distinguishes between monetary and non-monetary costs and benefits. Monetary cost mainly occur in form of infrastructure investments, namely new railways and terminals for loading and unloading. Moreover, costs for the tram vehicles themselves and for renting and buying vehicles for the last mile delivery have to be taken into account. Other investment cost might occur for software implementation, project planning or back office activities. On the operational side costs occur for the operation of the tram in form of driver wages and maintenance costs. Moreover, costs for cross-docking and last-mile delivery services have to be taken into account and other smaller operational costs might occur as well. These costs are compared with the benefits, which are earnings obtained from the conduction of the transport service and potential savings that might occur to the shippers.

As non-monetary costs the negative impact of the rail construction activities on the environment and on the number of retail customers can be seen. On the other side, non-monetary benefits include a reduction in GHGs, noise, pollution, better quality of life or time savings. However, those non-monetary elements can only be included in a calculation if they can be quantified.

The application of this framework to the specific case of the tram project in Paris resulted in a negative economic outcome. When including quantified social and environmental elements in the calculation, a positive result was obtained. The framework of Gonzalez-Feliu (2014) might only look at one possible scenario but nevertheless it gives a good indication on how an urban logistics project using a mobile depot and emission free last mile vehicles can be evaluated and which parameters that have to be taken into account.

A specific description of vehicle cost accounting, specifically looking at urban electric freight vehicles, is provided by Gries et al. (2014). They mention that a common preconception exists that electric commercial vehicles require large investments; a problem that hinders a wider employment of such vehicles. This is because there is a lack of economically sound profitability analyses. In their paper the authors therefore compare different electric commercial vehicles with their conventional, diesel fuelled counterparts. They also evaluate different purchase options, namely pure vehicle purchase, vehicle purchase with battery leasing and pure vehicle leasing.

In the calculations km-dependent variable costs and time-dependent fixed costs are calculated to finally add up the total costs. Variable costs are the costs for depreciation, battery leasing, vehicle leasing rate, lubricants and oils, tires, fuel or electricity and maintenance and repair. Fixed costs occur for personnel, taxes, insurance, city fees or other general costs. These elements vary between the different vehicles. In favor for the electric vehicles are mainly lower taxes, electricity costs or exemption from city fees. However, their purchase price is usually higher.

The way that the distinct costs affect the final calculated result depends highly on the operating conditions e.g. their annual mileage. Furthermore, the fluctuation of fuel prices and operational life span play are important to consider. A general conclusion is that electric commercial vehicles have higher fixed cost whereas their variable costs are usually lower than those of conventional vehicles.

Furthermore, more specific cost listings have been developed for different transport modes, such as for road transport by Lowe (1989), or for rail transport by Flodén (2011). Those frameworks give a description of relevant cost variables, their depending parameters and how they are calculated. They thereby provide practical tools that can be applied in order to investigate the cost implications of transport operations.

This section has shown that there are several different approaches to evaluate transport projects. They vary from solely financial calculations up to comprehensive frameworks that additionally include non-monetary social and environmental aspects. It can also be differentiated between approaches that only calculate the costs for one specific scenario, those that compare costs and benefits of one scenario, and those that compare different scenarios to each other. The most suitable framework depends on the specific project and situation. Ideas from other projects can therefore be seen as inspiration and input for developing an evaluation concept tailored to a specific project.

## 3.5 Summary of literature review

The literature review clearly shows that urban logistics is a topic of growing importance. In general, demand for deliveries into city centers increases and in specific the field of CEP has been growing mainly due to changes in retail. This has in recent years lead to a rise in alternative transport solutions for city logistics. These solutions have the aim to cope with the negative externalities that are caused by increased traffic volumes. In specific, the use of consolidation centers and mobile depots in combination with small emission free last mile transport modes has grown in popularity. A big focus is on greening city logistics and various projects with different outcomes have been conducted in the last years. It has become apparent that next to environmental and social gains, economic feasibility represents an important success factor. However, there still is no common method or tool that can be used to evaluate innovative transport projects. In contrast, the viability of new projects is often not tested beforehand but rather after different reasons for failure are attested. However, the review about the topics system innovation and innovation project management shows that proactive management and control is essential in order to successfully manage change and transitions. Moreover, a sound financial plan is usually a pre-condition to get access to the funding that is needed for the initial setup of new projects. This literature review has therefore identified as a gap in research of the lack of a sound method to evaluate innovative transport solutions for city logistics in monetary terms.

# 4 Research findings

The purpose of this research is to develop a cost model that can be used to financially evaluate innovative city logistics projects ex-ante, specifically looking at the BRD project. The research of this thesis thus aims to investigate two things, the cost implications of the conventional model and those of an innovative solution as well as comparing these against each other in different scenarios in order to better estimate the financial potential of the BRD. Furthermore, non-monetary aspects must also be considered in the evaluation of a new project in urban freight distribution. Therefore, this will be delved deeper into in the qualitative analysis.

Much academic research has been conducted in order to investigate the social costs and benefits of different distribution models as well as comparisons of their costs and service level capabilities, as seen in the literature review. However, it is often concluded that cost estimations are difficult and that there is a lack of tools for financial evaluations of innovative city logistics projects. This thesis will thus contribute to science by filling the research gap in terms of investigating the total cost implication of the conventional parcel distribution model and of the innovative solution by clearly demonstrating transparent data and applicable calculations. Moreover, the same service level performed by the two models is assumed as this thesis aims to objectively compare whether the alternative solution can be cost efficient or cost neutral. This is related to e.g. Osterwalder's (2004) business model canvas, and argues that the value proposition and the customer demand are assumed to remain constant. This thesis also aims to provide cost aspects of the BRD project that can contribute to create a fully developed business case, which in turn can be used to initiate the project, depending on the outcomes of this investigation.

This section thus investigates the cost aspects of the respective models and compares the total costs, thereby answering RQ1, RQ2 and RQ3 in the quantitative analysis. The cost model developed here can (with individual project adjustments) serve as a tool for transport operators when comparing their business as usual, or as-is scenario, to an alternative solution, the to-be scenario. Furthermore, the sensitivity analysis sets out to answer RQ4 and the analysis of qualitative data investigates the non-monetary aspects of an innovative project in urban freight distribution and thereof answers RQ5.

First of all the relevant costs are mapped for a base scenario developed from the current demand structure. The input data have been collected throughout the research process. The data used are transparent and publicly available in order to increase the reliability and quality of this thesis. Following the cost calculations of the base scenario, the same calculations are performed for a scenario with a large scale, i.e. where a higher demand is assumed, this in order to investigate how scale influences the viability of the innovative idea. A scaled scenario is necessary to investigate the actual cost implications of any idea in innovative urban freight projects. The next section presents a sensitivity analysis that can be described as the what-if scenario and further investigates the variables that affect the outcome the cost analysis. In the sensitivity analysis the labor costs, the fuel costs, the delivery rate of parcels per stop, the delivery speed of the distribution vehicles as well as congestion charges and parking fees are elaborated individually in order to investigate alternative break-even points where one of the two models make more economic sense. Additionally, the $CO_2$ emissions and the social implications for the conventional and the innovative model are evaluated in order to illustrate a broad overview of the environmental implications of the BRD project.

Finally, a qualitative data analysis complements the quantitative investigation where the topics of business cases, reluctance to change, governance tools, financial investments and the potentials and barriers associated to innovation projects in urban freight in general and for the BRD in particular will be emphasized.

## 4.1 Quantitative Analysis

### 4.1.1 Base Scenario of the BRD project

In the base scenario two different models of parcel distribution are evaluated based on the current demand structure, summarized in Table 3. The numbers presented in Table 3 are derived from primary data collection of the operations of a medium size parcel distributor in the city of Gothenburg. From here on, the numbers presented in the analysis are elaborated based on this information.

| **Parcel delivery in Central Gothenburg – Base scenario** | |
|---|---|
| Return trips per year | 520 |
| Parcels per return trip | 80 |
| Parcels per year | 41,600 |
| Number of stops per return trip | 53 |
| Number of stops per year | 27,560 |
| Parcels per stop | 1.5 |

*Table 3: Parcel delivery in Central Gothenburg – Base scenario*

It is assumed that parcel deliveries are only made on weekdays, as the majority of customers are business customers that are not working on weekends. With 52 calendar weeks this leads to 260 working days a year. As a major constraint all the deliveries have to be made within a six hour time window between 10am to 4pm, which reflects the business hours of the customers and therefore reflects the service level.

The average weight of a parcel is set at 4 kg and it has an average volume of 19,532 $cm^3$ which equals e.g. a standard DHL packaging box with the dimensions 33.7 cm x 32.2 x 18 cm (DHL, 2015).

In the next section, the operational setup of the conventional model is presented followed by the setup of the innovative model.

#### *4.1.1.1 Conventional model*

One way to analyze the performance and worthwhileness of a new solution is to compare it to the current solution in place. Referring back to the UN's (2003) appraisal framework for transport projects, the benchmark which a new solution is measured against, is the do-minimum scenario, the state that would be in place if the current situation is continued without any innovations. In order to identify the impacts that a new scenario has, such a do-minimum scenario, hereafter referred to as the "conventional model", has been defined for the distribution of parcels in city areas. It is based on the experiences made during a field trip with a parcel distributor in Gothenburg as well as the findings from literature review.

In this conventional model, parcels are distributed with diesel-fuelled vans. To fulfill the demand specified in the base scenario at a reasonable service level, two such vehicles need to be employed. The vehicles are loaded at a distribution center outside the city and the parcels are then delivered to the final recipients on a round trip.

The average distance per return trip per vehicle is 74 km and consists of two components. The first component is the distance that is driven on highway, from the distribution center to the city center. It is 12 km for the single trip and hence 24 km for the round trip. The second component is the distance travelled inside the city center for making the actual deliveries. This delivery round varies, depending on which and how many customers have to be served, but takes approximately 50 km. As each vehicle makes 260 return trips per year, the annual mileage for distributing parcels is 19,240 km per van.

As delivery vehicle a “Ford Custom 2,2l TDCI, 92 kW (125 PS), 6 gears, L1H1” has been chosen as its characteristics are common for urban parcel distribution vehicles. It has a volume load capacity of 5.9 $m^3$ and a weight carrying capacity of 815 kg.


*Figure 1: Ford Custom 2.2l TDCI, 92kW, L1H1 (Source: Ford, 2013)*

Technical data and price information used in the calculations are withdrawn from vehicle brochures, available from Ford’s corporate website (Ford, 2013 and 2015). Other input data like taxes or insurance, which reflect the typical fees of a western European country have been obtained from internet databases, contacting relevant companies and authorities, as well as other literature.

### *4.1.1.2 Innovative model*

In the BRD, a freight bus serves as a mobile depot through the city together with two electric cargo bikes with trailers that perform the last mile deliveries. Certain specifics have been investigated in order to accurately depict the alternative scenario and the costs that follow. First of all, the freight bus takes the same route to the city as the van. Thereafter, the freight bus makes six stops in the delivery route as shown on the map below.

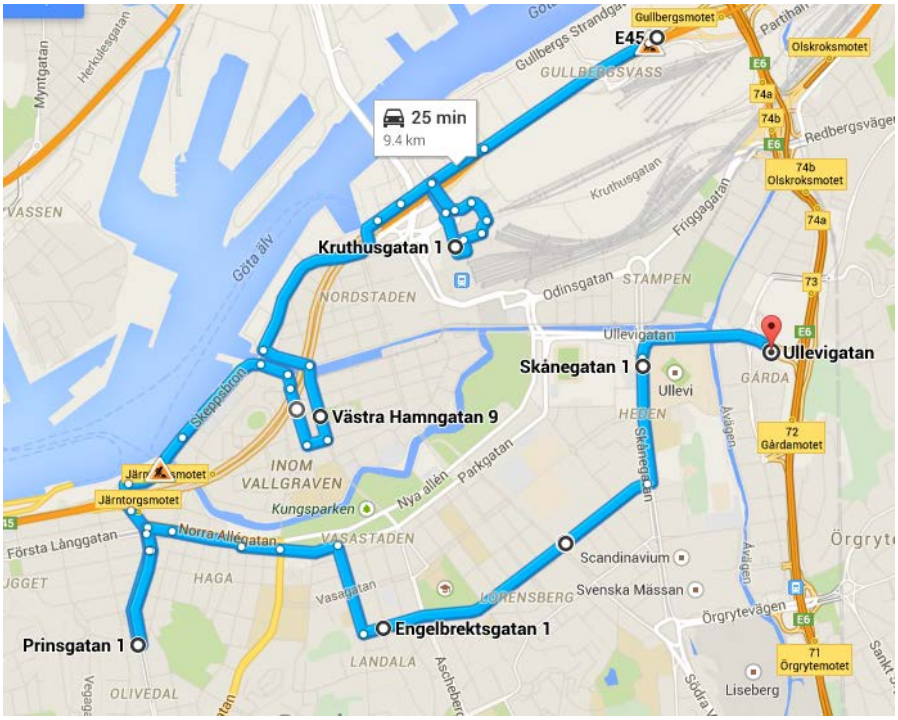


*Figure 2: Route of freight bus through central Gothenburg*

When compared to the conventional model where two vans serve the city and deliver 80 parcels each, this means that the freight bus would be loaded with 160 parcels and deliver 27 parcels per stop. This assumes an equally distributed demand for parcel deliveries along the delivery route. For the delivery from the bus as a mobile depot to the final recipients, two electric cargo cycles need to be employed to meet the required service level. The bus driver operates one of the two bikes by taking the bike with him on the bus and transporting it to the next stop after each delivery round. Moreover, the bus driver has an important managerial function to coordinate the bikes and decide when to move the mobile depot to the next stop.

The delivery distance is calculated to be 9.4 km for the freight bus within the city center. The distance on highway is 2 km shorter than in the conventional model as another highway entry is used for the return trip, which is located closer to the distribution center. The total distance driven by the bus is therefore set at 31 km. (9 km+22 km)

The total distance for the electric delivery bikes in the inner city is 24 km. It consists of two components. One is the distance to go from one delivery area, i.e. parking point of the bus, to the next of the altogether six delivery areas. The second component is the distance covered to fulfill the delivery assignments within a delivery area. The distance for the first component is calculated from an online distance calculator service where the six stop addresses have been inserted and then the shortest bike route is calculated. This gives a distance of 6.4 km for the electric delivery bike of travelling between stops. It should be mentioned that in reality, this distance would be lower due to the fact that the electric delivery bike would not travel back to the center of the radial delivery area that it covers before going to the next stop, but rather goes straight from the last delivery point of one area to the loading point of the next area where the freight bus stops. It is assumed that the bike operates in a radius of 500m around each bus stop, indicated by the red circles in Figure 3. As a proxy for the distance covered in this area the circumference of this circle is calculated. This means if equal customer density is assumed, the electric delivery bike covers 3,142 meters (2*500m*∏) per delivery area. In addition, the assumption that this distance is exaggerated has been made, and the estimated distance travelled per stop by the electric delivery bike is rounded down to 3 km. Therefore the total distance of the delivery route travelled by each electric delivery bike is calculated to be 24 km. (6 km+3 km*6=24 km)

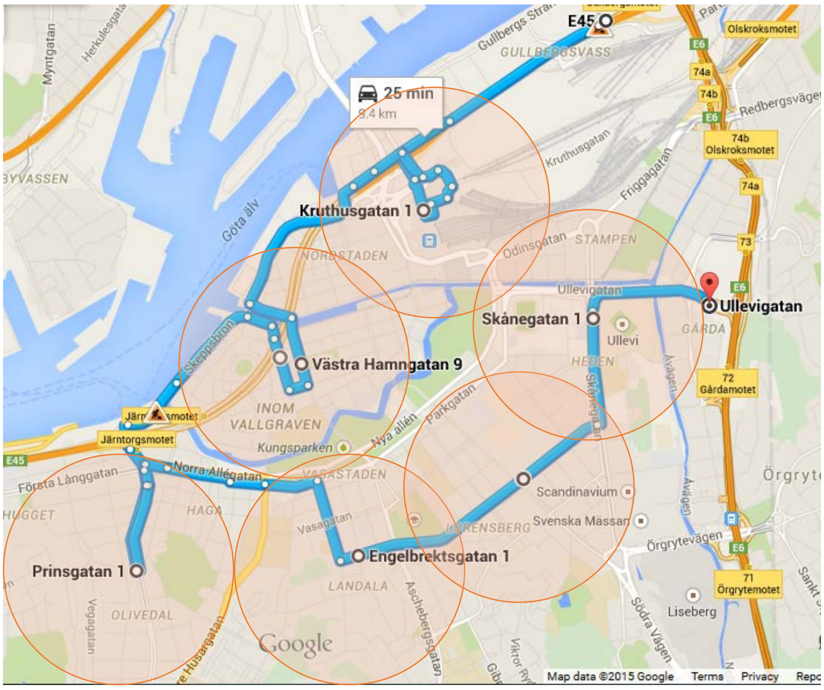


*Figure 3: Delivery area of the cargo bikes*

The capacity of one fully charged battery is 25 km, which means that one battery should be enough to cover the daily parcel distribution. However, it is suggested that one extra battery is accounted for.

In the following the technical specifics of the bus and the electric cargo bikes are described in more detail.

<u>Freight bus (Mobile Depot)</u>

City busses are mainly constructed for passenger transportation and a freight bus is not a common concept. Nevertheless, such a bus provides the advantage of a low entrance level that supports more efficient loading and unloading procedures when employed as a mobile depot. For the cost analysis a “MAN LION`S CITY CNG / A21” city bus has been chosen. It has a low entrance that can be equipped with a ramp and it runs on natural gas, which is beneficial from an environmental point of view. This bus was primarily designed for passenger transport and therefore must be retrofitted in order to operate as a freight bus. The vehicle has an unladen weight of 12,025 kg and the technically admissible gross vehicle weight is 19.5 tons. The bus is 11.98 meters long, 2.5 meters wide and 2.88 meters high, resulting in a volume of 86.26 m$^3$. It is estimated that 60% of this volume can be used to carry freight, which equals 51.76 m$^3$. This estimate is based on the blueprint of the bus and on the assumption that certain areas have to be kept clear for loading and handling activities. In addition, neither the bus driver compartment nor the total height can be fully utilized (MAN, 2012; Nahverkehr Zwickau, 2015).


*Figure 4: MAN Lion's City CNG / A21 city bus (Source: AutoScout24, 2015a)*

<u>Electric cargo bike (last mile delivery)</u>

As for the second part of the BRD urban freight solution, E-CBs for last mile deliveries are used. In this case, the cargo bike investigated is an "Explorer" from the company EcoRide, a Swedish electric bike manufacturer. It is a basic model that can be seen as being rather at the lower end of the price range. In order to improve the validity of this research, a higher purchasing price for the bike was also simulated. A higher purchasing price did not change the outcome of the calculations significantly, therefore the selected model and price level are considered relevant. Furthermore, purchasing prices for more advanced E-CBs can be assumed to decrease in the near future due to increase in demand and production mass (INSG Insight, 2014). The E-CB is used with a closed trailer, into which the parcels are loaded and where they are protected from external influences like weather or theft. The trailer has a weight load capacity of 125 kg and a volume load capacity of 2 $m^3$. It can fit approximately 30 regular size parcels from any of the conventional delivery firms such as PostNord or DHL freight business parcels. This is equivalent to about 60 express delivery parcels (Erlandsson, 2015a).


*Figure 5: Example of cargo bike and trailer (Sources: Ecoride, 2015a; Pling, 2014)*

In the following, the costs for the two alternatives for parcel distribution are evaluated based on an own developed, general cost framework that could not be found in literature. This framework has been developed by looking into and benchmarking several cost listing frameworks (e.g. Lowe, 1989; Flodén, 2011; Gries et al, 2014). For reasons of conformability and to allow for replication of the calculating process with changed input data, all the assumptions made and the reasoning behind them are stated. All costs are stated in Euro (€), as this is the common currency in most European countries. The exchange rates provided by the European Central Bank (2015) as of March 17 have been used for the conversion of currencies.

#### *4.1.1.3 Cost analysis*

Companies that perform goods transportation for business purposes between different spatial points have a certain production cost for providing this service. It is important for a transport service provider to have full knowledge of the cost side of his business in order to charge appropriate rates to cover those costs and moreover to generate a profit margin. In literature, several cost components can be found that are relevant for road transport providers. The distribution of parcels in cities is a road transport business, although some characteristics like average trip length, number of stops or types of vehicles used, largely differ from other road transport business such as long-distance trucking. Nevertheless, the same cost variables exist even though their relevance might differ. In general, the operating costs of a road transport provider can be divided in three main areas: Standing costs, running costs and overhead costs.

In the following, the various cost variables for each area and their influencing parameters as well as the way they are calculated are described, thus covering RQ1, RQ2 and RQ3. Moreover, where applicable, special characteristics in regards to CEP-business are provided. The specific costs for the van the freight bus and the electric cargo bikes are then calculated. Table 4 provides an overview of the relevant cost variables and influencing parameters that will be used in this part.

| Cost variables | Parameters |
|---|---|
| Standing costs | |
| License & Permit | - Vehicle characteristics (e.g. gross weight, emission factor)<br>- Operational characteristics (e.g. type of goods, border-crossing)<br>- Regulatory environment (e.g. specific national or regional permits) |
| Vehicle Insurance | - Vehicle characteristics<br>- Operational characteristics<br>- Driver (e.g. one or more drivers; professional license) |
| Taxes | - Vehicle characteristics<br>- Regulatory environment |
| Labor | - Vehicle characteristics (e.g. professional driver with truck license)<br>- Operational characteristics (e.g. education for transport of dangerous goods)<br>- Country specific characteristics (e.g. minimum wages, social costs) |
| Interest | - Interest rate |
| Depreciation | - Purchase price<br>- Residual value<br>- Working life of vehicle |
| Running costs | For all: distance travelled |
| Fuel | - Vehicle characteristics (e.g. specific fuel consumption)<br>- Operational characteristics (e.g. city or highway traffic)<br>- Fuel price |
| Lubricants & Oil | - Vehicle characteristics |
| Tires | - Quality of tires<br>- Operational characteristics (e.g. curbs, off-road driving) |
| Maintenance & Repair | - Mandatory maintenance schedule of OEM or company policy |

| | |
|---|---|
| | - Labor wages<br>- Replacement part cost |
| Others<br>- Tolls & Fees<br>- Parking<br>- Extra equipment | - Regulatory environment (e.g. city fees, toll routes, tunnel fees, parking)<br>- Vehicle specifics (e.g. battery for e-bike) |
| Overhead | - Administration<br>- Labor wages<br>- Property and rents<br>- Utilities (e.g. electricity, communication) |

*Table 4: Cost variables and their influencing parameters*

An overview of the cost calculation for each vehicle can be found in Appendix A.

