Urban freight distribution: Assessing time efficiency of daily activities for future development of medium-duty electric vehicles

Master's thesis in Supply Chain Management

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Abstract

The increasing amount of goods required by the intense urbanization has triggered a considerable growth of urban distribution. To meet the increased demand, this Master's thesis seeks to map and quantify the duration of activities that take place in a typical urban distribution tour for medium-duty trucks, and identify potential actions to enhance the time efficiency of these activities. Thereafter, the aforementioned findings are combined with a research in the advancements of all-electric vehicles to see if their characteristics fit with the existing demands in urban freight distribution.

The methods used for data collection involved both field and desk research. Primary data was collected through a time study with Company X's truck drivers. The time study was supplemented by distribution route tracking and interviews with 17 different participants. The interviewees consisted of operational and managerial level participants from Company X, and experts in the electric driveline technology. Additionally, secondary data was gathered through a revision of Volvo Group Truck Technology's internal documents.

31 work related activities for truck drivers were identified and classified into six categories. The categorization was based on the location where the activity took place. Observations envisage that there are notable time differences among the activities. Driving and breaks accounted for the vast majority of the truck driver's time consumption (44.5 percent). 15 improvement initiatives were proposed to enhance truck drivers' safety and increase time efficiency in urban distribution. In addition, the average driving distance was 63.9 km. The research revealed that existing electric powertrain technology is able to address the transport operators' distribution demands in the Gothenburg area. As of today, no major infrastructural changes are necessary to utilize all-electric fleets.

Keywords: urban freight transportation, medium-duty trucks, battery electric vehicles, time study, route tracking, sustainability

Acknowledgements

This thesis was a challenging work leading to interesting facts about the urban freight distribution. We have learned about the operational activities taking place in a truck driver's daily work routines. We have gained knowledge about the time consumption and how time efficiency potentially can be improved by implementing new improvement initiatives. This work and new knowledge have also affected us and our understanding of sustainability and led to considerations on how we can lower our environmental impact by the utilization of new vehicle technology.

We would like to express our deepest appreciation to all those who provided us the possibility to complete this thesis. First and foremost, we would like to pass on a special gratitude to our supervisors, Iván Sánchez-Diaz (Chalmers University of Technology) and Rafael Basso (Volvo Group Trucks Technology) for your contribution, support, insightful discussions and valuable feedback throughout the thesis.

We are also grateful to the Urban Transport Solutions division at Volvo Group Trucks Technology for the warm welcome and continuous support. Thank you for believing in us and giving us the opportunity to contribute to your research.

We also want to acknowledge with much appreciation the crucial role of the staff of Company X, who granted us the permission to conduct the time study and the interviews. A special thanks goes to the drivers for letting us accompany them and contributing to a good work atmosphere during the study.

Finally, we must express our profound gratitude to our families and friends for providing us support and continuous encouragement throughout our years of studies. All of this would not have been possible without you.

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Anders Levandi & Jimmy Mårdberg, Gothenburg, May 2016

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List of Abbreviations

3PL	Third Party Logistics
AV	Autonomous Vehicle
BEV	Battery Electric Vehicle
CO	Carbon Monoxide
ET	Electric-powered Pallet Jack
EU	The European Union
GHG	Greenhouse Gas
HCs	Hydrocarbons
HEV	Hybrid Electric Vehicle
ICE	Internal Combustion Engine
LTL	Less-Than-Truckload
NOx	Nitrogen Oxides
O3	Ozone
OPHD	Off-Peak Hour Deliveries
PJ	Pallet Jack
RQ	Research Question (1, 2, 3)
SO2	Sulphur Dioxide
TST	Traveling Salesman Tour
US	The United States

1

Introduction

This chapter provides an introduction to the Master's Thesis. The chapter starts by providing the background and the main problems regarding urbanization, followed by the formulation of the purpose and problem analysis that motivated the research in this thesis.

1.1 Background

In the recent past, urbanization has experienced significant growth, which has propelled the demand for global supplies. The development has raised numerous distresses as cities are already responsible for above 80 percent of the global domestic product, are accountable for more than 70 percent of global greenhouse gas emissions, and use roughly 67 percent of the world's energy (The World Bank, 2016). The industrialization in the mid-nineteenth century contributed with mechanisms enabling a development of cities (More, 2000). Since then, cities have developed into more dense residential areas. Currently, about 54 percent of the world population live in urban environments and the rate of urbanization increases by approximately 2.1 percent annually (CIA, 2015, United Nations, 2008). Therefore, the urbanization trend is indubitable and implies an increased demand of supplies in urban areas (Carter et al., 2015).

The increasing amount of goods required by the intense urban activity has triggered a considerable growth in urban distribution (McKinnon, 2015). In 2004, urban freight activities in London were responsible for the movement of 200 million tons of goods (Schoemaker et al., 2006). In addition, urban freight activities also involve a large number of trips: 643,201 trips in NYC Metro area (Sanchez-Diaz et al., 2016). These figures are clear indicators of the necessity for comprehensive logistics services. To successfully manage the overly-rapid urbanization rate there is a need for a sustainable logistics system which takes into account all stakeholders' requirements and satisfies their needs. In general, satisfying all stakeholders is an immensely complex task due to different preferences for all of the participants (Lindholm, 2014). Consequently, the development of an overall consensus solution in urban distribution is difficult.