Standing costs

Standing or fixed costs occur irrespectively of whether a vehicle is moved or not. Hence, these are time-dependent costs that incur in a certain frequency, usually annually. As the amount of standing costs is fixed per year, its portion of the total operating costs declines when more transport work is done, i.e. more kilometers are driven. The total fixed costs consist of several individual elements (Lowe, 1989; Road Haulage Association, 2015).

**Licenses & permits**

Operating a road transport business is subject to different requirements, and depending on each country different permits and licenses are required to perform this business legally. In the EU, for example, an operator's license is required for commercial transportation of goods when the vehicle exceeds the weight limit of 3.5 tons. Also, different types of licenses exist depending on whether the goods are transported within a country or across borders. To obtain such a license, several requirements have to be fulfilled, and fees for the application, issue, change and renewal of licenses occur. Those fees have to be added to the fixed costs of a road transport operator. For a CEP-provider it is possible to avoid this fee if the gross weight of its vehicles is below 3.5 tons (Lowe, 1989; EU Regulation 1071/2009; UK Government, 2015).

In Sweden, looking at the costs for the specific case, a permit is needed for any transport operator performing goods transport services for business purposes (Transportstyrelsen, 2015a). In order to apply for a permit, the organization needs to fulfill certain requirements, including participation in two theoretical courses with a cost of €35 each. The permit application itself costs €620 and is valid indefinitely. However, if a company already obtains a permit, no addition permit charges are required for operating or adding an additional vehicle to the vehicle fleet. In addition, the permits issued from the Swedish transport agency Transportstyrelsen, since 2010 for light or heavy trucks do not differ (Transportstyrelsen, 2015a).

It is assumed that a license for operating transport vehicles for business purposes already exists, and the additional costs would thus be zero for adding or omitting an extra vehicle to the fleet. Consequently, the Ford Custom is assumed to not need any additional operator's licenses and the costs for this post is therefore zero.

According to Transportstyrelsen (2015a), a refitted freight bus would in this case be classified as a truck, even though it might look like a bus from the outside. The definition of a truck is a vehicle that is employed for freight transport, and the definition of a bus is a vehicle with 9 or more seats employed for passenger transport. For the freight bus the same assumptions as for the van are made, meaning that a license for operating transport vehicles for business purposes already exists, and the additional costs would be zero for adding or omitting an extra vehicle to the fleet.

The electric bike with a trailer does not require an operator's license neither. There is however a membership fee that is requested by Innerstaden, the organization for the shops in the inner city. The organization requires a minimum member fee of €109 per annum (Erlandsson, 2015a). As this is a general one-off annual fee for the operator that is independent of the number of bikes employed it will be included under overhead costs for the cost calculation.

**Vehicle insurance**

The costs for vehicle insurance also have to be added to the amount of fixed costs. The premiums that have to be paid depend amongst others on the type of the vehicle that is used for the transport operation. Its dimensions, weight limits, emission factor etc. influence how it is categorized by the insurance and which premium has to be paid accordingly. Other factors that can influence the insurance rate are the type of operations in that the vehicle is employed, e.g. if it is used to transport dangerous goods, or the characteristics of the driver, e.g. if the driver obtains a professional driver's education. The classification varies from country to country. Other insurances, e.g. for goods in transit, are not added to the fixed costs as they are dependent on a specific transport assignment (Lowe, 1989; Gries et al., 2014).

To obtain an insurance premium for the van, the Swedish company IF Insurance has been contacted. For the Ford Custom model used for business purposes, the annual insurance is €1,939.

According to the same company, the costs of insuring the freight bus is €5,510.

For cargo cycles no specific insurance has to be obtained in Sweden. It falls under the general company insurance that is included under the overhead costs.

**Taxes**

States require vehicle owners to pay taxes for their vehicles. Factors like weight, $CO_2$- and noise emissions influence the amount of tax that has to be paid. Again, vehicle characteristics and specific national regulations can influence the required percentage of tax to be paid (Lowe, 1989; Gries et al., 2014; Wallstreet:online, 2015).

To obtain the yearly amount of tax that is due for a Ford Custom van, the Swedish tax authority Skatteverket (2015a) has been contacted. The annual tax that has to be paid for one vehicle is €573.

The CNG bus profits from a tax relief in Sweden, which is granted to vehicles that comply with certain emission standards (Skatteverket, 2015b; Lowndes, 2012). The yearly tax that has to be paid for the CNG freight bus is €107 according to Skatteverket.

For any vehicle that is classified as a cycle, there are no additional tax rates in the Swedish tax system. In addition, trailers with a total weight of less than 750 kg are exempt from tax (Skatteverket, 2015a).

**Labor costs**

The labor costs for the driver of the vehicle usually has to be paid irrespectively of the distance driven. Therefore the costs for salary and social costs also contribute to the standing costs. The labor costs that have to be paid can differ quite significantly between different countries and regions, depending on the general salary level, existence of regulations for minimum wages and social costs. Moreover, the type of operations and vehicle employed influence the gratification that has to be paid. For instance, the operation of bigger trucks requires a special driving permit and for the transport of dangerous goods special training is needed. The more specific the requirements are, the smaller is the labor pool that fulfills the requirements and therefore higher wages have to be paid (Lowe, 1989; Gries et al., 2014).

For the CEP-business in cities, smaller vehicles are usually operated and thus no specific driver's license is required. However, country specific differences in wages and social fees still exist.

For the costs of labor, the information from the Swedish salary statistics has been used together with the statutory payroll and social benefits contribution paid by the employer (Lönestatistik, 2015). The employer fees that have to be paid in addition to the salary include fees for age retirement, sick insurance, parental insurance etc. The official number used is 31.42% of the employee's salary before tax (Ekonomifakta, 2015). For van delivery personnel, the average monthly salary is €2,291. This gives the total cost for labor of €36,130 per employee per annum. (€2,291*12*1.3142)

The monthly average salary of a bus driver is listed at €2,455 (Lönestatistik, 2015). Including the additional 31.42 % social costs, this leads to an annual labor cost of €38,716 per person. (€2,455*12*1.3142)

For bike delivery personnel, the monthly wage in Sweden is set as the median salary of €2,174 (Lönestatistik, 2015). The reason why the median has been used in this case, as opposed to the average, is that the statistics showed abnormally high and low values, which made the average misrepresentative for the population. Therefore, the calculated cost for labor are be €2,853 (€2,174*1.3142) monthly, per bike operator. This gives an annual labor cost of €34,236 per employee. (€2,853*12)

**Cost of capital**

For any investment made by a company the annual interest costs should be added to the fixed cost. In the case of a vehicle purchase that is financed through borrowed capital, the annual loan interest has to be added to the standing costs. Even if the vehicle can be financed by own capital assets, an amount equal to the current interest rate on the capital market should still be considered in the fixed costs. This is because of the opportunity costs, meaning if the money was not financing a vehicle purchase, it could be invested in other projects, which might yield an even higher return on investment (Lowe, 1989).

The specific cost of capital that has to be diverted depends on the purchase price on the one hand, and the interest rate on the other hand. At the moment (spring 2015) the interest rate in Europe is at an all-time low. Therefore, to give a realistic picture, the average long-term interest rate of the Euro countries over the last five years, as provided by the OECD (OECD.stat, 2015), is used for the calculation of capital costs. This interest rate is 3.29% and it has to be multiplied with the average capital locked up by the vehicle. The capital locked up is half the purchase price, as the vehicle is assumed to be worth 100% of its purchase price when it is new and 0% at the end of its operating life. The selected Ford Custom van has a new purchase price of €27,050. The annual cost of capital is therefore €445. ((€27,050/2)*3.29%)

The described MAN city freight bus is available as second-hand vehicle at a net price of €227,000. According to the online retailers webpage it was first registered in December 2013 and has run 6,014 km (AutoScout24, 2015a). It can therefore be assumed to be almost new. The savings compared to a completely new variant can be used for refitting activities. No reference could be found that would state the cost of such refitting activities for a bus. However, the costs of converting passenger trams in Zürich in order to use them for freight transport were €32,000 (Arvidsson and Browne, 2013). Therefore, the costs for refitting are estimated to be €30,000. The annual amount of capital locked up by the vehicle then amounts to €4,228. ((€257,000/2)*3.29%)

The selected e-bike has a purchase price excluding battery of €1,307 (EcoRide, 2015a). In addition it costs €2,179 to acquire the trailer. The annual cost of capital for one cargo cycle with trailer are then €57. (€3,486/2*3.29%)

**Depreciation**

Vehicles must be replaced on a regular basis and as a consequence transport operators have to reserve a certain amount of money annually for refinancing, this is referred to as depreciation. This means that the funds for financing a new vehicle have to be earned by the current vehicle. The annual amount of depreciation depends on the anticipated operating lifetime of the vehicle and the residual value that can be obtained when it is sold at the end of the lifetime. There exist different methods for calculating the amount of depreciation each year. In the simplest form, the vehicle is subject to a linear depreciation, which means that the depreciation rate is the same each year. The annual amount of depreciation that has to be added to the fixed costs can then be calculated in the following way:

$$Depreciation = \frac{Price\ new\ vehicle - \ price\ for\ a\ set\ of\ tires - residual\ value\ old\ vehicle}{anticipated\ working\ life}$$

The value of a set of tires has to be deducted, as the costs for tires are seen as kilometer-dependent costs and will therefore be accounted for in the running costs. If instead of an anticipated operating life time an anticipated mileage is used as a basis for depreciation, then the depreciation value has to be added to the running instead of the fixed costs (Lowe, 1989; Barnes and Langworthy, 2003).

The Ford Custom was first released in 2013 and therefore no long-term data on the development of its value exist yet (Ford, 2014). However, the residual value of older models, which can be obtained from online second-hand car portals, can be used as a proxy for the calculations. The residual value for a Ford Custom with an annual mileage of 20,000 km is ca. 37% of its initial purchase price after six years. The six years have been selected as depreciation period (Autokostencheck.de, 2015; Schumann, 2013). The price of a new set of tires that has to be deducted is approximately €360. The annual depreciation rate is therefore €2,780. ((€27,050-4*€90-(€27,050*37%))/6)

For busses, an average lifetime of 12 years is mentioned in literature (ESMAP, 2011; APTA, 2014; MacKechnie, 2015). A research for busses on different online portals showed second-hand values for busses of similar configuration and 12 years older than the selected bus, which lie between €8,403 and €18,403 (AutoScout24, 2015b). This equals 3.3% and 7.2% respectively of the capital invested in the selected bus. The prices for CNG fuelled busses are rather on the lower end of the scale, therefore a residual value of 5% is assumed for the cost calculations. However, as the market for second hand busses, especially those running on alternative fuels, is limited, this number has to be handled with care especially as the vehicle has been refitted for freight activities. The actual value that can be obtained depends therefore largely on the specific case. When including the capital investment, the residual value, the price of a set of tires and the useful life span in the equation for the depreciation costs, a value of €20,139 for annual depreciation cost is retrieved. ((€257,000-6*€413-(€257,000*5%))/12)

The cargo cycle is assumed to have a lifespan of five to eight years (where major reparations are assumed to be required after five years). The residual value of a cargo cycle depends on the market demand for this type of vehicle, which is why the residual value for a cargo cycle in Denmark, where 15% of the population uses cargo cycles, is almost as high as the purchase price (Andersson, 2010). However, it is assumed here that the average lifespan is six years, and the residual value after this time is assumed to be 40% of the purchase price (Erlandsson, 2015a). This means that for the purchasing price of €3,486 the 40% residual value of the electric bike and the trailer is €1,394 (€3,486*40%). The cost for one set of tires that has to be excluded from the calculations is €172. This gives an annual value for depreciation of €320. ((€3,486-4*€43-(€3,486*40%))/6)

Running costs

In contrary to the fixed costs, the running or variable costs change with the amount of transport work performed by a vehicle. Hence, these costs are kilometer-dependent and correlate positively with the distance travelled by a vehicle. These costs are here calculated in € cents per km and the total sum per year can be obtained by multiplying the running costs per km with the total amount of kilometers travelled in a year. The total variable costs also consist of several individual cost elements (Lowe, 1989; Road Haulage Association, 2015).

**Fuel**

Fuel costs are often one of the highest running cost elements for transport providers. Three parameters influence the total amount of fuel costs: the specific fuel consumption of a vehicle, the distance driven and the fuel price (Lowe, 1989; Combes and Lafourcade, 2005; Fender Pierce, 2012).

$$Fuel\ costs = Fuel\ consumption \times distance\ travelled \times fuel\ price$$

The last variable is independent and cannot be influenced by the transport provider, and fluctuating fuel prices result in uncertainties in cost estimations. The specific fuel consumption, however, can be predicted with relatively high certainty. It depends, among other factors, on the type of vehicle employed and on the driving conditions, i.e. if operating in stop-and-go city traffic or long distance overland trucking (McKinnon, Browne and Whiteing, 2012). The specific fuel cost per kilometer for each vehicle can be obtained by analyzing its fuel consumption against the distance travelled.

CEP-providers that operate within urban areas are consequently faced with relatively high fuel consumption per km. The relatively low average driving speed and the constant accelerating and braking in city traffic as well as parking, starting or idling the engine for making the parcel deliveries to the customers negatively influence the fuel efficiency (McKinnon, Browne and Whiteing, 2012). However, the fact that the distance covered in cities is much shorter than for overland trucking reduces the impact of this cost variable.

The yearly distance that is travelled by each van for delivering the parcels has been calculated at 19,240 km. Two thirds of the distance is covered on highway, and the remaining part is travelled inside the city limits. According to Ford (2014) the specific fuel consumption of the Ford Custom is 8.1 liters per 100 km inside cities and 6.3 outside. This leads to a combined fuel consumption of 7.5 liters per 100 km for the described operations. However, several industry experts have expressed doubts about the veracity of this comparably low consumption rate and have suggested higher figures in terms of fuel costs (Flodén, 2015; Maes, 2015). These recommendations are considered and a fuel consumption of 10 liters per 100km is therefore used for the calculation of the fuel costs for the van. As the fuel price is currently (spring 2015) at a relatively low level and subject to frequent fluctuations, the average value over the last 2 years has been selected to smooth out unusual deviations. Accordingly, a price of €1.54 per liter is used for the following calculation (OKQ8, 2015). The annual fuel costs per vehicle are thus €2,963. ((10l/100km)*19,240 km*€1.54)

A CNG city bus has an average consumption of 42 kg CNG per 100 km (Schäfer, 2013). The price for natural gas is relatively high in Sweden at approximately €1.85 per kg compared to other countries in Europe where the average price per kg has been around €1.08 in e.g. Germany over the last years. However, CNG is subject to reduced tax in Germany in order to allow it to be more competitive against conventional fuels (Gibgas, 2015; Neumann, 2015). For this calculation the Swedish value is used as the delimitations have determined Gothenburg as trial city. The annual fuel costs for the bus, which covers an annual distance of 8,060 km, are therefore €6,263. ((42 kg/100km)*8,060km*€1.85)

In terms of an electrically assisted cargo bike, the only fuel costs are for the electricity that charges the battery. A fully charged battery of 250 W takes about 4 hours to charge and assists a distance of 25 km. According to energy price statistics in the EU, electricity costs for consumers in Sweden are €0.21 per kWh (Eurostat, 2014b). The energy consumption of the bike has been calculated at 0,018 kWh/km. With a yearly distance of 6,240 km, this leads to annual costs for electricity of €24. (0.018kWh/km*6,240 km*€0.21/kWh)

**Lubricants & Oils**

The consumption of lubricants and oil is also a distance dependent variable. It therefore has to be added to the total running costs, even though its portion is usually relatively low. The specific consumption can differ between different types of vehicles. Electric vehicles for example do not use lubricants and oils and therefore this cost is zero for them (Lowe, 1989; Gries et al., 2014).

For vans, the costs for lubricants and oil are about 1% of the fuel costs according to Wittenbrink (2014). Therefore this cost item is estimated to be €30 for the Ford Custom. (€2,963*1%)

No specific share of oil and lubricant costs for busses could be found in literature. However, from a cost comparison study of diesel and CNG busses conducted by Lienin (2009) it can be back calculated that the costs for oil were less than 1% of the fuel costs in this specific case. Taking into account, that also other lubricants have to be replaced regularly, the costs for lubricants and oil is kept as 1% of the fuel costs for the cost calculation. This gives an annual amount of €63 for this cost component. (€6,263*1%)

The cost for oils and lubricants are not a considerable cost element for bikes. This cost item is therefore included in the maintenance costs.

**Tires**

Tires are subject to wear and tear and have to be changed after usage over a certain mileage. Therefore, throughout the life of a vehicle, numerous sets of tires are usually needed. In addition to the distance travelled, the operating conditions, i.e. off-road or on-road use, can also influence the tires' lifetime.

In the CEP-business, one additional reason for wear on tires is the frequent parking of the vehicles on and next to sidewalks. When scratching the curb, tires are easily damaged and have to be replaced before they reach their expected lifetime in mileage. Apart from that, tire costs are usually not a large cost component in city traffic, since the distances travelled are normally shorter and tire prices for smaller delivery vehicles lower than for those of big trucks. Finally, the former are also equipped with fewer tires due to fewer axles than the latter (Lowe, 1989; McKinnon, Browne and Whiteing, 2012).

For the Ford Custom, a tire model in the medium price range has been selected. The “Viking TransTech II 215/65 R16C 109/107R” comes at a price of €90 per tire (ReifenDirekt.de, 2015). An average tire with a life span of 40,000km is assumed (Gries et al., 2014). This leads to an annual tire costs of €173. (€90*4*19,240 km/40,000 km)

The MAN city bus is equipped with two tires on the front axle and four tires on the rear axle. For the cost calculation the “Goodyear G661 275/70R22.5 J/18PR“ tire has been selected, which comes at a cost per tire of €413 (Delticom, 2015). Tires for busses have to be changed after 116,000 km on the front and after 165,000 km at the rear axle (Continental, 2008). Therefore the annual tire costs for a mileage of 8,060 km per year are €138. ((€413*2*8,060 km/116,000 km) + (€413*4*8,060 km/ 165,000km))

Cargo bikes use regular tires in the summertime and winter tires during the colder period of the year. The prices for new tires of the brand “Nokia” are €35 and €51 respectively. One tire has a lifespan of 10,000 km (EcoRide, 2015b; Elcykelbutiken, 2015). The EcoRide Explorer bike is equipped with two tires and in addition, the attached trailer runs on two tires as well. Taking the average tire price, this leads to annual cost for bike and trailer of €107. (€43*4*6,240 km/10,000 km)

**Maintenance & repair**

The aim of scheduled maintenance and service is it to prevent the expensive breakdown of vehicles during operation and as a result unscheduled repair activities. Moreover, OEMs prescribe regular maintenance services of vehicles, otherwise they might be exempt from their product liability. The costs for the replacement of wear and tear items, maintenance and repair need to be added to the variable costs. They can differ strongly between different areas, as they depend on the labor costs for performing the service and on the costs for replacement parts (Lowe, 1989; Barnes and Langworthy, 2003).

For the Ford Custom a monthly value for maintenance and repair of €46 was found in an online vehicle cost calculator for an annual mileage of 15,000 km. However, according to the provider this amount does not include wear and tear parts but takes the cost for oil and lubricants into account (Autokostencheck.de, 2015). The automobile club ADAC (2014) provides a yearly overview of vehicle costs for different models. According to the 2014 report the monthly maintenance and repair cost for a similar Ford model are €51 for an annual mileage of 15,000km and a working life of 4 years. This value is also used for the calculation in this thesis. Translating this total amount into a variable cost component gives a value of 4.08 cent/km (€51*12/15,000km). With an annual mileage of 19,240 km, the result for the annual maintenance and repair cost therefore becomes €785. (4.08c/km*19,240 km/100)

For the maintenance and repair costs of CNG busses, different studies have identified a value between 3.1 and 4.9 cent/km, with the most recent study showing the lowest value (Giesel, 2007; Schäfer, 2013). For the performed calculation a value of 4 cent/km is selected. This leads to annual maintenance and repair costs of €322. (4c/km*8,060 km/100)

After consulting a cargo bike operator and different bike stores selling electric and cargo bikes, the annual maintenance costs for the cargo bike with trailer are estimated at €340 (5.45c/km*6,240km/100). This includes the material costs for the wear and tear parts as well as the labor costs for performing the service (EcoRide, 2015b; Elcykelbutiken, 2015).

**Other running costs**
Some authorities charge tolls for the use of their infrastructure. For example, in many countries tolls have to be paid for the use of highways, and the amount often depends on the type of vehicle operated and the distance driven (Tolltickets, 2014). In addition, more and more cities have started to raise fees, charged from vehicles entering the city area. This is often described as a method to make vehicle operators internalize the external costs that they cause the society, e.g. air pollution. Such costs only occur because the vehicles are moved and use the described infrastructures; therefore they need to be added to the variable costs (McKinnon, Browne and Whiteing, 2012; Gries et al., 2014). Other costs that can occur to transport operators are parking fees or costs for additional vehicle equipment like batteries for electrified vehicles.

In Gothenburg a congestion charge has to be paid for the entrance into the city area. The specific amount differs between different times of the day. For the calculation an average value of €1.7 per entry and exit is used (Transportstyrelsen, 2015b). With 260 roundtrips per year each van has to pay an annual fee of €884. (€1.7*2*260)

Busses that weight over 14 tons are exempt from this city fee (Transportstyrelsen, 2015c). The MAN Bus comes at a gross vehicle weight of 19.5 tons and therefore no fee has to be paid (MAN, 2012). However, as the vehicle acts as a mobile depot, it has to be parked for longer periods of time in the central city. According to the Gothenburg City authority the general loading zones for goods vehicles could be used for this operation and therefore no additional charges apply.

Electric cargo bikes and regular cargo bikes are not subject to congestion charges neither (Transportstyrelsen, 2015c). However, the costs for the batteries occur as additional cost item. The capacity of the battery is often the bottleneck factor that limits the operation of the cargo bike. A cargo bike can drive 25 km with one battery load. Yet weather conditions (e.g. cold climate) and wear of the battery over time can reduce this distance. Therefore it is assumed that two batteries are used per bike in order to assure uninterrupted operations. The useful life of a battery is 16,250 km and a new battery comes at a cost of €361. Therefore the annual costs for battery are €277. (€361*6,240 km /16,250 km*2)

<u>Overhead costs</u>
Overhead costs are costs that cannot directly be associated with individual vehicles. Different types of overhead costs are e.g. administration and communication costs, general insurance, rent for buildings, management salaries or electricity bills. Overhead costs often make up a significant portion and occur independently of whether actual transport work is performed or not. Overhead costs are calculated by taking a certain percentage of the total vehicle cost, that is the sum of annual standing and running costs (Lowe, 1989; Road Haulage Association, 2015).

The specific overhead costs depend very much on the specific business setup and the size of the vehicle fleet. However, in literature generally values between 9 and 15% of the annual total are used as a base for calculation (Gries et al., 2014; Wittenbrink, 2014). For this calculation 12% are used. The annual cost of fixed and variable costs for the Ford Custom are €46,702. Hence the overhead costs are set at €5,604. (€46,702*12%)

Accordingly, the annual overhead costs for the bus are €9,058. (€75,486*12%)

For the bike overhead costs of €4,244 occur. (€35,368*12%)

Total operating costs

The total operating costs of a vehicle is the sum of the three described cost areas. It is important to have full knowledge of all the aforementioned costs in order to assess operational performance and make proper management decisions. Often, only a general sum might exist that reflects the costs per km or per parcel in the case of a CEP provider. This might especially be the case when the actual delivery operation is sub-contracted and a certain gratification is paid per parcel. This might be sufficient for a general overview of the cost structure and for a calculation assessment of the costs that need to be covered by the price charged to the customer. However, to identify main cost drivers and potential fields of savings and to compare different alternatives to each other, a higher level of detail is essential.

The total yearly operating costs for one Ford Custom for the described operations is €46,702. This corresponds with a cost of €2.51 per parcel for 20,800 parcels delivered per van each year.

The sum of all the costs for the CNG bus is €84,544. This value divided by the 41,600 parcels distributed by the bus per year leads to a delivery cost per parcel of €2.03.

The total yearly operating costs for an electric cargo bike with trailer for the described operations is €39,605. This corresponds with a cost of €1.90 per parcel for 20,800 parcels delivered a year. In order to increase the reliability of the results and to compare the costs per parcel of the innovative model, the bike delivery company Pling Transport in Gothenburg was contacted. According to Johan Erlandsson, co-founder of Pling Transport, a price of approximately €4.39 per parcel would be charged in the base scenario. This is set as a benchmark price, which could potentially be negotiated in situations of increased parcel deliveries to the same address (Erlandsson, 2015b). However, it must be considered that this is the price for using the subcontractor and thus not the cost of its operations.

#### *4.1.1.4 Comparison*

This section compares the costs between the different vehicle types employed and between the conventional and innovative model in the base scenario. Thus, RQ3 “How do the total costs between the conventional and the innovative model differ?” is answered.

When looking at the costs shown in Table 5 for the three different vehicle types it is obvious that the bus by far has the highest total operating costs per year. This is due to the high capital investment that has to be made for purchasing and refitting, which is much more expensive (almost ten times as high) than obtaining a new van. For the same reason the bike with trailer has the lowest total operating cost, its acquisition price is only about one eighth of the purchase price of the van. Another fact that becomes apparent when looking at the different cost components is that the labor element sticks out most. In fact, in the specific example the labor costs do not differ largely between the different transport modes and make up 45-86% of the total annual operating costs. In contrast to typical road haulage operations where fuel costs make up about one third of the total costs, this is only a minor cost component for the described parcel delivery operations. This is because merely short distances are travelled. However, the differences in fuel costs between the different transport modes are significant. The bus has the highest total fuel cost of the three vehicles even though it travels less than half of the distance of one van (8,060 km compared to 19,249 km). The reason for its high fuel costs is the higher fuel consumption due to the large size and weight, as well as the high costs for the CNG-fuel itself. In contrast, the fuel costs for the cargo bike are almost negligible as the cost for electricity and the specific fuel consumption are very low.

| Cost comparison Van / Bus / Bike – Base scenario | | | |
|---|---|---|---|
| | **Van** | **Bus** | **Bike** |
| **Cost of Capital** | 445 | 4,228 | 57 |
| **Depreciation** | 2,780 | 20,139 | 320 |
| **License/Permit** | - | - | - |
| **Insurance** | 1,939 | 5,510 | - |
| **Labor** | 36,130 | 38,716 | 34,236 |
| **Tax** | 573 | 107 | - |
| **Fuel** | 2,963 | 6,263 | 24 |
| **Lubricants** | 30 | 63 | - |
| **Maintenance** | 785 | 322 | 340 |
| **Tires** | 173 | 138 | 107 |
| **Others** | 884 | - | 277 |
| **Overhead Costs** | 5,604 | 9,058 | 4,243 |
| **TOTAL OPERATING COSTS** | **52,306** | **84,544** | **39,605** |
| **per parcel (41600 parcels per year)** | 2.51 | 2.03 | 1.90 |

*Table 5: Cost comparison Van / Bus / Bike - Base scenario in €*

The specific vehicle setup that is needed in the base scenario to deliver 160 parcels per day consists of two vans for the conventional model and one bus and two electric cargo bikes for the innovative model. Table 6 shows the difference in costs for the two models.

| Cost comparison Conventional & Innovative model – Base scenario | | | | | |
|---|---|---|---|---|---|
| | **Conventional** | | **Innovative** | | **Difference** |
| **Cost of Capital** | 890 | 1% | 4,342 | 3% | 3,452 |
| **Depreciation** | 5,561 | 5% | 20,779 | 16% | 15,219 |
| **License/Permit** | - | 0% | - | 0% | - |
| **Insurance** | 3,878 | 4% | 5,510 | 4% | 1,632 |
| **Labor** | 72,260 | 69% | 72,952 | 56% | 692 |
| **Tax** | 1,146 | 1% | 107 | 0% | -1,039 |
| **Fuel** | 5,926 | 6% | 6,310 | 5% | 384 |
| **Lubricants** | 59 | 0% | 63 | 0% | 3 |
| **Maintenance** | 1,570 | 2% | 1,003 | 1% | -567 |
| **Tires** | 346 | 0% | 353 | 0% | 6 |
| **Others** | 1,768 | 2% | 554 | 0% | -1,214 |
| **Overhead Costs** | 11,208 | 11% | 17,545 | 14% | 6,337 |
| **TOTAL OPERATING COSTS** | **104,612** | | **129,517** | | **24,905** |
| **per parcel (41600 parcels per year)** | 2.51 | | 3.11 | | 0.60 |

*Table 6: Cost comparison Conventional & Innovative model - Base scenario in €*

With the demand structure of the base scenario, the innovative model comes at about 24% higher cost than the conventional model. The main cost difference lies in the depreciation costs, which are higher especially because of the high investment costs for the bus, as described above. Also depreciation and cost of capital is a bigger cost element (19% of the total cost) than it is in the conventional model (6%). The labor costs are a dominating cost element for both models but do not differ by much between the two. The reason is that in both solutions two employees have to be paid whereof the salary of the two van drivers in the conventional model lies in between that of the bus and the bike driver in the innovative model. Altogether, the fixed costs make up 80% of the total operating cost in both models. The fact that the costs are spread over a relatively low amount of parcel deliveries leads to a cost of €3.11 per parcel in the innovative setup, which is €0.60 more than in the conventional model.

However, it has to be noted that the innovative model yields savings in some cost elements. Due to the more environmentally friendly vehicles employed, tax expenses are lower. In addition, the vehicles used in the innovative model are not subject to congestion charges. These charges are a high variable cost element for the vans.

Nevertheless, altogether the innovative setup does not show a financially viable option under the conditions of the base scenario.

### 4.1.2 Scaled Scenario of the BRD project

In the base scenario the available resources are not fully utilized. Table 7 gives an overview of the vehicle utilization rates under the base scenario. The percentages in Table 7 are derived from the number of parcels that each vehicle carries in the base scenario and the resulting space and weight occupation. The bus transports 160 parcels and each of the two vans 80 parcels. The bikes, however, must be considered to make 6 delivery rounds around the bus that serves as a mobile depot. They transport 14 parcels each per delivery round, which equals a weight utilization of 43% and a volume utilization of 13%, as shown in Table 7.

| Vehicle utilization - Base scenario | | |
|---|---|---|
| | **Weight** | **Volume** |
| **Van** | 39% | 26% |
| **Bus** | 9% | 6% |
| **Bike** | 43% | 13% |

*Table 7: Vehicle utilization - Base scenario*

The bus, which has the highest carrying capacity of all of the three vehicles, is only utilized at a very low rate. The constraining element for the bus is the weight it can carry, i.e. it will weigh out before it cubes out. At a 100% load factor it can carry 1869 parcels (7,475 kg carrying capacity / 4 kg per parcel), which means a utilization rate of 70.5% of its volume carrying capacity. For the scaled scenarios different load factors in between the current utilization rate in the base scenario and the maximum load factor are investigated. Namely the cost implications for 25%, 50%, 75% and 100% of the bus utilization rates are evaluated.

For the van and the bike, the delivery time has been identified as the constraining element. In order to sustain the current service level, the deliveries have to be made within a certain time window. This time window is the office hours of the business customers, who form the main customer group. It has been defined that the time span during that deliveries can be made is from 10am to 4pm. This equals a 6 hours/360 min time window. At the moment it takes approximately 4 hours/240 min to deliver 80 parcels to 53 stops (1.5 parcels per stop) in Gothenburg. This equals a delivery time of 4.5 min per stop or 3 min per parcel. Taking this delivery time as a benchmark, the maximum amount of parcels that can be delivered per van or bike per day is 120 (360 min time window/3 min delivery time per parcel). This indicates that for every multiple of 120 parcels an additional van and/or bike have to be employed. Figure 6 illustrates the numbers of vehicles needed, depending on the selected scale of operations.

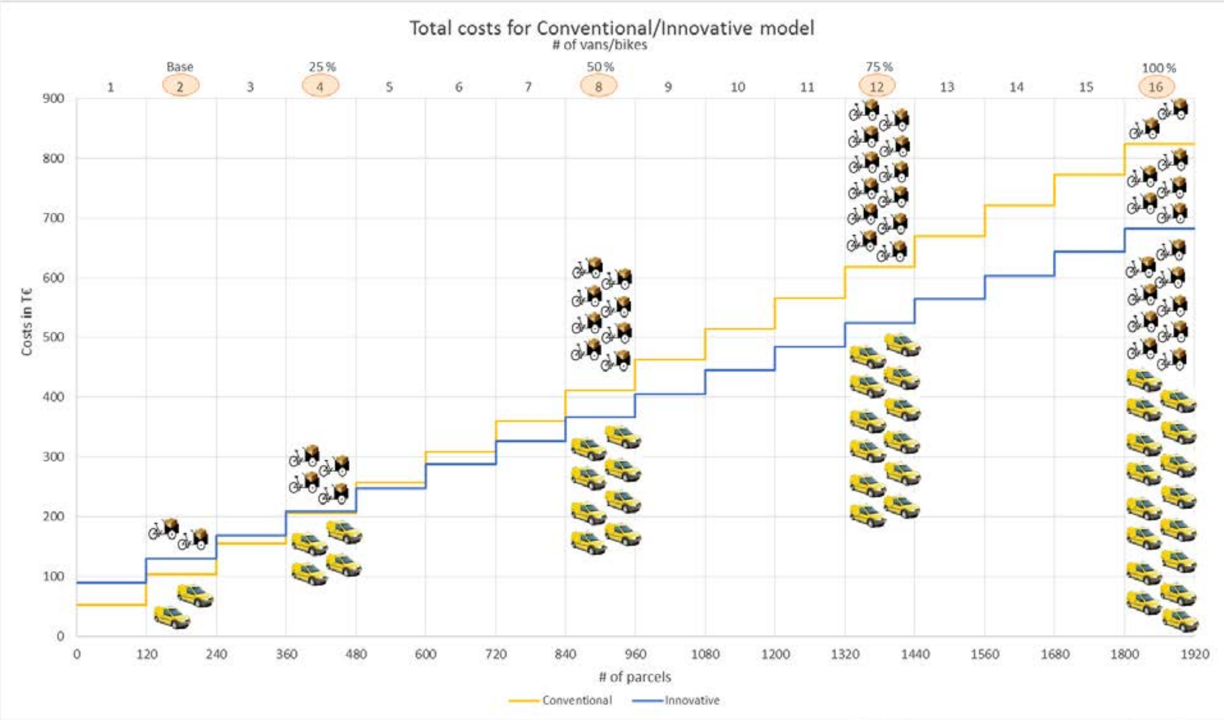


*Figure 6: Number of vehicles needed in the different scenarios*

The cost implications for the different setups are shown in Table 8.

| Cost comparison Conventional & Innovative model – Scaled scenarios | | | | |
|---|---|---|---|---|
| | | **Conventional** | **Innovative** | **Difference** |
| **Base scenario** | Total operating costs | 104,612 | 129,517 | 24,905 |
| | per parcel | 2.51 | 3.11 | 0.60 |
| **25%** | Total operating costs | 209,225 | 208,727 | -498 |
| | per parcel | 1.72 | 1.72 | 0.00 |
| **50%** | Total operating costs | 418,450 | 367,146 | -51,304 |
| | per parcel | 1.72 | 1.51 | -0.21 |
| **75%** | Total operating costs | 627,674 | 525,564 | -102,110 |
| | per parcel | 1.72 | 1.44 | -0.28 |
| **100%** | Total operating costs | 836,899 | 683,983 | -152,.916 |
| | per parcel | 1.72 | 1.41 | -0.31 |

*Table 8: Cost comparison Conventional & Innovative model – Scaled scenarios in €*

It can be seen that if the daily amount of parcels is almost tripled (25%-scenario) compared to the base scenario, the cost difference between the two delivery models is equalized and the financial performance of the two models is almost identical. If the demand level is increased to an amount of 935 parcels a day (50%-scenario) the innovative model becomes superior to the conventional model in cost terms. The reason is that the high fixed costs for the bus become less significant, as they are spread over a larger amount of parcels, whereas the lower investment cost in a new bike compared to a new van work in favor of the innovative model. The result is lower annual operating costs for the innovative model. Anticipating even higher demand for parcels, the gap between the two models grows further and in the case of 100% load utilization of the bus, the delivery costs per parcel would be €0.31 lower in the innovative setup. Figure 7 illustrates, how the operating costs per transport mode develop with growing parcel numbers.

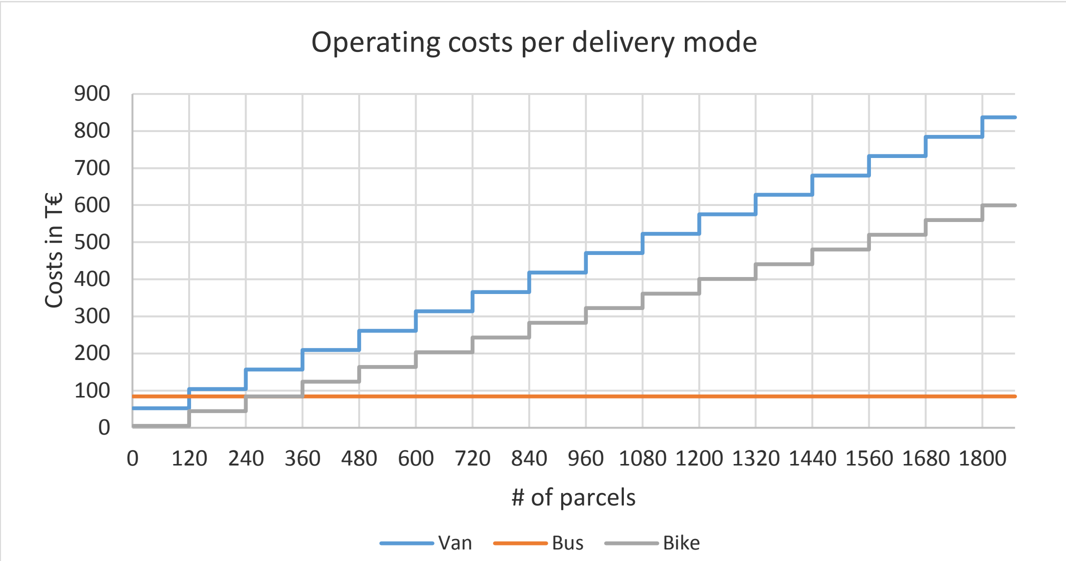


*Figure 7: Operating costs per delivery mode*

It can be seen that the cost curves for the bike and the van are not linear but increase stepwise. The reason is that the total operating costs stay the same within a certain range of parcels, i.e. there is no difference in total costs no matter if 1 or 120 parcels are delivered per day. The vehicles and drivers have to be paid independently of how efficiently they are utilized. As mentioned, each bike and van can deliver a maximum of 120 parcels per day within the defined service level. If this threshold is trespassed an additional vehicle and driver must be employed, which is where a jump in the cost curve appears. The total operating costs can therefore be seen as fixed within a certain range of parcels. Nevertheless, the costs per parcel are not constant and decline along with more efficient vehicle utilization, as illustrated in Appendix B. The same argumentation as for the bikes and vans applies to the bus, with the only difference being that the range of parcels for which the total operating costs remain constant is 1 to 1869 parcels. This is the maximum amount of parcels that the bus can carry at 100% utilization rate. When looking at Figure 7 it also becomes obvious that the gap in total costs between the vans and bikes increases the more parcels are transported. This is caused by the higher marginal costs of for employing a new van compared to a new electric cargo cycle. Hence, when the cost gap between vans and bikes reaches a point where it equals the fixed costs of the bus, the break-even-point for the innovative model is reached.

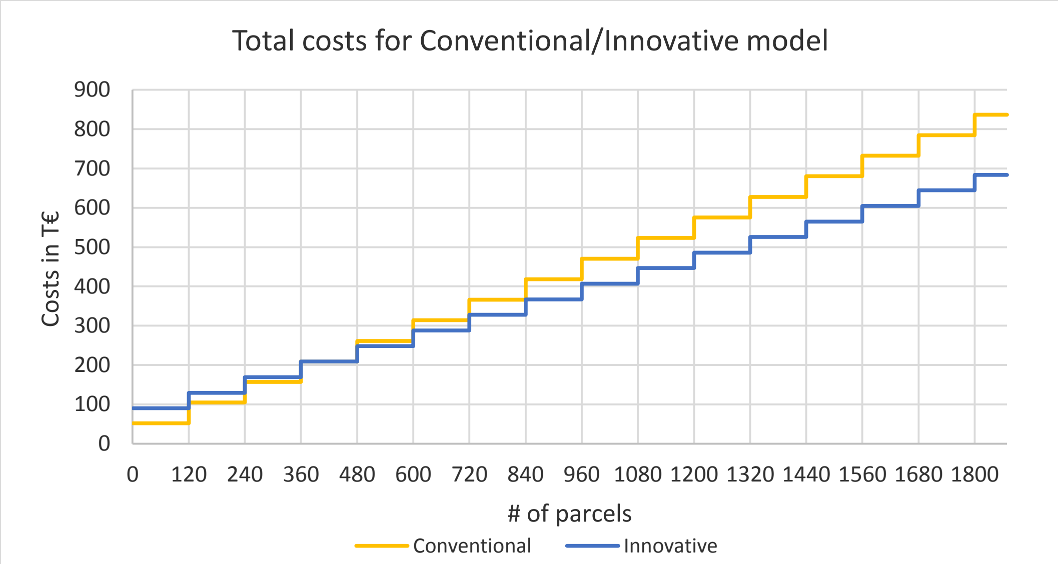


*Figure 8: Total costs for Conventional/Innovative model*

Figure 8 shows the aggregated costs for the conventional and the innovative model, as they would develop over a growing demand for parcels under the assumptions made. It can be seen that the two graphs are almost overlapping in the range of 361-480 parcels. Here the total costs of operating are almost identical for the two models. For a lower amount of parcels, the conventional model is less expensive and for a higher amount the innovative model is. Looking at these numbers, the demand for parcel delivery has to become approximately three times higher compared to the base scenario, for the innovative solution to become viable.

### 4.1.3 Sensitivity analysis of the BRD project

This chapter evaluates how altering different cost components and assumptions influences the result of the cost calculation. Six different variables are investigated that could possibly be affected, and thus alter the cost results, if the parcel delivery operations would be set up in another environment. For instance if the BRD would be tried in a country with lower labor costs.

First, three variables that influence the costs of the conventional as well as the innovative model are investigated. These are the labor costs, the fuel costs and the delivery rate of parcels per stop. Next, the assumption about the delivery speed is altered first for the bike and then for the van. Finally, two cost components that are only present for one of the two models are examined. These are the congestion charges, which only apply to the conventional model, and the parking fees, which are only raised in the innovative solution.

It is evaluated how the cost difference between the conventional and the innovative model changes in the base as well as the scaled scenarios if those variables are adapted. Moreover, where applicable, it is mentioned when the change of one variable shifts the break-even point of when the innovative solution becomes less expensive than the conventional one.

Labor costs

Labor costs make up the largest proportion of the total costs for operating either of the three vehicle types. These represent two thirds, half and almost ninety percent of the total costs of van, bus and bike, respectively. Moreover, labor costs differ significantly between different countries. Sweden is rather on the upper scale when it comes to labor costs. According to statistics from the Federal Statistical Office in Germany (Statistisches Bundesamt, 2014) the hourly labor costs in Sweden are the highest among the EU27 countries and 45% higher than the European average. Compared to other countries with similar economies, Sweden's labor costs are more than 50% higher than those in the UK and 26% higher than the ones in Germany. The labor costs in the Czech Republic are only about one quarter of those in Sweden. Since labor is a major cost component that differs greatly between various countries, it is evaluated further in this section how a change of this variable would influence the calculation result.

In specific it is investigated how a reduction in labor costs to 75%, 50% and 25% of the current value influences the result. As mentioned, the current scenario assumes labor costs that are on the upper end of the potential cost scale. Therefore no variation of the labor costs to a higher value is investigated.

Starting from the base scenario, where two vans or the freight bus together with two cargo bikes are needed to conduct the parcel deliveries, a 25% reduction in labor cost would reduce the labor cost of the conventional model by €18,065 and of the innovative model by €18,238. Thus, the total cost difference between the two models would decrease only by €173. The innovative model would however still be €24,732 more expensive than the conventional one. If the labor costs decrease further down to 25% of the current value, the innovative model is still €24,386 more costly than the conventional one. Thus, not even a major reduction in labor costs makes the innovative model financially viable, although it can decrease the cost gap between the two solutions.

As the labor costs correlate with the number of vehicles employed it is of interest to investigate how a change in labor costs influences the scaled scenarios. When applying the reduced labor costs to the scaled scenarios, it can be seen that with a larger demand the cost change induced by lower labor rates is in favor of the conventional model. That is that the cost savings for the conventional model are higher than those for the innovative model as more workers are needed. Taking for example the scaled scenario where the bus is 100% utilized and the labor costs are only half of the current value, the cost advantage that the innovative model originally enjoyed is reduced from €152,916 to €140,004. It is still financially viable, but the cost difference between the two models has declined by €12,912.The reason for the more favorable development for the conventional model on a larger scale, is that the labor costs for a van driver are higher than those of a bike driver. Thus, the savings that are obtained for each additional employee are also higher.

Table 9 summarizes the cost differences between the conventional and the innovative model in the five different scenarios at different labor rates. The scenarios at the current (100%) labor costs are highlighted by a frame and it is furthermore shown how the reduced labor rates change the cost gap compared to the current scenario. For example in the base scenario at the current (100%) labor cost the total operating costs for the innovative model are €24,905 higher than for the conventional one. This difference decreases when the labor rate is lowered, down to €24,386 (≙ - €519) at a 25% labor rate in the base scenario.

| **Differences in costs Innovative - Conventional model for different scenarios at different labor costs** | | | | | |
|---|---|---|---|---|---|
| **Bus utilization:** | **Labor cost at:** | **100%** | **75%** | **50%** | **25%** |
| **Base scenario** | Total cost difference | 24,905 | 24,732 | 24,559 | 24,386 |
| | Increase/decrease | | -173 | -346 | -519 |
| **25%** | Total cost difference | -498 | 276 | 1,050 | 1,824 |

| | | | | | |
|---|---|---|---|---|---|
| | Increase/decrease | | +774 | +1,548 | +2,322 |
| **50%** | Total cost difference | -51,304 | -48,636 | -45,968 | -43,300 |
| | Increase/decrease | | + 2,668 | +5,336 | +8,004 |
| **75%** | Total cost difference | -102,110 | -97,548 | -92,986 | -88,424 |
| | Increase/decrease | | +4,562 | + 9,124 | +13,686 |
| **100%** | Total cost difference | -152,916 | -146,460 | -140,004 | -133,548 |
| | Increase/decrease | | + 6,456 | +12,912 | +19,368 |

*Table 9: Differences in costs Innovative - Conventional model for different scenarios at different labor costs in €*

An additional factor that has a major impact on the cost difference between the two models is to what extent the total labor potential of the bus driver can be used to make final parcel deliveries. As described, the bus driver has an important managerial function in having to coordinate the bike drivers and decide on the appropriate time when to move the mobile depot to its next parking spot. In the current calculations it is assumed that the bus driver can completely supersede one bike driver. If this is realistic in a real life application depends highly on the specific context, on the supporting IT solutions and on how big the scale is. Especially in a large-scale scenario where many bikes are employed, the managerial function of the bus driver might preponderate. This means that he or she might not be able to deliver any parcels himself or fewer than the other bike deliverymen who do not have this coordinating function. This means that an additional bike driver has to be employed either as a fulltime or part time employee, depending as mentioned on how many parcels the bus driver actually can deliver. This leads to an increase in labor costs in the innovative model and shifts the break-even point of when the model becomes financially superior to the conventional solution. As described, the break-even point is currently reached at a daily demand of more than 360 parcels. In case the bus driver cannot be employed for making any parcel deliveries, the break-even point increases to a daily volume of 721 parcels or more. So in the case of a real life application it has to be evaluated exactly how much the bus driver can contribute in making parcel deliveries and how this influences the cost calculations.

<u>Fuel costs</u>

Fuel costs constitute the highest variable cost item for the van and the bus. Similar to the labor costs, the energy prices for diesel and CNG differ significantly between various countries. As of April 2015 the diesel prices in Germany, China, the U.S. and Russia were only 84%, 59%, 48% and 38% of the price in Sweden (GlobalPetrolPrices.com, 2015). In the UK in comparison the price was 14% higher. Likewise, CNG prices show a big variation between different countries as well (Del Álamo, 2013; NGVA Europe, 2014; CNGprices.com, 2015).

In the following it is investigated how different levels of CNG and diesel prices influence the result of the cost calculation. As the energy price for charging the battery of the cargo bike is far less than 1% of the total costs and therefore considered a minor cost component, it is excluded from the calculation and the cost is kept at the current level.

In specific it is evaluated how the fuel price at a level of 115%, 85%, 60% and 45% from now changes the total costs of the conventional and the innovative model. This reflects the costs of some important countries as mentioned above. Based on findings from online research it is assumed that diesel and CNG prices develop in the same direction, i.e. in cases where diesel prices are higher, CNG prices are higher as well, and vice versa. It must, however, be mentioned that this is not always the case and it is possible that the two energy prices change in opposite directions in some countries or not increase or decrease at the same proportions.

When looking at the base scenario, a change in the fuel costs only has a minor impact on the overall outcome of the cost calculation. Raising the fuel cost to 115% of the current level increases the total costs difference between the two models by €51. Reducing the fuel cost to 45% decreases the difference by €185. The low impact of the change in this variable can be explained by the fact that the fuel costs only make up 6% and 5% of the total operating costs of the conventional and the innovative model respectively in the base scenario. Therefore, even a significant variation in this cost component does not change the overall result proportionally.

The effects that can be observed when changing the fuel rates for the scaled scenario at 100% utilization rate (=1869 parcels a day) of the bus are more significant. In this scenario 16 vans have to be employed and therefore the fuel consumption impacts the fuel costs of the conventional model more compared to the innovative model, where one bus is sufficient to comply with demand. Increasing the fuel price by 15% works in favor for the innovative model, as the fuel costs for the conventional model increase by €7,111 whereas it is only €940 more for the bus. In contrary, a reduction of the fuel price to 45% from the current level decreases the fuel costs for the conventional model by €26,074 whereas it is only €3,444 for the bus. This means that the cost advantage of the innovative model becomes less.

Table 10 shows the total cost differences between the models for different levels of fuel prices and in different scenarios. Again a frame highlights the numbers for the scenarios at the current fuel price.

| Differences in costs Innovative - Conventional model for different scenarios at different fuel prices | | | | | | |
|---|---|---|---|---|---|---|
| **Bus utilization:** | **Fuel price at:** | **115%** | **100%** | **85%** | **60%** | **45%** |
| **Base scenario** | Total cost difference | 24,956 | 24,905 | 24,855 | 24,770 | 24,720 |
| | Increase/decrease | +51 | | -50 | -135 | -185 |
| **25%** | Total cost difference | -1,336 | -498 | 341 | 1,738 | 2,576 |
| | Increase/decrease | -838 | | +839 | +2,236 | +3,074 |
| **50%** | Total cost difference | -53,920 | -51,304 | -48,687 | -44,327 | -41,711 |
| | Increase/decrease | -2,616 | | +2,617 | +6,977 | +9,593 |
| **75%** | Total cost difference | -106,503 | -102,110 | -97,716 | -90,393 | -85,999 |
| | Increase/decrease | -4,393 | | +4,394 | +11,718 | +16,111 |
| **100%** | Total cost difference | -159,087 | -152,916 | -146,744 | -136,458 | -130,286 |
| | Increase/decrease | -6,171 | | +6,172 | +16,458 | +22,630 |

*Table 10: Differences in costs Innovative - Conventional model for different scenarios at different fuel prices in €*

It can be seen that the fuel costs influence the total costs difference to a low extent if the demand for parcel deliveries is small. However, the bigger the operational scale becomes, the more impact this cost component gets. A decrease in fuel prices then leads to a higher reduction in overall costs for the conventional model than it does for the innovative setup as it affects multiple vans compared to only one bus. An increase of fuel prices for the scaled scenarios has the opposite effect.

Deliveries per stop

The number of parcels that are delivered at each stop is on average 1.5 at the moment. However, this number can vary between different operators and cities with different demand structures. In a densely populated area the amount of parcels that are delivered per stop could be significantly higher, if a lot of customers have their offices in the same building for example. The driver could then deliver the packages for multiple customers at one stop. The delivery rate can therefore be seen as a proxy of the customer density of a city.

The number of deliveries per stops influences how many parcels can be delivered by one vehicle within the given time window. Assuming the time per stop remains the same (4.5 min per stop), doubling the amount of parcels delivered per stop would also double the total daily amount of parcels that can be delivered. Theoretically, the rate of parcels per stop could be increased to any random number. In practice however, the daily amount of parcels that can be delivered per vehicle without changing other variables of the operational setup is limited by its technical capacity. The Ford Custom that is employed as delivery van in the conventional scenario can carry 203 parcels à 4 kg per delivery round before it weights out. This means that if the number of parcels per stop would increase to a level higher than 2.5 (=203 parcels / 80 stops) either a vehicle with higher carrying capacity has to be employed or the van has to make an extra return trip to the consolidation center to pick up the excess parcels. The first option would increase the total annual costs for the van compared to the original scenario as the investment and also the running costs for a bigger vehicle are likely to be higher. The second option would negatively influence the operational efficiency, as some time of the six hours delivery time window is used for commuting and picking up parcels instead of making deliveries. Therefore, for all other things to remain equal, a maximum amount of 2.5 parcels per stop is investigated for this this section of the sensitivity analysis. Furthermore, the cost results for one delivery per stop, the lowest possible scenario, and for 2 deliveries per stop is evaluated.

Table 11 gives an overview of the daily parcel volumes that can be delivered per vehicle, making a maximum of 80 stops a day, depending on the respective amounts of deliveries per stop.

| Daily amount of parcels for different amounts of deliveries per stop | |
|---|---|
| **Deliveries per stop** | **Daily amount of parcels** |
| 1 | 80 |
| 1.5 | 120 |
| 2 | 160 |
| 2.5 | 200 |

*Table 11: Daily amount of parcels for different amounts of deliveries per stop*

The consequence of changing the amount of deliveries per stop is that the break-even point of when the innovative model becomes cheaper than the conventional model is shifted. The costs for the bus remain the same and are independent of the rate of deliveries per stop. As long as the daily amount of parcels delivered does not exceed 1869 parcels only one bus has to be employed and the costs for that have to be borne. Changing the rate of deliveries per stop would however influence the number of vans and bikes that have to be employed. The higher the delivery rate is, the fewer vehicles have to be employed since this allows for more parcels to be delivered per vehicle. Taking e.g. a rate of 2.5 parcels per stop, only one bike or one van is needed to fulfill the daily demand of 160 parcels in the base scenario, as each vehicle can now deliver a maximum of 200 parcels per day while providing the acceptable service level. Consequently, the total costs for delivering these 160 parcels decrease by €52,306 for the conventional model and by €39,604 in the innovative model. It can be seen that the cost decrease is higher for the conventional model. This is because the total costs for operating a van are higher than those of a bike. Therefore a reduction of the number of vehicles employed, which comes along with higher delivery rates, is more beneficial for the conventional model. Vice versa, fewer deliveries per stop increases the number of vans and bikes that have to be employed and the rise in costs is less for the innovative solutions with the cheaper bikes. Figure 9 shows the cost development for both delivery models at different delivery rates.

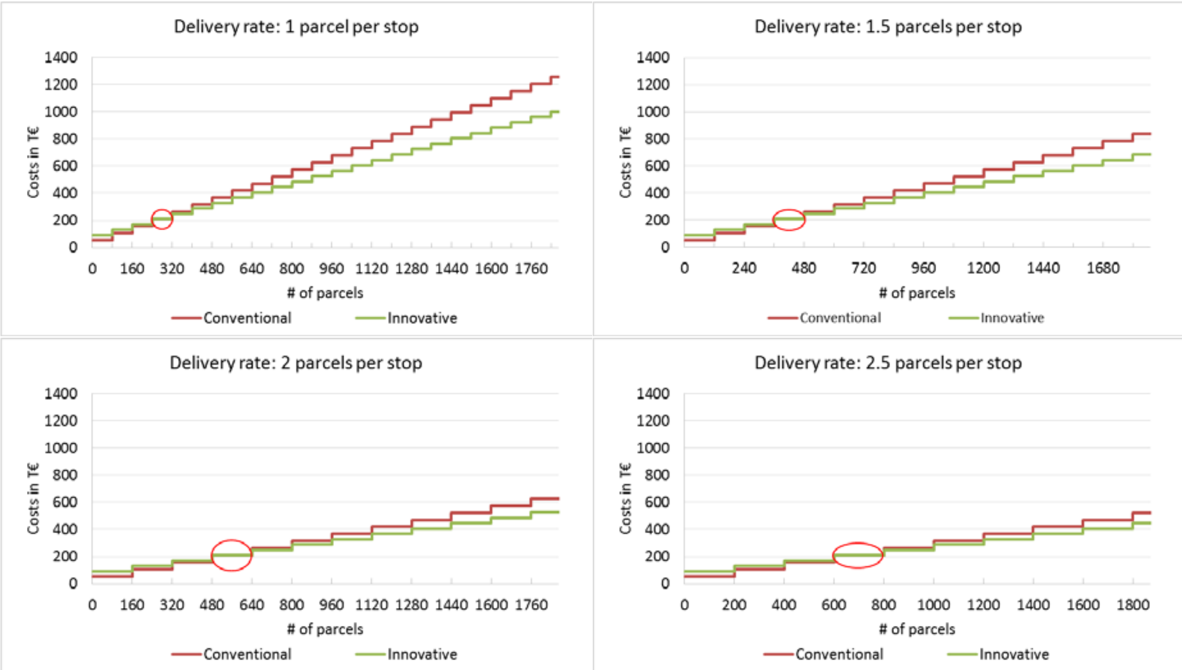


*Figure 9: Break-even point at different delivery rates*

The red circle indicates when the break-even level is reached. In the current model with 1.5 deliveries per stop, the break-even point is reached if the demand increases above 360 parcels a day. With an increase to 2 or 2.5 stops per delivery, a break-even of the innovative model is reached first at a demand higher than 480 or 600 parcels a day respectively. If the delivery rate is lowered to only 1 parcel per stop the break-even is already reached at a quantity of 240 parcels or more.
Hereby it can be seen that a higher delivery rate of parcels per stop is favorable for the conventional model with the higher per-vehicle costs.

Delivery speed

In the current cost analysis it is assumed that the delivery speed of the bikes and vans is identical. This assumption might not hold true in all operational setups. For example, in a city with lower customer density, the distances between the different delivery locations are longer. As the vans can drive at a higher speed, it takes them less time to cover these distances than it takes for the cargo bikes. In contrast, in a city with a historic city center with narrow streets, restricted parking or limitations to vehicle access, bike operations are more flexible and perform deliveries more quickly than vans.

In the following it is therefore investigated how a variation in delivery speed influences the result of the cost calculation. Two scenarios are evaluated: one where the bike operates at a 33% lower delivery speed compared to the current scenario and another where the van is 33% slower. This is assumed to be a moderate alteration of the delivery speed and admittedly smaller or bigger variations are equally possible.

In the base scenario it is estimated that the delivery time is 3 minutes per parcel or 4.5 minutes per stop for both vans and bikes. Assuming that it takes the bikes one third more time to deliver their goods, the delivery time per parcel and stop increases to 4 and 6 minutes respectively. As a consequence, the bikes can deliver fewer parcels in the time window of 360 minutes. The delivery capacity per bike is thus reduced from 120 to 90 parcels a day and consequently more vehicles are needed to fulfill the demand. In the base scenario this would not make a cost difference yet, as two cargo bikes are still sufficient to cover the daily demand of 160 parcels. However, the larger the scale becomes, the more severe the cost effects are. At a 50% utilization rate of the bus, 11 bikes are needed vs. 8 vans. In the 100% scenario, 5 more bikes than vans are needed. This has a severe impact on the total costs of the innovative model. It can be seen in Figure 10 that under the changed assumptions the innovative solution never reaches a break-even point where it is less expensive than the conventional model.

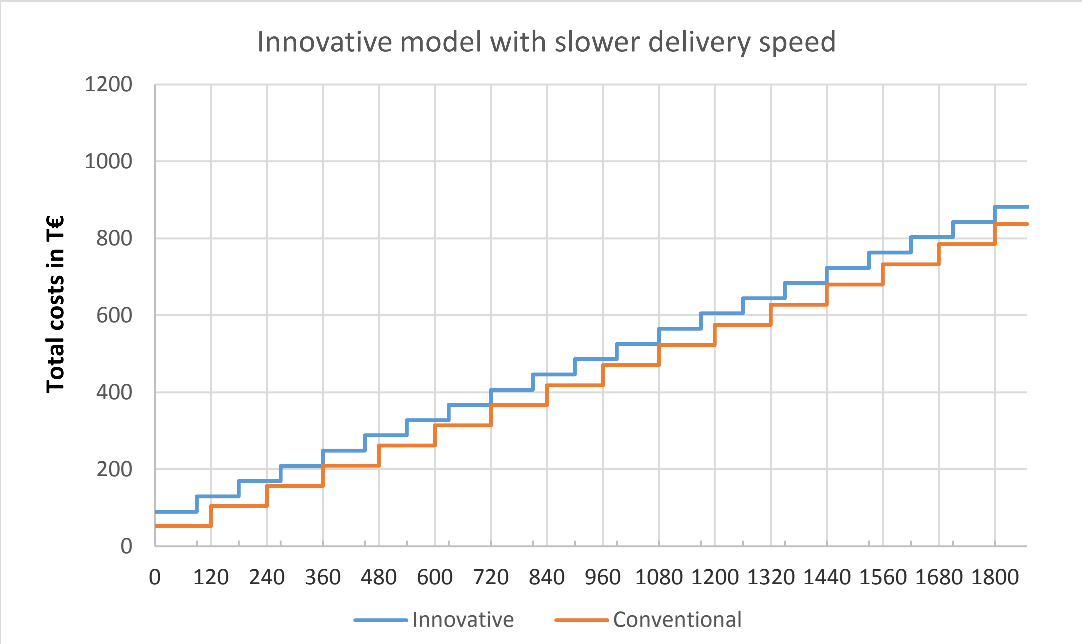


*Figure 10: Cost development with innovative model operating at a slower delivery speed*

In contrast, if the delivery speed of the vans is assumed to be one third lower than those of the bikes, the innovative model becomes less costly than the conventional one at a lower demand than in the base scenario. The same delivery speed and delivery volume per day, as described above, for the bikes now applies to the vans. Figure 11 illustrates that for a daily demand between 90 and 320 parcels the total operating costs of the two solutions are similar. Depending on how many vehicles that must be operated, one of the models will be slightly more or less expensive. However, for a demand exceeding 320 parcels a day the innovative model alone becomes financially more viable. In addition, as the costs for the conventional model grow steeper than those for the innovative one, the gap between the two models grows when the demand for parcels increases. Under the changed assumptions, the conventional model costs €414,447 more than the innovative solutions in the 100% scaled scenario. This cost difference is €261,531 higher than in the current setup, where both vehicles operate at the same speed.

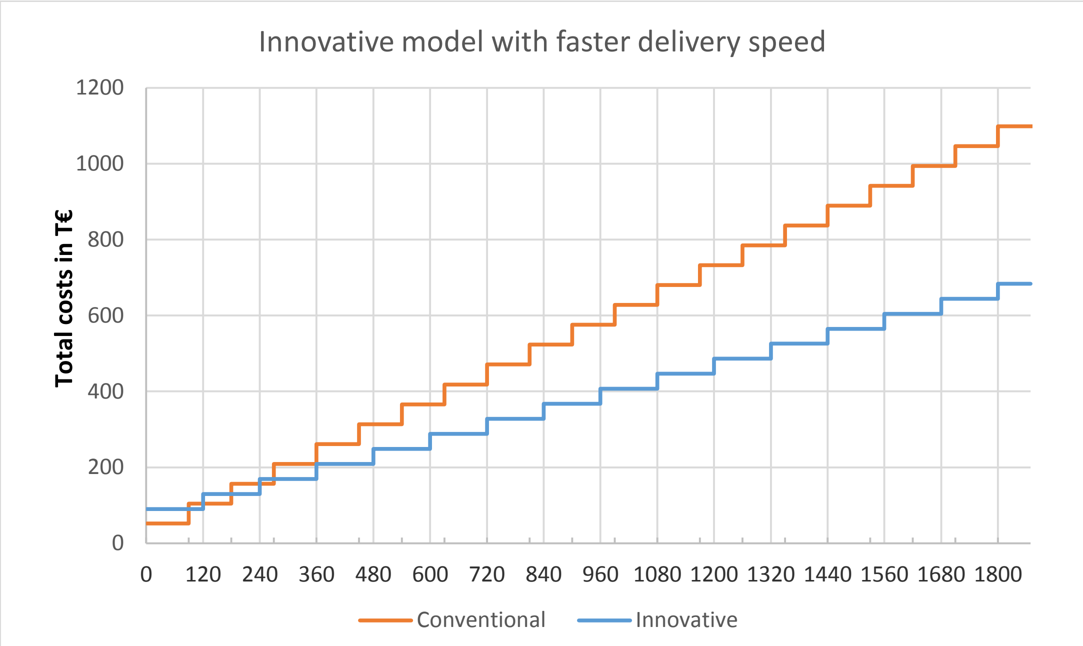


*Figure 11: Cost development with innovative model operating at a faster delivery speed*

Congestion charges

Raising congestion charges from vehicles entering the city center is a governance tool for public authorities to handle increasing traffic flows in urban areas. The form and extent of such charges varies largely between different cities. As previously mentioned, the congestions charges in Gothenburg vary from €0 to a maximum of €2.4 per entry/exit between different times of the day. In Milan the daily congestion charge is €5 and in London it is even as high as €16.5 per day, independently of the number of entries/exits into the city center (Comune di Milano, 2015; Transport for London, 2015; Transportstyrelsen, 2015b). Congestion charges make up a considerable amount of the variable costs for the operation of the vans in the conventional model. In contrast, the more environmentally friendly vehicles employed in the innovative model are exempt from this cost item. This section evaluates how different levels of congestion charges influence the results of the cost calculation. Four different levels of congestion charges are investigated that represent 0% (=€0), 200% (=€6.8) and 300% (=€10.2) of the current congestion charges (=€3.4 ≙ 100%).

In the base scenario, two vans that are subject to congestion charges are employed in the conventional solution. In the case that no congestion charges are raised, the conventional model will become €1,768 cheaper than it is now. In contrast if the charge is doubled or tripled, the costs increase by €1,768 or €3,536.

This cost increase multiplies if the same congestion charge increases are applied to the scaled scenarios. For example, in the 100%-scaled scenario 16 vans are operated, and congestion charges three times higher than now would lead to a total cost increase of €28,288. Figure 12 illustrates how the costs for the conventional model develop at different congestion charges. Today's congestion charges (=100%) are represented by the red graph, whereas the blue, gray and yellow lines show the increase or decrease in congestion charges.

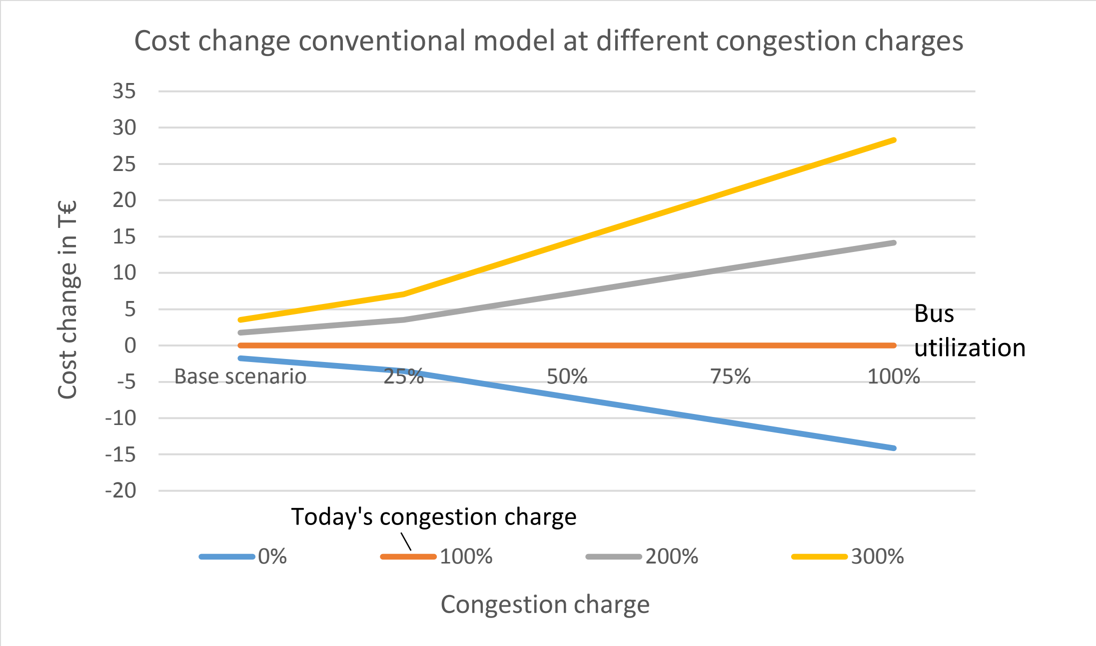


*Figure 12: Cost change conventional model at different congestion charges*

Parking fees

In the current calculations, no parking fees for the bus as a mobile depot are assumed in accordance with a statement from the Gothenburg municipality. This exemption might however not be eligible in other cities. Especially in urban areas where congestions is a major problem or where space is scarce due to specific geographical constraints, high parking fees are often the reality. In Brussels, charges for on street parking between €1.5 and €3.5 apply, depending on the duration and location of parking. In central Berlin the rate is €3, in Paris €3.6 and in London €6.8 is charged per hour of on street parking (Car-parking.eu, 2015; City of London, 2015). Therefore, in order to successfully operate a mobile depot, one problem is to ensure that the locations that have been identified as ideal parking spots for the mobile depot are available once the freight bus arrives. Special agreements might be needed to ensure this and possibly specific locations have to be rented out exclusively for the freight bus.

In this section it is investigated how different charges for parking influence the financial viability of the innovative model. Therefore daily parking fees of €10, €20 and €40 are assumed when altering the calculations.

| Annual parking cost for innovative model at different fees | | | | |
|---|---|---|---|---|
| **Daily parking fee** | 0 | 10 | 20 | 40 |
| **Parking Costs** | 0 | 2,600 | 5,200 | 10,400 |

*Table 12: Parking Cost Innovative model at different fees in €*

Table 12 shows that a daily parking fee of €40 would increase the total annual costs of the innovative model by €10,400. In the base scenario this would be equal to an 8% cost increase for the innovative model whereas it would only imply 1.5% higher costs when taking the 100% scaled scenario as a reference. The reason is that the parking fees only affect the bus and not the bikes, and the relative impact of the costs for the bus, as a part of the total costs, for the innovative model declines the larger the scope becomes. This is because only one bus is operated no matter if 1 or 1869 parcels are delivered. In contrast, the number of bikes that have to be employed increases if the daily demand of parcels increases. Therefore the parking costs have less significance in relation to the total costs the bigger the scope of operations becomes. However, the higher costs imposed by the parking fees can lead to a shift of the break-even point. For parking costs of €10, €20 and €40 a day, the daily demand has to be higher than 480 parcels, before the innovative solution becomes financially superior. Compared to that, the break-even point of demand in the current set up without any parking fees is 361 parcels.

Summary

In Figure 13, the base scenario and the 100% scaled scenario are illustrated together with a demonstration of how the total cost difference between the conventional and the innovative model changes if different cost variables and assumptions are altered. The columns in darker colors show the changes for the base scenario, the lighter columns for the scaled scenario at 100% utilization rate of the bus. For values above the x-axis the cost difference changes in favor of the conventional model and for values below the x-axis in favor of the innovative model.

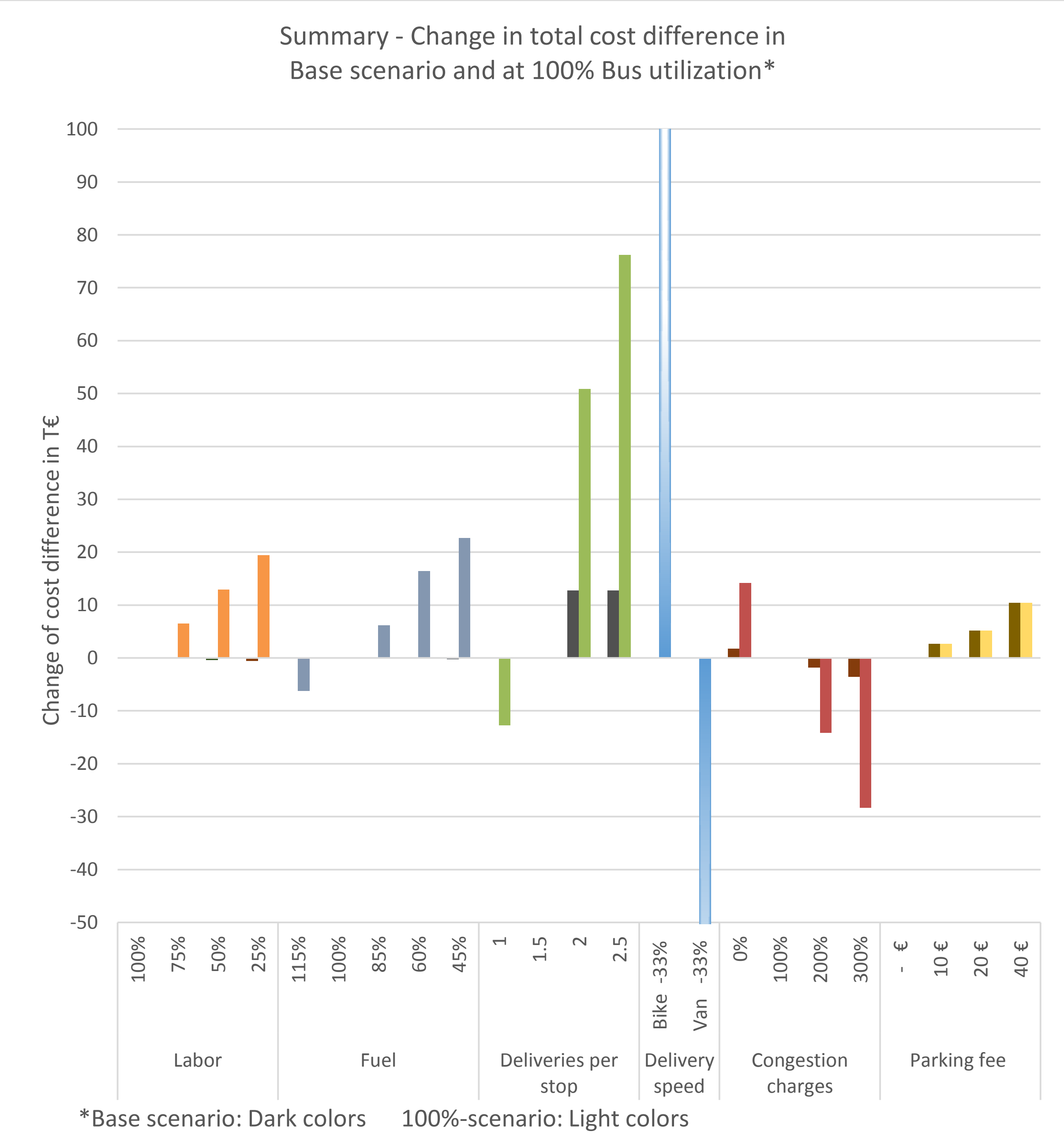


*Figure 13: Summary - Change in cost difference in Base scenario and at 100% Bus utilization*

It can be seen that a change in labor or fuel costs only has a minor impact in the base scenario. The reason is that only a smaller number of vehicles are employed in order to fulfill the demand of 160 parcels a day and the original cost difference between the innovative and conventional model for these variables is small. However, the cost effects are multiplied in the scaled scenarios where more vehicles and employees have to be put to operation. Consequently, a reduction of these cost components is more beneficial for the conventional model compared to the base scenario. The reason is that the van drivers have a higher salary than the bike drivers and the fuel costs for the van become greater than those of the bus. Therefore the savings that can be generated from a reduction of those cost components is also bigger.

A change in the number of parcel deliveries per stop influences how many vehicles that have to be employed and has a significant impact on where the break-even point lies. A higher delivery rate leads to fewer vehicles that have to be employed and the break-even point of the innovative model is only reached at a higher demand. A lower delivery rate has the opposite effect. Similar, a lower delivery speed implies that more vehicles need to be operated and higher costs occur in the operational setup with the slower vehicles. Especially in the scaled scenario, this leads to huge changes in the total cost difference between the two models. In Figure 13 the extent of those changes is only indicated by the columns with blue color gradient, as including the real size would disrupt the clarity of the chart.

For the cost variables that influence only one of the two models, a high rate of congestion charges that affect the vans can considerably harm the financial viability and the business model of the conventional model. Especially in the scaled scenarios, higher congestion charges indicate increased costs for the conventional model and can lead to a break-even point of the innovative model at a lower demand. In contrast, parking fees for the bus have major negative impact on the costs for the innovative solution in the base scenario. The bigger the scope of operations however becomes, up to a 100% utilization rate of the bus, the less significant these extra costs are. The reason is that this cost item remains constant, and thus its share of the total costs decreases the bigger the operational scale becomes.

## 4.2 Environmental implications of the BRD project

In order to provide a complete comparison between the conventional and the innovative model for urban CEP distribution, a calculation of the two models' $CO_2$ emissions has been conducted. This has been done in order to provide more precise information regarding the environmental gains from switching or maintaining the distribution model. Realistically, there are many other GHG emissions apart from $CO_2$ stemming from the operations of either diesel vans or CNG busses. However, as the purpose of this thesis is not to make a full analysis of the two models' environmental effects but rather to investigate additional, non-monetary implications, the $CO_2$ emission calculation is assumed to provide an indication of the environmental impact caused by the different models.

In the innovative model investigated, the CNG bus employed is powered by a fossil fuel and hence emits GHGs. One main idea of the new operational setup for parcel delivery is however to reduce air pollutants such as $CO_2$, NOx and PM. To express the environmental effects in numbers, the $CO_2$-emissions of the diesel vans and the CNG bus have been estimated according to the "Guidelines for Measuring and Managing $CO_2$ Emission from Freight Transport Operations" (Cefic and ECTA, 2011). In these guidelines the Well-to-Wheel fuel emission conversion factor for diesel fuel is stated to be 2.9 kg $CO_2$ per liter diesel consumed and for CNG 3.3 kg $CO_2$ per kg CNG burned. With the specific fuel consumption of the vehicles and the yearly distance they cover, the annual $CO_2$ emissions in the base scenario for the conventional model is 11,160 kg $CO_2$ (2*2.9 kg $CO_2$/liter*10liter/100 km*19,240 km) and for the innovative model is 11,171 kg $CO_2$ (3.3 kg $CO_2$/kg*42 kg/100 km*8,060 km). The electric cargo bikes employed in the innovative model are considered to be emission free, as electric energy in Sweden is 100% $CO_2$ neutral (Johansson and Åhman, 2000). It can be seen that the $CO_2$ emissions of the two models are almost identical and therefore under the current demand structure in the base scenario no significant $CO_2$ reductions would be obtained. However, the emissions from CNG are lower than those of conventional fuels in terms of other air pollutants such as NOx and PM. Another advantage of using CNG fuel for vehicles in a city context is that such vehicles produce less noise (McKinnon, Browne and Whiteing, 2012). Moreover, in the scaled scenarios with a larger demand for parcels, more diesel-fuelled vans have to be employed and consequently more $CO_2$ would be emitted. On the contrary, the emissions from the CNG-fuelled bus remain constant up to a daily parcel demand of 1869, which represents the maximum capacity of one freight bus. Therefore, under the current assumptions the new concept would need a certain scale to achieve major environmental benefits. Figure 14 shows how the $CO_2$ emissions develop for the two models, if the operational scale is increased.

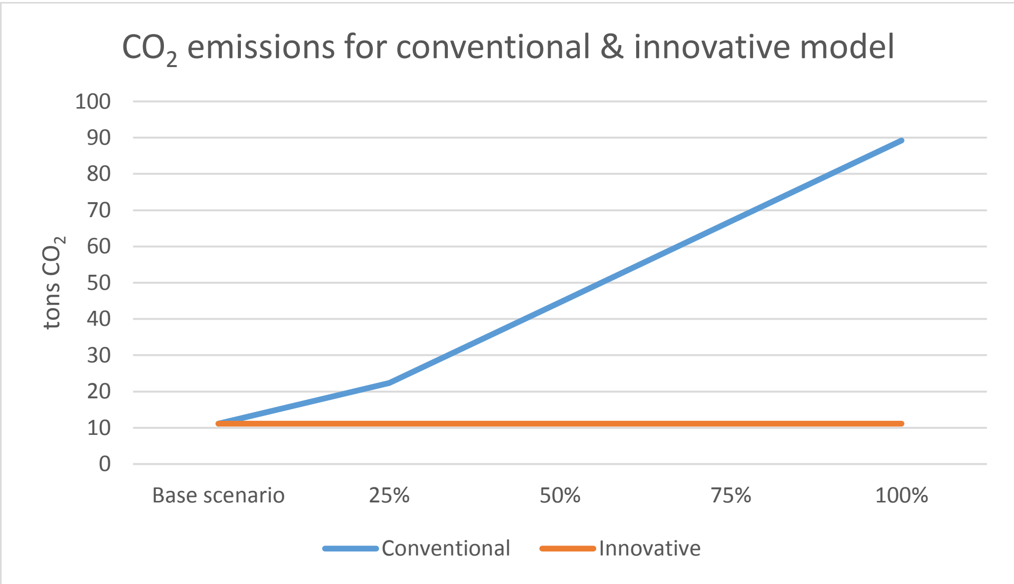


*Figure 14: $CO_2$ emissions for conventional & innovative model*

Alternatively, in order to allow for immediate environmental benefits, using a completely emission free vehicle as mobile depot, such as an electrically fuelled freight bus, could be considered. The major drawback of this proposal is, however, that it would indicate considerably higher investment costs and therefore negatively harms the financial viability of the innovative model (MacKechnie, 2015). The same idea could also be applied to the conventional model and electric vans could be used instead of fossil-fuelled ones for parcel delivery in urban areas. Nevertheless, a consolidation solution for urban freight distribution has the potential of solving other severe problems that occur in cities with large amounts of traffic, such as congestion, noise and visual intrusion.

## 4.3 Social implications of the BRD project

In addition to the economic and environmental effects, a new model for parcel delivery in urban areas is also subject to social implications. Social implications of distribution activities can for example be space occupation or visual intrusion in the city.

Especially occupancy of public space and congestion are posing increasing problems in city centers. To quantify the extent of the social implications of the BRD, the total road space and time occupancy is calculated as described by Browne, Allen and Leonardi (2011). This number takes the space that is taken up by a vehicle and the time that it spends inside the city into consideration. The space that each mode of transport requires, can be calculated by multiplying its length and width. Table 13 provides an overview of the dimension of the vehicles used in the conventional and innovative model and their resulting space occupation.

| Dimensions per vehicle | | | |
|---|---|---|---|
| | **Length in m** | **Width in m** | **Space occupancy in m²** |
| **Van** | 4.97 | 1.99 | 9.87 |
| **Bus** | 11.98 | 2.50 | 29.95 |
| **Bike** | 1.90 | 0.70 | 1.33 |
| **Trailer** | 2.00 | 1.00 | 2.00 |

*Table 13: Dimensions per vehicle*

The time that the vehicles spend in the inner city is determined by the number of parcels they have to deliver. The delivery time per parcel is 3 minutes and thus the total time that the vehicles spend in the city center increases with growing demand. Each van and bike with trailer can deliver a maximum of 120 parcels within the 6 hours delivery time window. For a demand exceeding this number an additional vehicle has to be employed. This means that for a 120 parcels delivery, one van or one bike with trailer has to be employed for 6 hours (3 min per parcel * 120 parcels). Accordingly, the total road space and time occupancy, which is expressed in the unit of $m^2$-hours, is in this case 59 $m^2$-hours (9.87$m^2$*6h) and 20 $m^2$-hours (3.33$m^2$*6h) respectively. If the demand increases above the threshold of 120 parcels to e.g. 122 parcels, the number of vehicles employed doubles. This means the space occupied by the vehicles also doubles, although the total time spent in the city center reduces since each vehicle only has to deliver 61 parcels now, which takes approximately 3 hours (3 min per parcel * 61 parcels). As a consequence the total road space and time occupancy increase linearly for the van and the bike with trailers. In contrast, total road space and time occupancy for the bus follows a zigzag-curve, as illustrated in Figure 15. This is because of the fact that only one bus has to be operated regardless if one or 1869 parcels are delivered and the space the bus takes up remains constant at 29.95$m^2$. However, the time that the freight bus spends in the city center depends on the delivery time of the bikes. The bus remains in the city until all parcels have been delivered. Thus, if only one bike delivers 120 parcels the bus stays six hours, whereas this becomes no more than three hours in the case where two bikes deliver 61 parcels each, in accordance to the example described above. The total road space and time occupancy of the bus therefore varies between 94 and 188 $m^2$-hours.

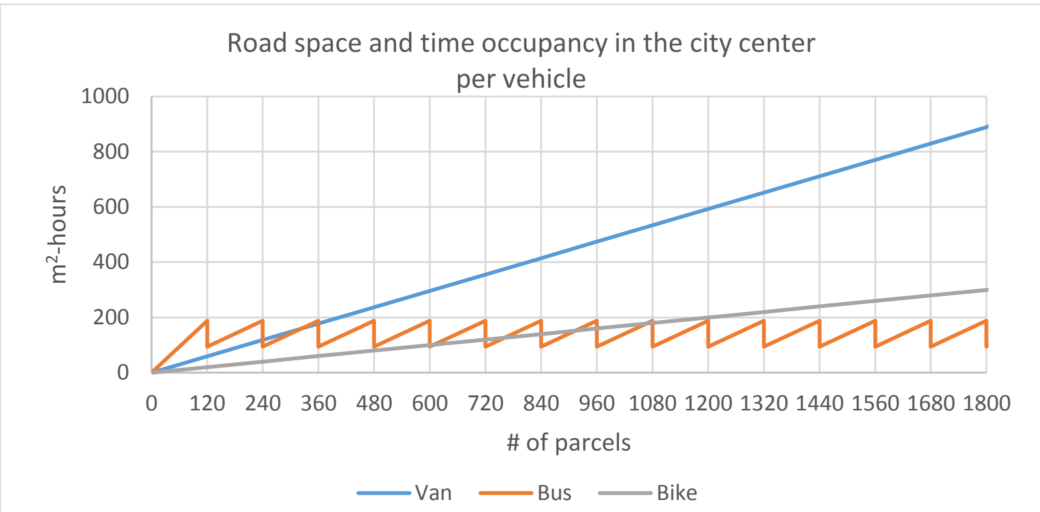


*Figure 15: Road space and time occupancy in the city center per vehicle*

It can be seen that the curve of the road space and time occupancy of the van is steeper than that for the bike with trailer. This is because one van takes up approximately three times more space than a bike with trailer and thus each additional vehicle employed leads to a steeper increase of the total $m^2$-hours. However, in the base scenario where 160 parcels are delivered by two vans or one bus together with two bikes, the total road space and time occupancy of the innovative model is 67 $m^2$-hours higher than for the conventional one. With increasing scale the disadvantage of the bigger bus is offset and for a demand exceeding 480 parcels a day, the total road space and time occupancy in the inner city is lower for the innovative model.

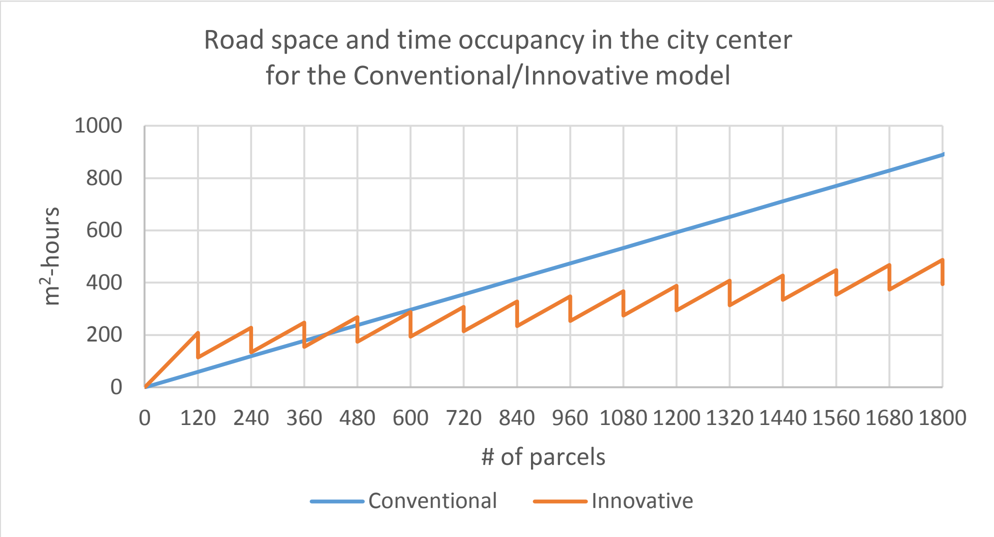


*Figure 16: Road space and time occupancy in the city center for the Conventional/Innovative model*

In addition to the space occupied, there are other social implications resulting from parcel delivery in inner cities. However, these are often difficult to quantify. For example, visual intrusion is an element that is highly subjective and differs between different people. Therefore, the impact that the two different delivery models would have on this variable can only be assumed. It is likely that bikes are perceived as less intrusive than vans, especially as the former are linked to negative externalities to a lower extent. However, the big freight bus that is parked for longer periods of time in central locations in the city might be perceived negatively. The same is true for pedestrian safety, which is likely to be associated as higher for the bikes compared to vans, as their limited size and speed reduces the likelihood of fatal accidents. However, compared to the other two vehicles, the freight bus is larger in size and an accident can potentially lead to more severe injuries. Nevertheless the vans are higher in number and also circulate to a larger extent than the bus, which is parked most of time. It is therefore difficult to make a judgement which transport model is preferable in terms of its social implications. The specific implications also depend on the characteristics of each city and on the scale of demand.

## 4.4 Qualitative Analysis

In this section, the qualitative data derived from in-depth interviews and from the online survey regarding urban freight and mobile depot solutions in general and the BRD in particular are presented.

Based on findings in the literature review as well as on the informal interviews with industry experts, non-monetary implications have been further investigated. These aspects are of importance when determining the success of a new project in urban freight distribution. The aim of the qualitative analysis is therefore to widen the understanding of the complexity of this field and complementing the analysis with non-financial success factors and obstacles.

The findings in the qualitative data first of all discuss the topics of business cases and reluctance to change. Next, governance tools and financing of urban freight distribution projects are covered by taking both potentials and barriers into account. Thereafter mobile depots and their potentials and barriers in particular are reviewed. The chosen structure is based on some of the most important, disputable and complex areas of urban freight distribution. As this thesis investigates cost elements and financial viability of innovation projects in urban freight distribution, the questions of the survey and in-depth interviews aimed to study the complexity and discussion regarding the same. In the conducted semi-structured interviews the listed topics were frequently mentioned and are thus central to consider in terms of alternative and innovative solutions for urban freight distribution. An overview of the interviews with Behrends, Browne, Heitz and Woxenius is found in Table 1 and Appendix C presents the interview catalogue and the results of the online survey.

### 4.4.1 Business cases

From the collected data through qualitative interviews, the importance of developing realistic business cases that show the benefits of innovative urban distribution projects in order to get both private and public financial as well as non-monetary support was emphasized. In general, knowledge of regulations, incentives, benefits and taxes issued by local municipalities makes it possible to create realistic business cases for innovative solutions for urban freight distribution. In order to provide a financially viable business model it is necessary to show the compensation mechanisms of reimbursement by the benefits that are generated in the system, which most likely appears on the receiver side of operations (Browne, 2015). Therefore, not only must a valid business model demonstrate the costs and benefits of an idea, as according to Osterwalder’s (2004) business model canvas, it must also show the mechanisms where the actors that do not receive any benefits are compensated in order for changes to be in the interest of all actors and stakeholders.

One emphasized difficulty was that cost calculations in general and model creation in particular are difficult to develop due to the dependence on local conditions of these factors. A problem with creating realistic business cases is to attain real cost data from the transport operators, and researchers claim it to be difficult to acquire real cost figures for business cases and cost calculations (Behrends, 2015; Heitz, 2015). If unable to conduct well-defined business cases including clear cost calculations, it is difficult to prove an innovative model viable and build trust in investors, often leading to a project never being initiated (Browne, 2015). Additionally, it is important to reflect upon the cost variables that differ the most between different options, or the variables that have the highest proportional impact on the given model. For instance, it has been explained that labor costs are significantly higher for transport operators in Sweden compared to many other countries, which means that this variable makes a significant difference in the costs of an operation (Behrends, 2015).

### 4.4.2 Reluctance to change

In terms of innovative projects in urban freight distribution in general and of consolidated shipments in particular, researchers in the logistics and urban freight field have several concerns, one of which is often mentioned as being reluctance to changes. First of all, Browne (2015) raises the issue of reluctance that makes it difficult to implement changes into peoples’ lives and business activities. Most people are resistant to changes and typically believe that the way things are operated is right, and even if they are dissatisfied with it there is still reluctance to behavioral change. In addition, much can be derived from the discussions regarding consolidated shipments in order to improve city logistics and reduce congestion. There is often reluctance from operators in terms of using UCCs for merged shipments, unless the operator's own UCC is employed. This type of reluctance is related to the fact that passing through an UCC requires additional handling and might reduce individual parcel efficiency and customer service levels. Also, reluctance amongst workers and managers to changing vehicles or operations impacts the feasibility of changing to certain new distribution alternatives.

According to Browne (2015) switching from one way of operating to another is not easily done, even though a new project can be shown to be financially neutral. On the one hand, it can be expected that companies switch from a conventional model to an innovative urban freight project if it shows additional, non-monetary, benefits such as improved air quality and noise reduction. However, on the other hand the resistance and unwillingness to change complicate such switches and must be regarded when evaluating the feasibility of a new project.

### 4.4.3 Governance tools

The impact that governance tools have on decision-making and financial outcome for transport operators and urban distribution in general is of outmost importance. The different ways governments and municipalities are able to interfere with how urban traffic and distribution is operated in order to support or regulate traffic in urban areas are many, spanning from subsidies and regulations to operational, on-going support to initial set-up support. First of all, efforts can be monetary or non-monetary, and ways to interfere with market forces to perfect the marketplace are taxation tools, subsidies and incentives such as providing bus lanes or specific parking space or urban micro warehouses, regulations and restrictions such as zero-emission zones, weight limitations, time windows and congestion charges. According to Browne (2015) there is a difference between operational subsidies and initial public support. To get an innovation project in urban distribution started, public authorities can support the initiation of the project by making publically owned space, such as parking space as well as access to land, available. In addition, the option of financing an attractive project in order to introduce it exists.

In terms of public funding, subsidies are the more affordable and lowest risk-option for municipalities to undertake compared to financial investments (Heitz, 2015). Governments do not always see instant results of their investments, yet they continue to invest in new urban freight transportation solutions because they are confident that they are investing in future benefits (Heitz, 2015). According to Heitz (2015) investments in urban freight distribution experiments are often positive for municipalities. However, these trials normally only consist a small percentage of the delivery flows in a city, meaning that it might not have large impact on total distribution patterns or urban congestion.

*Potentials of governance tools in innovative urban distribution projects*

There are many reasons why governments and municipalities would interfere with urban freight operations. First of all, even though freight receives less attention than passenger transport, freight still impacts urban areas where a larger amount of people, in a denser environment, are affected by the way freight is managed. Transports in general and goods transport in particular generate external costs such as poor air quality, congestion, noise etc. By engaging in urban freight distribution management tools, governments address these issues and can even avoid certain costs and fines related to poor management, environmental impact and air quality.

In countries where financial government support for urban freight distribution projects is difficult to justify, such as in the United States, public intervention still has potential to solve problems with congestion in urban areas. One strategy is to provide incentives for operators to optimize their delivery operations. The incentives thus stem from the potential savings that such an intervention provides, and the total benefits for the city include lower levels of congestion. One example is to allow operators to perform off-hours deliveries. This is not a monetary subsidy but a way to re-distribute or re-allocate operations in order to attain more efficient distribution activities. Many researchers strongly believe in the potential of regulations and restrictions mechanisms as tools to regulate the marketplace for urban freight operations in order to create a more optimal landscape for urban freight distribution. Such implementations also have the potential to make it possible to create real and realistic distribution solutions (Behrends, 2015).

In many cities today, delivery transportation with trucks is regulated to only operate before a certain hour of the day (e.g. 10am), meaning that once shopping streets and dense areas become crowded with people, no trucks or distribution activities are allowed. However, in the example from the city of Gothenburg, Sweden, electric vehicles from the government supported UCC are allowed, which creates an incentive to use the UCC for shippers that want the flexibility of offering all day deliveries (Behrends, 2015). In addition, Behrends (2015) states that municipalities' influence and power of allowing access to bus lanes for certain trucks that are, e.g., proven to be less polluting is something that creates incentives for transport operators to prefer the use of certain vehicles or mobile depots before others in urban areas.

Behrends (2015) suggests that the issue of organizing urban freight distribution should be higher on many public authorities' agendas in order to achieve the goal of the EU White Paper (Com 144 Final, 2011) of practically zero emissions from urban logistics operations in 2030. Addressing the same goal, the transport sector needs to be more efficient while at the same time reduce the number of vehicles involved in urban distribution operations. One suggestion is to consolidate all urban shipments to large transport operators such as DHL, UPS or DB Schenker that have the most efficient operations compared to smaller operators. In addition, it is possible for governments to subsidize efficient goods transportations in the same way that monetary and non-monetary support from public authorities subsidize efficient and necessary passenger transportation. Where public passenger transportation is subsidized as it serves a public need, the same reasoning could be made for the public need of shelf-available goods in stores (Behrends, 2015).

In addition, derived from both interviews and survey responses, some researchers claim that in order for a project to be successful public funding and public investments are needed as a "quality assurance" for other investors (Heitz, 2015). This means that the government's approval of a project is demonstrated by the investment, which in turn is viewed as a guarantee for others to do the same. This is something that can significantly improve the funding of a project.

Moreover, according to Browne (2015) an operational subsidy directed to solve a clear allocation problem such as achieving lower levels of congestion or better air quality might be a valid use of resources due to the clearly stated objective. For instance, in a city like London where air quality has become poor due to intense traffic work and pollution, the city will fail to meet the European targets set in the EU White Paper (Com 144 Final, 2011). This indicates that the city of London could be fined unless its air quality improves (Browne, 2015). If it is possible to demonstrate that a new project in urban freight will improve air quality there may be an argument to use public finance to support the cost of implementing the service. Therefore, according to Browne (2015) it is justified for authorities to fund innovative urban freight projects that can improve the city's air quality, as the fine could be greater than the costs of investing in the project itself. In general, when a clear objective and allocation goal for an urban freight distribution project cannot be stated, financial means are better spent on aims such as a study that demonstrates the feasibility of the case. In that case, investments can be made to collect enough data that allow for the argument, and when there is no business case or clear re-allocation objective, an investment in showing the value is more valuable than operational subsidies (Browne, 2015). This relates to the issue of enabling realistic and thorough business cases.

According to Heitz (2015), it is often necessary that projects in innovative solutions for urban freight transportation receive help from municipalities since the competitive climate makes it difficult to set up alternative freight solutions, which is an important reason for governmental interference or investment. In addition, many municipalities and public authorities need to act as role models and leaders in every field, including urban freight and sustainability, and therefore need to enable innovation in competitive environments and investment in future and long-term development.

*Barriers of governance tools in innovative urban distribution projects*
As another side to the matter, restrictive regulations are sensitive political issues due to the fact that such efforts often aim to make it more difficult for transport operators to access their customers in the urban area and municipalities in general do not want to complicate business operations in the city. Accordingly, municipalities often spend years on building functioning relationships with businesses and transport operators and a restrictive regulation might severely harm the relationship (Browne, 2015). City authorities have the power to create zero emission zones where all diesel vehicles are banned and only electric vehicles and bikes are allowed (Behrends, 2015). However, this type of political measure creates a difficult operating environment for transport providers. Today such drastic measures are most of the time not employed. Nevertheless, time windows deliveries are one form of restricting vehicle access to urban areas.

Another observed barrier is negative reactions from project initiators and companies in regards to government interference and especially in terms of financing. One example is that if it is believed that a company relies on public subsidies to be viable, their customers would as a consequence be less trusting of the company. Researchers conclude that the customers have the impression that prices will increase as soon as the public subsidy phase expires (Browne, 2015).

### 4.4.4 Financial investments in innovative urban distribution projects

It is interesting to investigate the sensitivity of a cost increase versus a cost decrease for an innovative project in urban freight distribution, such as the BRD, compared to a conventional model. This investigation researched the perceived potential of a project that generated higher costs by 5%, lower costs by 5% or that was shown to be financially neutral.

*Potential for financial investments in innovative urban distribution projects*
In terms of the financial sensitivity for new projects in urban freight distribution, Woxenius (2015) and Browne (2015) claim in accordance that in general, a financially neutral project most likely will show non-monetary benefits, meaning that it makes theoretical sense to invest in. This means that certain environmental gains or other external benefits justify switching one model for another if such improvements can be shown and costs are neutral.

There are more reasons than financial profit for investments in innovative projects for urban freight, many being non-monetary and related to reputation and visibility. In terms of dealing with extra costs, Browne (2015) states that investing in innovative urban freight projects is, in part, an image question, both for companies and municipalities and investment decisions are not solely based on costs but also rooted in an organization’s CSR and PR policies. Because of this, many experiments end up as showcases that create external value for the initiator (Woxenius, 2015; Behrends, 2015; Heitz, 2015). This type of activity thus becomes part of the organization's CSR activities and by investing in environmentally friendly initiatives as well as standing out in a crowd with innovative solutions, organizations can make their brand more popular.

*Barriers for financial investments in innovative urban distribution projects*

Seen from the qualitative data, an increase in costs by, for example, 5% is of importance. According to Browne (2015) a cost increase of 5% is significant in an industry that is characterized by low margins, such as the transport sector. Therefore, a significant cost increase of 5% is difficult to justify unless it can be proven that this more costly option still generates some form of benefits in other ways. Furthermore, if benefits can be shown, the next step is to calculate the savings and understand where the savings are allocated. This is something that altogether often becomes an obstacle in many innovative urban freight projects.

According to researchers and urban freight and logistics professionals a financially viable solution should not experience resistance from operators or investors, since companies need to make economic sense and invest in viable options. However, two areas were still pointed out as problematic. First of all, the profit margin or cost savings for companies to justify switching from one method to another should be around 10-15% in order to cover transaction costs etc. This therefore does not make a financially neutral solution attractive by default, but it rather needs to show significant profit margins (Woxenius, 2015). Secondly, Browne (2015) emphasizes the importance of reluctance and the fact that most people behind the decision-making are not prone to changes. These realities can put an end to a project, even though it has shown to be financially viable compared to the current operations.

For privately owned companies, the environmental aspects are not the priority reasons for investing in innovative urban distribution projects. On the contrary, according to both Heitz (2015) and Woxenius (2015), finding cost efficient solutions is necessary and economic incentives are priority and companies fear that they will lose market shares and customers if they are unable to serve certain inner-city areas.

### 4.4.5 Mobile depots

In the conducted online-survey, eight questions were asked (see Appendix C). In the first half of the questions, alternative solutions for urban freight distribution were investigated, with mobile depots being one option. The second half dealt more in detail with different mobile depot alternatives and the perception of their viability.

*Potential of mobile depots*

For mobile depots in general the results of the qualitative data collection showed different prospective areas for mobile depots and it was also stated that an adequate amount of feasibility studies have been conducted to make it an interesting alternative to conventional delivery models. According to Browne (2015) and Heitz (2015) logistics facilities are forced out of central city areas due to gradually higher realty and land rents, also observed in the literature review. This makes logistics space increasingly scarce in cities, and a free market tends to increase the land values and to push logistics space even further out. Therefore, the concept of a mobile depot provides the opportunity of one way to overcome the problem of scarce logistics capacity and space in the inner city. Woxenius (2015) states that there is high potential for employing mobile depots to help freight operations in urban areas and Arvidsson, Woxenius and Lammgård (2013) found that when referring to parcel deliveries the vehicles usually time out rather than cube- or weigh out. Therefore, mobile depots allow for delivery time to be consolidated and employ one driver with a rather large parcel quantity and then dividing it into several small delivery flows and thus avoiding the time out capacity issue (Woxenius, 2015). Furthermore, Browne (2015) states that people in leading or management positions that believe in a project or in its cause have power to drive such projects through and assure their success.

Another potential of mobile depots is that less handling on the receiver side, by e.g. receiving one combined delivery instead of receiving several individual deliveries, creates value and opens up for potential consolidation (Browne, 2015). Extra benefits from the receiver's point of view is the fact that one larger consolidated delivery allows for higher levels of precision in knowing when the delivery arrives, which allows the receivers to more accurately plan staffing and other operations.

In terms of the environmental potential, urban freight professionals believe that alternative models for urban freight distribution have potential to reduce environmental costs, and consolidation models seem to be efficient solutions. A mobile depot for freight solutions would make a difference in terms of solving urban congestion problems due to the fact that freight is consolidated, making many vehicles redundant. Mobile depots with small electric vehicles such as cargo bikes to make deliveries in urban areas are interesting in terms of small parcel deliveries. However, more traditional deliveries pose too many requirements in terms of volume, weight and JIT, neither of which are possible to provide with cargo bicycles (Heitz, 2015).

According to Behrends (2015) cities and municipalities are prone to show electric vehicles working in their area due to the attractiveness and positive associations made to these vehicles because of their fuel technology and environmental concern. However, Behrends (2015) claims that optimal urban freight distribution does not have to do with the technological development of electric vehicles. The bigger issue in cities is to solve the problem of excessive traffic, noise and congestion. Replacing entire vehicle fleets with electric vehicles does not solve these issues since such a solution would not reduce traffic and congestion. In addition, electric vehicles are more expensive compared to conventionally fuelled vehicles in terms of purchasing price, even though the operating costs are somewhat lower (Behrends, 2015). Instead, consolidating shipments and reducing the number of vehicles operating in the urban area can free up roads and public space for more and better bus lanes, bicycle paths, more green areas and more attractive space for citizens. This means that the concept of logistics consolidation should be the main focus and the technology should be secondary (Behrends, 2015). Certainly, last mile deliveries performed with electric vehicles are beneficial for the environment compared to conventionally fuelled vehicles, nevertheless the main benefits comes from the organization of distribution activities.

Urban freight professionals believe that the use of preexisting, and thus less capital intense or investment requiring, vehicles such as trucks or trailers is more likely to be accepted by stakeholders in terms of the type of vehicle that makes the most economic sense to use for consolidated shipments in the form of a mobile depot. One thing that needs to be taken into consideration when planning and investigating the feasibility of operating smaller vehicles together with a large mobile depot is to achieve high resource utilization and economies of scale of the operations, which is argued to be the key to cost efficiency (Behrends, 2015). The difference in high resource utilization and low resource utilization creates large differences in costs per unit produced or per delivery.

Finally, answers from the online-survey showed that trucks or trailers were seen as having the most economic potential. In the case of environmental potential, however, the truck or trailer alternative received only 5% of the professionals' votes, whereas the solution of operating a barge as a mobile depot was seen as having the highest potential of reducing environmental costs.

*Barriers of mobile depots*
The limited budgets municipalities and city authorities have to promote new distribution projects are often hindering many projects in urban freight distribution development. Another barrier that hampers innovation projects in urban freight distribution is the need of people with the right skills and sufficient power within the city side to take on a project idea, make it work and drive it forward. Also, extra handling costs are likely to reduce the attractiveness of consolidating shipments through UCCs or mobile depots and represent a clear barrier shown in both the literature review and through in-depth interviews (Heitz, 2015). This is related to the issue of complexity, and the fact that extra handling usually increases the level of complexity, capital costs, new equipment and the requirements for streamlined operations (Behrends, 2015; Heitz, 2015; Browne, 2015; Woxenius, 2015). According to Behrends (2015) the efficiency gains of consolidated distribution are often not large enough to motivate operators to consolidate shipments.

Furthermore, even though Behrends (2015) states that capital costs and vehicle costs decrease if an innovative model is able to employ a vehicle that already exists (such as a truck or a van), mobile depots often require new vehicles that are rare, such as freight buses or electronic vans in order to make environmental sense. Such vehicles are usually associated with high purchasing costs, as they are usually not produced in mass. According to Behrends (2015) this is one main reason why novel ideas and vehicles are difficult to implement. Barriers can thus be related to initial costs (such as investment costs), and the costs of rare and technologically advanced vehicles such as freight buses are usually high.

According to Browne (2015) the difficulties in operating UCCs and other consolidating solutions such as mobile depots mostly lie in the cost complexities. This is related to the difficulties in cost and benefit allocation. Browne (2015) argues that the distribution of costs and benefits that stem from a new project in urban freight distribution is not always clear and often asymmetric, meaning that the receiver of the benefits is not necessarily the same that covers the additional costs related to the project.

In terms of technical barriers it must be highlighted that all projects as well as cities differ, meaning that different settings imply different barriers. However, technical problems and high operating costs have shown to be obstacles of certain innovative urban freight distribution projects such as the Vert Chez Vous in Paris and the TNT Straightsol project in Brussels (Heitz, 2015; Verlinde et al, 2014). Technical problems for instance relate to lower carrying capacity of cargo cycles, which makes it difficult to cover the existing demand and might hamper the delivery efficiency of the distribution model. In addition, Heitz (2015) mentions the river barge operating as a mobile depot on the Seine River in Paris having been too old and not ideally suitable for delivery operations, which made the distribution too timely compared to conventional van deliveries. This being said, technology as well as managerial issues set up barriers for less conventional alternatives for mobile depots. Another obstacle for the BRD or other mobile depot solutions in urban areas is to access parking places, and successful route scheduling related to the zones of parking places from which different areas are supplied (Woxenius, 2015). The impact of the operating scale is also viewed as a potential barrier to the feasibility of mobile depot solutions. In parcel services there are a few dominant players that need to be onboard and supporting the mobile depot solution. Alternatively a business case study needs to be developed that can show larger players that the innovative solution will reduce costs for them if they pay for this service. One option is that one or several of the larger players in the market run the service in order to create incentives (Behrends, 2015).

## 4.5 Discussion of empirical findings

In the results derived from the cost calculation it can be seen that under the current assumptions for demand and for the operational setup the innovative solution is not financially viable. However, when increasing the scale of the operations to a higher number of parcels delivered per day, the innovative solution theoretically becomes less expensive than the conventional model. The reason for this cost development is that the innovative model has high initial fixed costs caused by the freight bus as a mobile depot. These costs are however offset by the lower marginal costs of the electric cargo bikes compared to the conventional diesel-fueled vans the bigger the scale of the operation becomes, i.e. the more bikes and vans have to be employed. Under the assumptions made, the innovative model would be superior in monetary terms from a daily demand of 361 parcels and above. This demand is more than double the demand described in the base scenario. It can be argued that this therefore is not a realistic scenario for a smaller city like Gothenburg. However, it has to be mentioned that the assumptions made for the base scenario only reflect the demand and operations of one CEP-operator. The aggregated amount of parcels delivered in the city by all operators is much higher. Nevertheless, a consolidation of different operators' operations cannot be expected, meaning that the innovative solution of a freight bus as mobile depot is likely to remain a hypothetical model for the case of Gothenburg. In other, bigger cities with a higher demand for parcel delivery, the innovative model could potentially be financially viable. Nevertheless, as no one city is like the other, some of the assumptions have to be altered and adapted to the specific case.

The sensitivity analysis provides a glance how the change of different variables and assumptions affects the calculation result. The highest impact have those variables that differ significantly between the two models and/or change to a great extent if the scale of the operations is enlarged. The latter is specifically true for the labor and fuel costs. The labor costs for the bike drivers are slightly lower than those for the van drivers and therefore in the base scenario, where only two employees are employed in each model, the cost difference between both solutions does not change significantly even when the labor rate is changed by large. In the scaled scenarios, the relatively low cost difference per employee is amplified and the more drivers that have to be hired the more influence the actual labor costs have on the final calculation result. Similar, a change in fuel prices has a significant impact mainly in the scenarios where the demand is higher. The main reason is that the fuel costs for the bus remain stable independent of the operational scale and the electricity costs of the bikes are not significant. In contrast, the energy costs in the conventional model grow quite steep the more vans are operated and a change in the fuel price therefore has a major impact on the total cost difference between the two models. The same cost development is true for the congestion charges, which only applies to the diesel-fuelled vans. They correlate with the numbers of vehicles employed and therefore changing this variable has a bigger cost effect in the scaled scenarios. In contrary, the parking fees that potentially have to be paid for the freight bus remain constant for a daily parcel demand between 1 and 1869. As the total operating costs increase in the scaled scenarios, the portion of the parking fees decreases accordingly. It must however be mentioned that an introduction of parking fees would hamper the attractiveness of the mobile depot solution compared to other alternative solutions like an UCC since one of the main reasons for using a mobile depot is to avoid the high rental fees in central city locations. Therefore, this advantage is offset by the introduction of parking fees. The most significant cost effects can be monitored when the assumptions about the delivery rate and delivery speed are changed. The reason is that these assumptions have large influence on the number of vehicles that have to be operated and therefore a change in this variable can lead to substantial differences in total costs. It has been shown that for the investigated case a higher rate of deliveries per stop is more beneficial for the conventional model. When altering the delivery speed the distribution model with the faster vehicles is at advantage as these vehicles can deliver more parcels per day and therefor the total amount of vehicles needed is less. Thus, the electric cargo bikes are potentially better suited for making deliveries than the bigger vans especially in cities with geographical constraints for larger vehicles and where customers are located in proximity to each other. This correlates with findings from another study in Brussels where it was argued that a high stop density is vital to make a delivery model with cargo bikes attractive (Verlinde, et al., 2014). One constraint in the setup of the study in Brussels was, however, that the trailer that served as mobile depot was restrained to one parking location and therefore the customer density around this delivery point had a big impact on the operational efficiency that could be reached. In contrast, the freight bus investigated in this thesis is assumed to move to different places around the city. This way a main constraint and disadvantage of the cargo bike, i.e. its limited delivery range per delivery round, is eliminated and the customer area that can be served by the innovative model is enlarged.

The sensitivity analysis of this research mainly investigated the cost changes that occur if variables are either increased by a certain percentage above the current level or decreased by a certain percentage below the same. In reality, the different costs in different setups might not change to the same extent for the different vehicle types employed or might not even change in the same direction. For example, in another country, CNG prices might be 30% lower than in Sweden whilst the diesel fuel is only 10% cheaper or even more expensive. Also in some countries bike drivers might be remunerated at a much lower salary than van drivers and therefore a major cost component would greatly differ. In addition, other assumptions might not hold true in another setup. This said, it is important to see what the real cost structure looks like for the specific case and based on this to evaluate different scenarios and induce trends about the cost development.

A main aspect behind the idea of implementing a new solution for parcel distribution in city areas is to reduce the negative externalities and impacts that occur in the current solution. One major harmful externality is the $CO_2$-emissions caused by commonly used diesel-fuelled vehicles. In the setup of this study in the base scenario these externalities would be almost identical for the conventional and the innovative model. Only for a bigger scale where more diesel-fuelled vans have to be employed as opposed to one CNG bus the environmental benefits become more substantial. An alternative to make the innovative model more environmentally attractive could be the use of a complete emission free mobile depot as opposed to the CNG bus. This would create a completely emission free concept. One major drawback is the higher investment cost for such a vehicle and it can also be argued that by using electric vans for the parcel distribution, the same environmental gains can be achieved. Furthermore, by critically reviewing the innovative concept's total potential achievements it is important to realize that the CEP business makes up only a small portion of all urban freight and the impact it can make is therefore only minor.

Looking at the third element of sustainability according to the triple bottom line, a new parcel distribution model also has social implications. One major negative effect that is connected to freight distribution in cities is that the delivery vehicles take up public space. The total road space and time occupancy resulting from the activities of the bus and the bikes in the base scenario is almost the double of that of the two vans used in the conventional model. Yet again, a higher demand resulting in more delivery vehicles employed leads to the innovative model becoming less intrusive in terms of space occupancy. Other social effects such as visual intrusion and pedestrian safety are more difficult to quantify and their perception is to some extent subjective. Therefore no general judgment or assessment can be made regarding a superior transport model in social terms, yet it is important to include the social implications in the comprehensive evaluation of an innovative idea for the specific case.

Out of the qualitative data, the findings serve to help understand the complexity of undertaking innovative projects in urban freight distribution. First of all, it is clear that policy measures such as supporting regulations and subsidies are important in terms of optimal urban freight distribution systems. Secondly, by investigating the different areas affected and affecting urban freight distribution and its decision-makers, it is seen that policy comprise one important component for functioning operations, and the other important components being technology and the structuring of logistics operations.

Regarding the funding of urban freight distribution projects, government funding is on the one hand regarded positively as a reassurance by investors but on the other hand it induces uncertainty to customers about the future financial state of the project. There is no simple answer to this complexity. However, it might be possible for municipalities to target their support and funding to the initial state of a project as opposed to providing operational subsidies in order to please both sides. This finding further complicates decision-making in urban freight distribution projects and supports the hypothesis that there is no one fits all solution. Furthermore, it is clear that financial viability is a disputable and complex area, since it does not hold solely the calculations of the net present value of investments, but also includes the discussion regarding external costs and benefits as well as reluctance to change. There is not only one break-even distinction for a financially attractive solution, on the contrary it depends on the decision-making functions and people and the values behind the decisions, as well as the market positioning strategy for the company.

When the optimal mobile depot was discussed through the qualitative data collection, the majority of the responses mention trailers or trucks, i.e. already existing vehicles with lower investment costs, as the best economical fit for a mobile depot. This has likely to do with the risk averseness of many investors and the technical complexity of other, less conventional, mobile depot solutions.

Even though a solution is proven to be monetarily neutral, external benefits and costs must be considered and might pose challenges that have not been regarded previously. This is strongly related to the argument regarding reluctance to change, which in the form of the human factor plays a major role in the potential and likelihood of success for an innovative mobile depot solution. However, looking at the consequential delivery costs for mobile depots and other innovative solutions for urban freight distribution it is clear that consolidation allows for more efficient distribution operations due to higher load factors per vehicle, making the last mile distribution more efficient. Moreover, regarding potentials and barriers of mobile depots, two opposing consequences of consolidation centers stick out, namely increased handling costs on the one side and more efficient distribution operations on the other.

The economic, operational, technical and practical potentials of employing a truck or a trailer as a mobile depot are shown by previous research. Nevertheless, when environmental effects are emphasized the empirical data do not show the same potential. This has to do with the fact that trucks and trailers are fuelled with conventional fuel that emits more greenhouse gases than the mobile depot alternatives. As other research has shown, waterborne transportation and intermodal transportation often show lower levels of $CO_2$ emissions, and the conducted survey showed the highest environmental potential for river barges as mobile depots. In terms of the environmental effects of a freight bus as a mobile depot operated along with electric cargo bikes, it is concluded that CNG emissions emit slightly lower levels of $CO_2$, NOx and PM than fossil fuel such as diesel.

Finally, the importance of well-developed business models is emphasized in both the literature review as well as through the empirical data. Tools such as discovery driven planning, as mentioned by McGrath and McMillan (1995) and the business model canvas developed by Osterwalder (2004) are suitable to achieve this. This thesis has aimed at focusing on the cost structure of the BRD project, which can be seen both as the first step of discovery driven planning i.e. 'reverse income statement' and under 'cost structure' on the left hand side of the business model canvas. This thesis project has thus demonstrated the cost structure of the BRD and been able to contribute to the further development and delivery of a thorough business model.

# 5 Conclusion

The purpose of this thesis has been to develop a cost model that can be used to financially evaluate innovative city logistics projects before their implementation. Furthermore, the purpose has been to apply this cost model to the specific innovative project BRD and analyze the barriers and potentials that such a project entails. In order to achieve the purpose of this thesis, the set out research questions have been answered.

*RQ1: What cost variables exist in parcel distribution in urban areas and what parameters affect the different variables?*

Three general cost areas when running a road transportation business are standing, running and overhead costs, which themselves consist of several cost variables. The specific cost variables that exist in the conventional model of parcel distribution as well as for the innovative model BRD have been presented in Table 4.

*RQ2: How do the cost variables differ between the conventional parcel distribution model and the innovative BRD model?*

Most costs variables remain the same in the two models due to common demeanors for transportation such as fuel, depreciation and labor costs. These are presented in Chapter 4.1 Quantitative Analysis. However, the implications of the cost variables affect the total costs differently in different models. Some specific cost variables exist for each separate transport mode such as battery costs for the electric cargo bike, parking costs for the freight bus and congestion charges for the vans.

*RQ3: How do the total costs between the conventional and the innovative model differ?*

The total costs per distribution model are demonstrated in Table 5. Conclusively, in the base scenario the innovative model is €24,905 more expensive than the conventional model.

*RQ4: How does an increase in demand and changes of certain cost variables affect the calculated total costs?*

For an increase in demand, the innovative model becomes more financially attractive. This is shown in Chapter 4.1.2 Scaled Scenario. The change of certain cost variables and assumptions affects the results of the cost analysis in different ways. This has been shown in Chapter 4.1.3 Sensitivity Analysis where changes of six cost variables have been tested and analyzed.

*RQ5: What non-monetary aspects affect the viability of an innovative project in urban freight distribution?*

In Chapter 4.4 Qualitative Analysis the topics of business cases, reluctance to change, governance tools, potentials and barriers are presented as having significant impact on the success of such a project.

Initially, a gap in research regarding financial evaluation tools for innovative projects in urban freight distribution was identified. This thesis fulfills the requirement of contributing to knowledge by developing a cost model and applying it to the innovative BRD project in Gothenburg. The results attained in this research can thus be used in further investigating or developing this project. Furthermore, the clear cost model presented in this thesis can be used as a benchmark tool for other cost analysis research projects for urban freight distribution models with the aim to reduce negative externalities.

This thesis was able to fulfill the goal of investigating the cost implications of the BRD compared to the conventional freight distribution operations in Gothenburg. However, due to resource limitations, certain areas remain unexplored. Therefore some recommendations for future research within the field are suggested. In order to conduct a full social cost-benefit analysis, it is necessary to quantify and internalize external costs in the calculations. For the potential practical implementation of innovative projects in urban freight distribution additional aspects apart from the financial ones need to be taken into consideration, such as the elaboration of a proper business model by further developing the aforementioned steps of discovery driven planning (McGrath and MacMillan, 1995) and the remaining building blocks of the business model canvas (Osterwalder, 2004). It should include features like identification and involvement of stakeholders as well as a precise declaration of the operational and technical setup and of the required hardware and software.

Through the cost analysis, this thesis demonstrates that an innovative solution can be cheaper than a conventional operation under certain circumstances. In this case, one detrimental implication is the scale of the operations. Furthermore, it should be acknowledged that the total benefits of such a project must be thoroughly investigated and evaluated compared to the business as usual. This is related to the fact that even if a positive break-even is achieved for an innovative project in urban freight distribution for a certain scale, people are reluctant to change and therefore financial viability is not always enough to initiate and successfully carry out a project. Public authorities have the power to influence and direct urban freight operations by the use of different governance tools such as subsidies, taxation and regulations. The findings in this thesis show that such involvement affects both the cost side as well as the general perception of an innovative project. Finally, it is concluded that all cities are unique and therefore have unique requirements of how urban freight distribution operations should be optimized. Because of this, no innovative model fits all but must be customized to specific circumstances in order to successfully extract maximum benefits and to make urban freight distribution more sustainable.

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# Appendices

## Appendix A – Detailed cost calculation per transport mode

### Van – Ford Custom

| VEHICLE COSTING | | | |
|---|---|---|---|
| **Vehicle:** | **Ford Custom** | | |
| | 2,7t, 2,2l TDCI, 92kW (125 PS), 6 gears, L1H1 | | |
| **ASSUMPTIONS** | | | |
| Van | Purchasing price (ex. VAT) | (€) | 27,050 |
| | Financing cost | (%) | 3.29% |
| | Depreciation | (Yrs) | 6 |
| | Residual value | (%) | 37% |
| | License/Permit | (€) | 0 |
| | Insurance: Total | (€/yr) | 1,939 |
| | Tax | (€) | 573 |
| | Number of Tires | (No) | 4 |
| | Price / Tire | (€) | 90 |
| | Tyre life new | (Km) | 40,000 |
| Labor | Annual Salary incl. benefits | (€) | 36,130 |
| Fuel | Usage (l/100km) | (l/100km) | 10 |
| | Cost per Liter | (CENTS) | 154 |
| Lubricants | % of Fuel Cost | (%) | 1.00% |
| Maintenance | Variable Maintenance Cost | (c/km) | 4.08 |
| Others | City fee per entry/exit | (€) | 1.7 |
| Overhead | % of vehicle cost | (%) | 12 |

| Trip details | | |
|---|---|---|
| Average distance per return trip | (km) | 74 |
| inside city | (km) | 50 |
| outside | (km) | 24 |
| Return trips per day | (No) | 1 |
| Working days per year | (Days) | 260 |
| Return trips per week | (No) | 5 |
| Weeks per year | (No) | 52 |
| Return trips per year | (No) | 260 |
| Parcels per returntrip | (No) | 80 |
| Parcels per year | (No) | 20,800 |
| Number of stops per returntrip | (No) | 53 |
| Number of stops per year | (No) | 13,780 |
| Kilometers per year | (Km) | 19,240 |

| COSTING: SUMMARY | | | | |
|---|---|---|---|---|
| **Fixed Costs** | **(€/yr)** | **%** | **(C/KM)** | **(%)** |
| Cost of Capital (Interest) | 445 | 1.1% | 2.3 | 1.1% |
| Depreciation | 2,780 | 6.6% | 14.5 | 6.6% |
| License/Permit | - | 0.0% | 14.5 | 0.0% |
| Insurance | 1,939 | 4.6% | 10.1 | 4.6% |
| Labor | 36,130 | 86.3% | 187.8 | 86.3% |
| Tax | 573 | 1.4% | 3.0 | 1.4% |
| **Total Fixed Costs** | 41,867 | 100.0% | 232.1 | 100.0% |
| | | | | |
| **Variable Costs** | **(€/yr)** | **%** | **(C/KM)** | **(%)** |
| Fuel | 2,963 | 61.3% | 15.4 | 61.3% |
| Lubricants | 30 | 0.6% | 0.2 | 0.6% |
| Maintenance | 785 | 16.2% | 4.1 | 16.2% |
| Tires | 173 | 3.6% | 0.9 | 3.6% |
| City Fee | 884 | 18.3% | 4.6 | 18.3% |
| **Total Variable Costs** | 4,835 | 100.0% | 25.1 | 100.0% |
| **Total Vehicle Costs** | **46,702** | | **257.2** | |
| | | | | |
| **Overhead Costs** | 5,604 | | 29.1 | |
| **TOTAL OPERATING COSTS** | **52,306** | | **286.3** | |

| | |
|---|---|
| Total operating cost per parcel | 2.51 |
| Total operating cost per stop | 3.80 |
| Total operating cost per returntrip | 201.18 |

## Freight bus – MAN Lion's City

| VEHICLE COSTING | | | |
|---|---|---|---|
| **Vehicle:** | **MAN City bus** | | |
| | MAN, LION`S CITY CNG / A21 | | |
| **ASSUMPTIONS** | | | |
| Bus | Used Bus + refitting activities | (€) | 257,000 |
| | Financing cost | (%) | 3.29% |
| | Depreciation | (Yrs) | 12 |
| | Residual value | (%) | 5% |
| | License/Permit | (€) | 0 |
| | Insurance: Total | (€/yr) | 5,510 |
| | Tax | (€) | 107 |
| | Number of Tires front | (No) | 2 |
| | Number of Tires rear | (No) | 4 |
| | Price / Tire | (€) | 413 |
| | Tyre life front axle | (Km) | 116,000 |
| | Tyre life rear axle | (Km) | 165,000 |
| Labor | Annual Salary incl. benefits | (€) | 38,716 |
| Fuel | Usage (kg/100km) | (kg/100km) | 42 |
| | Cost per kg | (CENTS) | 185 |
| Lubricants | % of Fuel Cost | (%) | 1.00% |
| Maintenance | Variable Maintenance Cost | (c/km) | 4.00 |
| Others | Parking costs | (€) | 0 |
| Overhead | % of vehicle cost | (%) | 12 |

| Trip details | | |
|---|---|---|
| Average distance per return trip | (km) | 31 |
| inside city | (km) | 9 |
| outside | (km) | 22 |
| Return trips per day | (No) | 1 |
| Working days per year | (Days) | 260 |
| Return trips per week | (No) | 5 |
| Weeks per year | (No) | 52 |
| Return trips per year | (No) | 260 |
| Parcels per returntrip | (No) | 160 |
| Parcels per year | (No) | 41,600 |
| Number of stops per returntrip | (No) | 6 |
| Number of stops per year | (No) | 1,560 |
| Kilometers per year | (Km) | 8,060 |

| COSTING: SUMMARY | | | | |
|---|---|---|---|---|
| **Fixed Costs** | **(€/yr)** | **%** | **(C/KM)** | **(%)** |
| Cost of Capital (Interest) | 4,228 | 6.2% | 52.5 | 6.2% |
| Depreciation | 20,139 | 29.3% | 249.9 | 29.3% |
| License/Permit | - | 0.0% | 249.9 | 0.0% |
| Insurance | 5,510 | 8.0% | 68.4 | 8.0% |
| Labor | 38,716 | 56.4% | 480.3 | 56.4% |
| Tax | 107 | 0.2% | 1.3 | 0.2% |
| **Total Fixed Costs** | 68,700 | 100.0% | 1102.22 | 100.0% |
| | | | | |
| **Variable Costs** | **(€/yr)** | **%** | **(C/KM)** | **(%)** |
| Fuel | 6,263 | 92.3% | 77.7 | 92.3% |
| Lubricants | 63 | 0.9% | 0.8 | 0.9% |
| Maintenance | 322 | 4.8% | 4.0 | 4.8% |
| Tires | 138 | 2.0% | 1.7 | 2.0% |
| Parking costs | - | 0.0% | 0.0 | 0.0% |
| **Total Variable Costs** | 6,786 | 100.0% | 84.19 | 100.0% |
| **Total Vehicle Costs** | **75,486** | | **1186.42** | |
| | | | | |
| **Overhead Costs** | 9,058 | | 112.4 | |
| **TOTAL OPERATING COSTS** | **84,544** | | **1,298.8** | |

| | |
|---|---|
| Total operating cost per parcel | 2.03 |
| Total operating cost per stop | 54.19 |
| Total operating cost per returntrip | 325.17 |

## Electric Cargo Bike – Ecoride Explorer

| VEHICLE COSTING | | | |
|---|---|---|---|
| **Vehicle:** | **Electric cargo cycle "Explorer" (Ecoride)** | | |
| | 125kg, 2,3 m2 | | |
| **ASSUMPTIONS** | | | |
| Bike | Bike (ex battery)+trailer | (€) | 3,486 |
| | Financing cost | (%) | 3.29% |
| | Depreciation | (Yrs) | 6 |
| | Residual value | (%) | 40% |
| | License/Permit | (€) | 0 |
| | Insurance: Total | (€/yr) | 0 |
| | Tax | (€) | 0 |
| | Number of Tires | (No) | 4 |
| | Price / Tire | (€) | 43 |
| | Tyre life new | (Km) | 10,000 |
| Labor | Annual Salary incl. benefits | (€) | 34,236 |
| Fuel | Usage (kWh/km) | (kWh/km) | 0.018 |
| | Cost per kWh | (CENTS) | 21 |
| Lubricants | % of Fuel Cost | (%) | |
| Maintenance | Variable Maintenance Cost | (c/km) | 5.45 |
| Battery | Costs for battery | (c/km) | 2.22 |
| | Number of batteries | (no) | 2 |
| Overhead | % of vehicle cost | (%) | 12 |

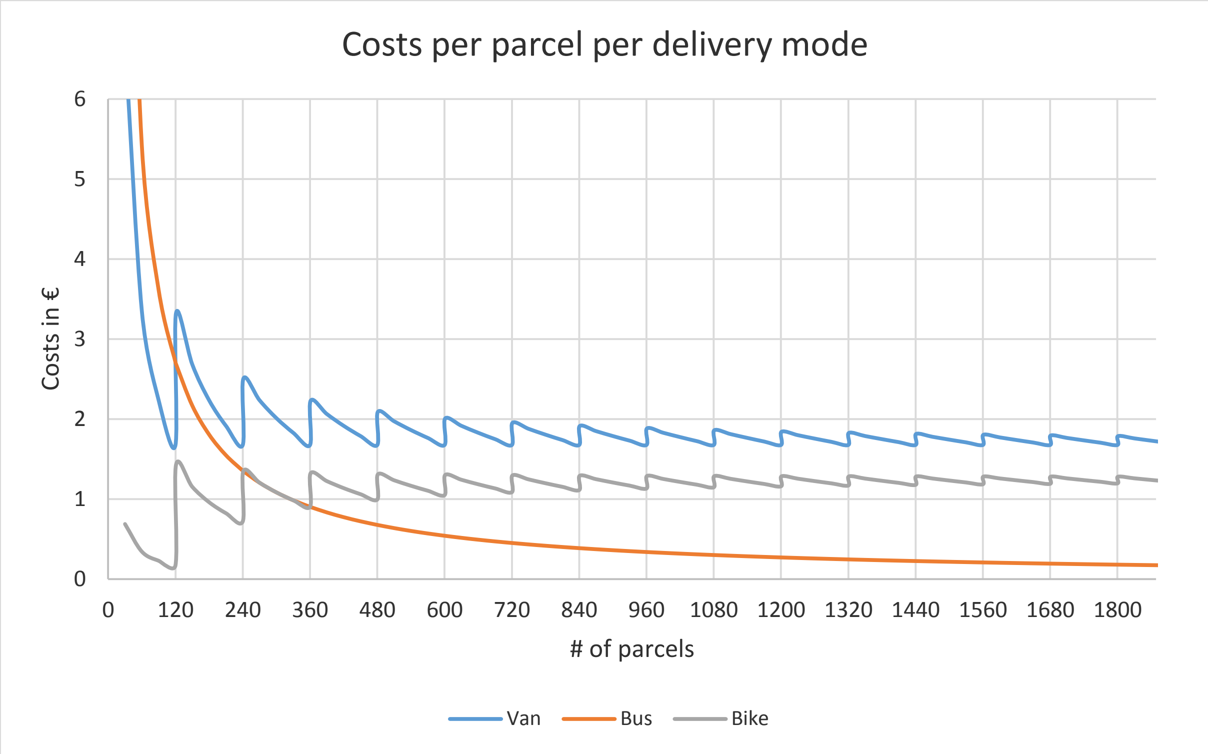
| Trip details | | |
|---|---|---|
| *Average distance per return trip* | (km) | 24 |
| *delivery round* | (km) | 18 |
| *in between stops* | (km) | 6 |
| *Return trips per day* | (No) | 1 |
| Working days per year | (Days) | 260 |
| *Return trips per week* | (No) | 5 |
| Weeks per year | (No) | 52 |
| *Return trips per year* | (No) | 260 |
| Parcels per returntrip | (No) | 80 |
| Parcels per year | (No) | 20,800 |
| Number of stops per returntrip | (No) | 53 |
| Number of stops per year | (No) | 13,780 |
| *Kilometers per year* | (Km) | 6,240 |

| COSTING: SUMMARY | | | | |
|---|---|---|---|---|
| **Fixed Costs** | **(€/yr)** | **%** | **(C/KM)** | **(%)** |
| Cost of Capital (Interest) | 57 | 0.2% | *0.9* | 0.2% |
| Depreciation | 320 | 0.9% | *5.1* | 0.9% |
| License/Permit | - | 0.0% | *5.1* | 0.0% |
| Insurance | - | 0.0% | *0.0* | 0.0% |
| Labor | 34,236 | 98.9% | *548.7* | 98.9% |
| Tax | - | 0.0% | *0.0* | 0.0% |
| **Total Fixed Costs** | 34,613 | 100.0% | *559.83* | 100.0% |
| | | | | |
| **Variable Costs** | **(€/yr)** | **%** | **(C/KM)** | **(%)** |
| Fuel | *24* | 3.2% | *0.38* | 3.2% |
| Lubricants&Expendables | | 0.0% | *0.0* | 0.0% |
| Maintenance | *340* | 45.5% | *5.5* | 45.5% |
| Tires | *107* | 14.3% | *1.7* | 14.3% |
| Battery | *277* | 37.0% | *4.4* | 37.0% |
| **Total Variable Costs** | 748 | 100.0% | *11.99* | 100.0% |
| **Total Vehicle Costs** | **35,361** | | **571.82** | |
| | | | | |
| **Overhead Costs** | 4,243 | | *68.0* | |
| **TOTAL OPERATING COSTS** | ***39,605*** | | ***639.8*** | |

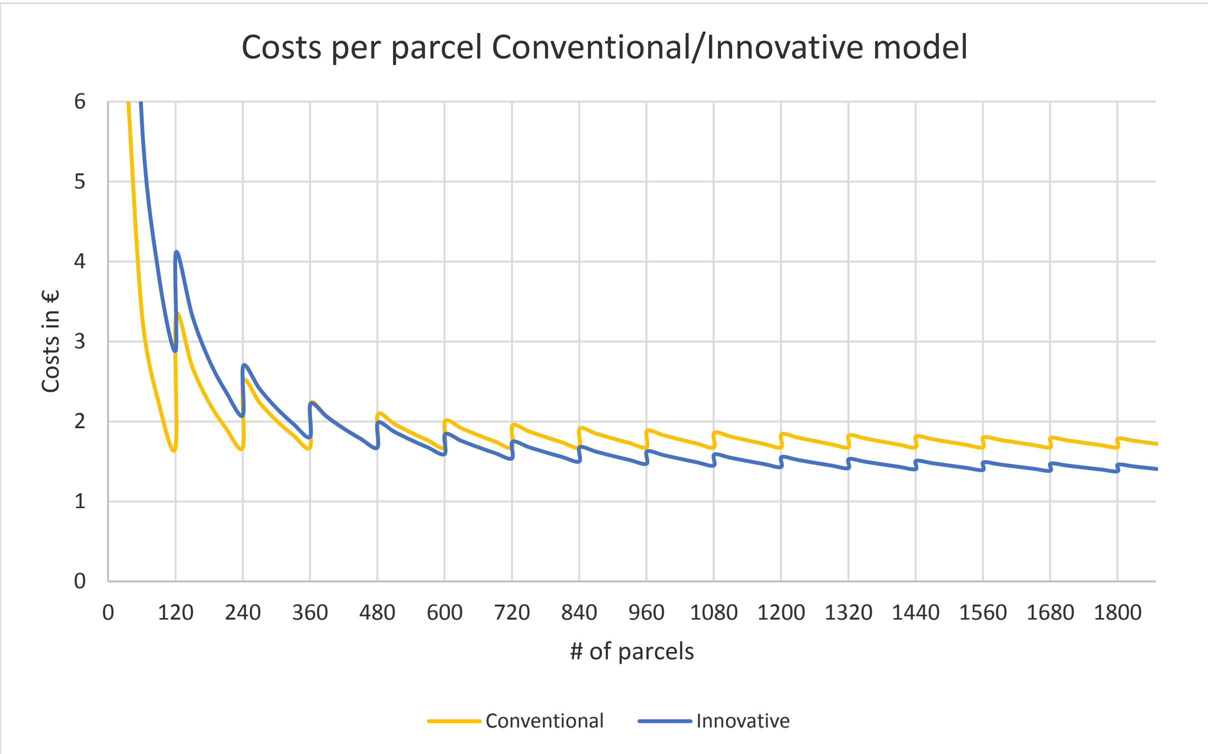
| | |
|---|---|
| Total operating cost per parcel | 1.90 |
| Total operating cost per stop | 2.87 |
| Total operating cost per returntrip | 152.33 |

## Appendix B – Cost per parcel

Per parcel cost per delivery mode




Per parcel cost per model



## Appendix C – Interview and survey

Question catalogue for semi-structured interviews.

1. What are the main obstacles when implementing new solutions for urban distribution?

(Costs/Technology/Stakeholders)

2. What do you think of the potential of mobile depots in general?

- Barriers?
- Opportunities?
- Specific Examples?

3. How do you think a business model for an alternative solution for urban distribution would be perceived if it would be

- Financially viable?
- Financially neutral?
- Five percent more costly?

4. Within how long should an innovation project in urban distribution be financially independent?

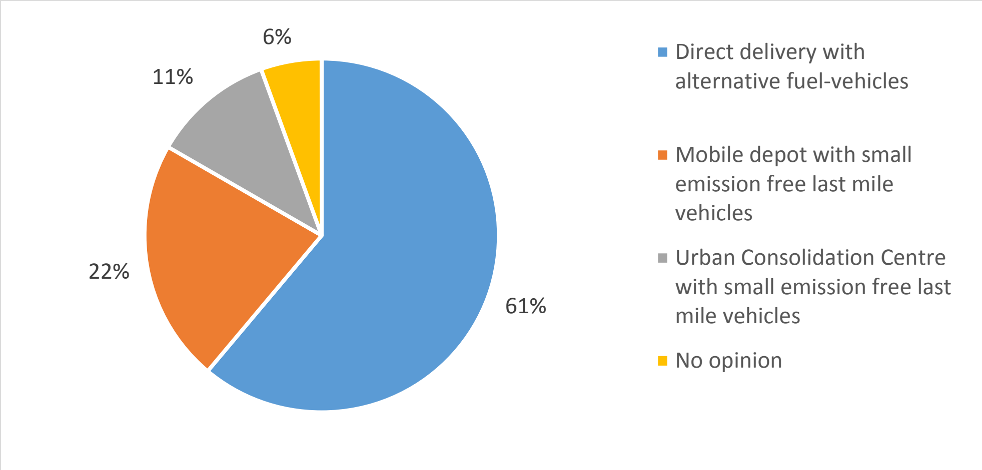
5. Are there any different cost variables in an alternative solution for urban distribution (e.g. BRD project) compared to conventional distribution? Which cost variable would hamper the new solution the most?

6. In terms of evaluating costs of innovation projects in urban distribution, what problems or barriers commonly occur? If you have not performed such cost analyses, what problems or barriers would you assume?

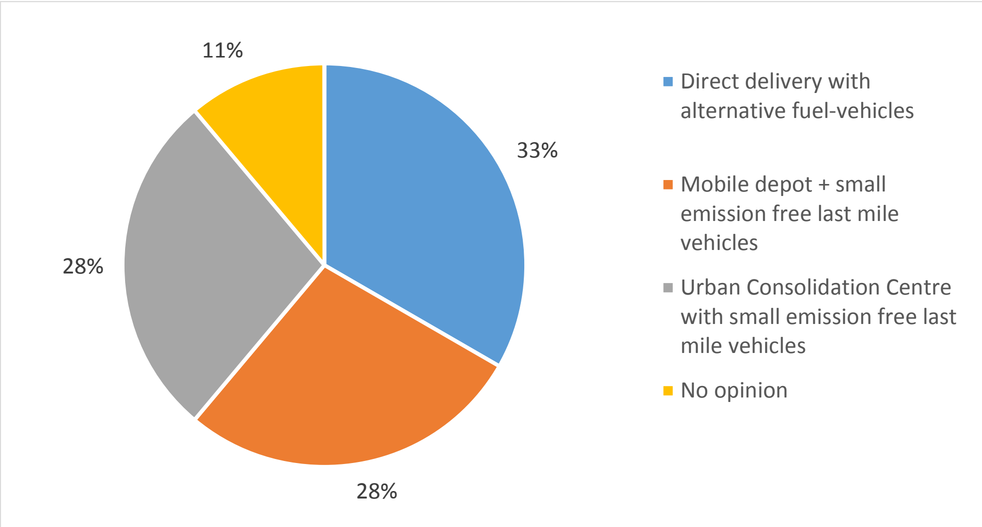
**Other comments/suggestions:**

Question catalogue for online-survey

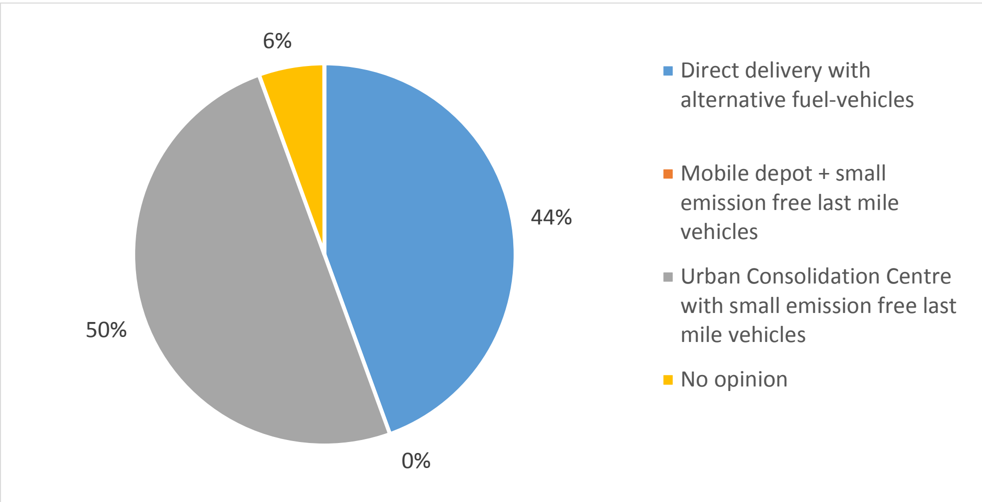
1. Which alternative for urban distribution has the most potential to be accepted by stakeholders?



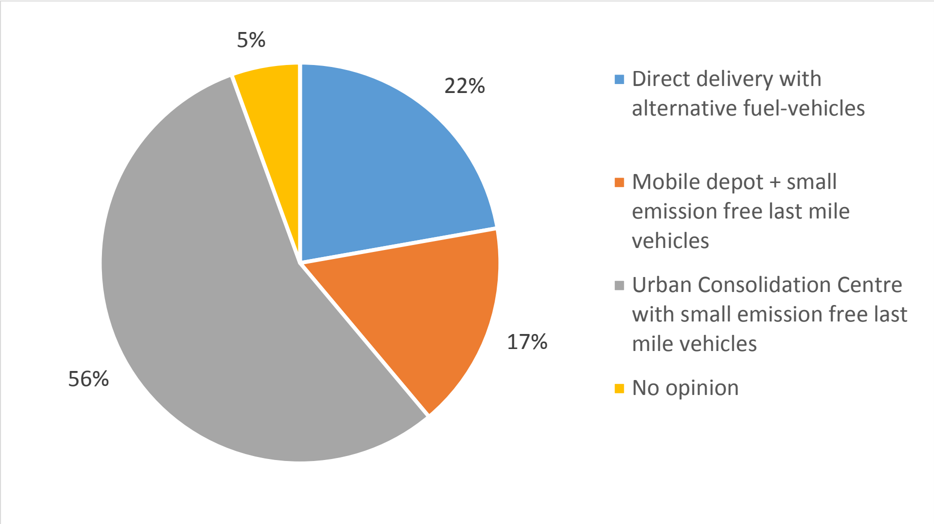

2. Which alternative for urban distribution has the most economic potential?



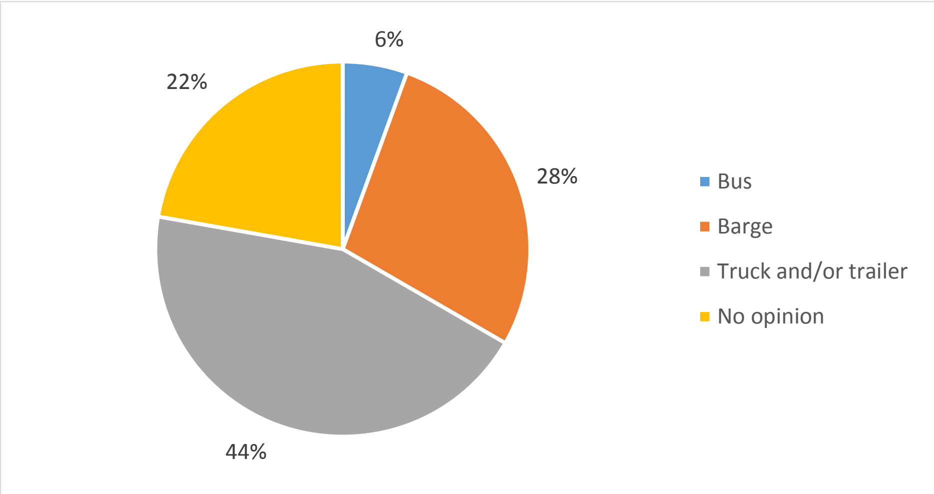

3. Which alternative for urban distribution is the most technologically/operationally feasible as of today?



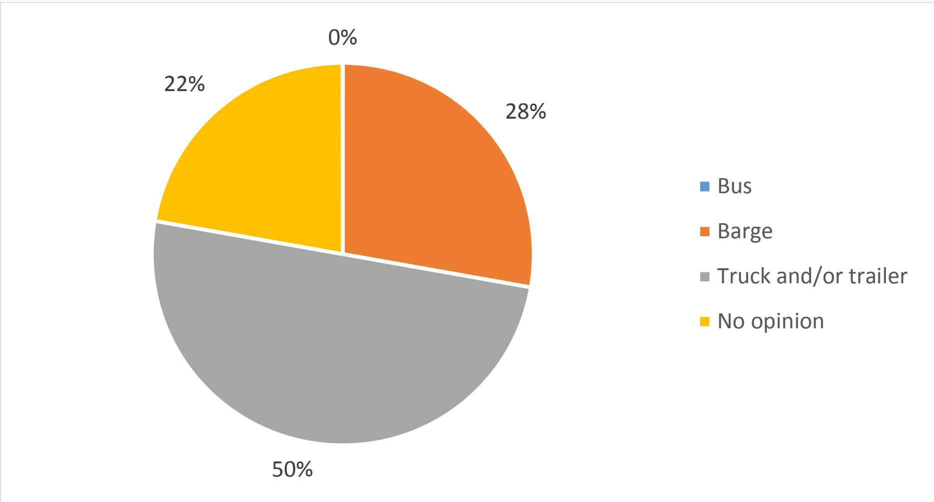
4. Which alternative for urban distribution has the highest potential to reduce environmental costs?



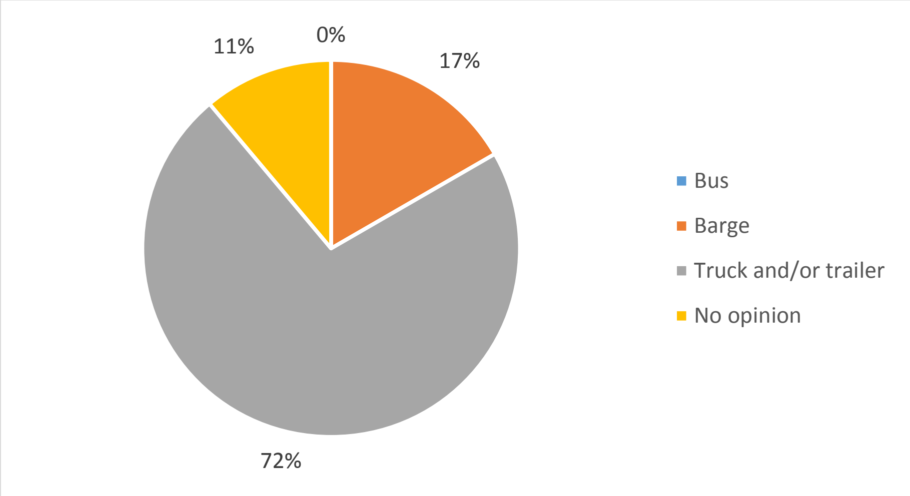

5. Which mobile depot solution has the most potential to be accepted by stakeholders?




6. Which mobile depot solution has the most economic potential?



7. Which mobile depot solution is the most technologically / operationally feasible as of today?




7. Which mobile depot solution has the highest potential to reduce environmental costs?