The increased demand of urban distribution causes growing issues regarding transport congestion and environmental degradation (BBC, 2014). Even though freight transportation represents 8-15 percent of total traffic, its external effects are substantially higher with greater influence on air quality and noise pollution, and higher congestion during freight distribution. This is because majority of the urban logistics vehicles are powered by conventional internal combustion engines which run on non-renewable fossil fuels, thus imposing greater risks than alternative vehicles running on renewable fuel (MDS, 2012). Policy measures such as environmental zones and off-hour deliveries have been established by the authorities to reduce the impact of the ongoing trend (Dablanc, 2007). These measures influence urban distribution and forces companies to streamline their operations in terms of time consumption and environmental impact. To create an appropriate urban distribution approach, identification and formulation of potential improvement areas for urban distribution of goods requires a holistic view combined with in-depth analyses.

At present, the Volvo Group Trucks Technology is developing new freight transport solutions for urban environments. The research and development include new vehicle technology such as alternative fuels. According to Volvo, one potential solution for the aforementioned challenges involve electric driven medium-duty trucks, which could operate in the urban freight distribution. Grauers et al. (2013) claim that electric vehicles are one of the main technological solutions considered to reach environmental goals. Nevertheless, since the key obstacle of electric vehicles is associated with driving range, it is important to study how the limited range affects the overall time efficiency in urban distribution.

Reducing congestion and the environmental impact of urban freight activities requires a combination of new technologies and actions that lead to efficiency improvements (McKinnon, 2015). Improving the time efficiency of activities create savings for the transport operator as more value creating activities can be performed throughout the day with the same amount of resources. For instance, reducing the time spent on planning, loading, unloading, and driving results in additional available time for truck drivers to perform more activities. Thus, the transport service provider can reduce the amount of necessary trucks without affecting the service level. Furthermore, it alleviates congestion and lessens environmental impacts. These general savings do not only benefit the transport operator, as other stakeholders such as receivers and authorities would also be able to increase their savings (Lindholm, 2014). To make this possible, it is necessary to study how time is spent in a typical urban distribution tour and how time losses can be reduced to upturn time efficiency.

1.2 Purpose

This thesis seeks to map and quantify the duration of activities that take place in a typical urban distribution tour, identify potential actions to enhance the time efficiency of these activities and analyze potential implications of the limited driving range of electric powered trucks on time efficiency.

The first objective of the research is to provide an overview of the current activities of a truck driver in urban distribution. There is an on-going project at Volvo Group Trucks Technology, EL-FORT, which aims to foster an advertising campaign for Volvo's electric driven trucks. In order to facilitate the project's progress, analyses and quantifications of the current urban distribution activities must be conducted. The results of this thesis will give the company a stronger basis for future decisions in research and development of urban distribution system solutions, which includes the development of electric and autonomous vehicles.

At present, time studies on medium-duty truck drivers' activities in urban distribution are almost non-existent, and as time efficiency is of high importance, this further highlights the necessity for such research. Therefore, the second objective is to present feasible solutions to increase time efficiency in urban distribution.

As the distribution routes will be tracked, the third objective is to analyze the implications of exchanging conventional internal combustion engines (ICEs) with battery electric vehicles (BEVs) in terms of driving range, and what adjustments might be necessary to promote a successful change.

1.3 Problem analysis

Volvo has raised concerns regarding the time efficiency of the urban distribution activities and claims that there are significant potential time savings to be gained. As this thesis seeks to identify non-efficient activities and propose suggestions for optimization, three main research questions have been established. The questions are presented one by one, followed by a short description.

- What are the activities that take place in a typical urban distribution tour?
  - What is the purpose of each of these activities?
  - How can these activities be categorized?

The first research question aims at identifying and mapping all activities related to a typical urban distribution tour. The sub-question comprises a categorization of all activities according to their characteristics. In order to answer these questions, a comprehensive field study will provide the necessary data to the research. Furthermore, categorizing the activities will be based on the location and character of the activity. The findings from the field study will be the foundation of this research.

- Which activities can be optimized to increase time efficiency for truck drivers?
  - What could be potential solutions to increase time efficiency for these activities?

Secondly, it is important to optimize activities as they contribute to additional time consumption. Potential areas for improvement will be highlighted and suggestions of feasible solutions to increase the time efficiency for truck drivers and transport operators will be presented. The collected data from the field studies and the interviews with urban logistics operators contribute to responses for the second research question.

- Would the current distribution route change if BEVs are utilized?
  - Are current routes appropriate for electric trucks?

Finally, as the electric vehicle is one of the main technological solutions to reach environmental goals, it is beneficial to align the suggested improvements with its characteristics. The last research question will highlight route related decisions as the trip duration is one of the most critical factors for BEVs.

Answering the research questions will allow to formulate and present proposals for improvements. The suggested enhancements will allow higher time efficient activities for truck drivers, increased vehicle utilization, better distribution tour planning and routing, and decreased traffic related issues, e.g. parking and congestion.

1.4 Limitations and delimitations

In order to maintain a coherent content throughout the thesis, certain delimitations were set. Although there exists links of transportation between all the entities in a supply chain, this research will solely look at the link between the third party logistics (3PL) supplier and the customer (see figure 1).

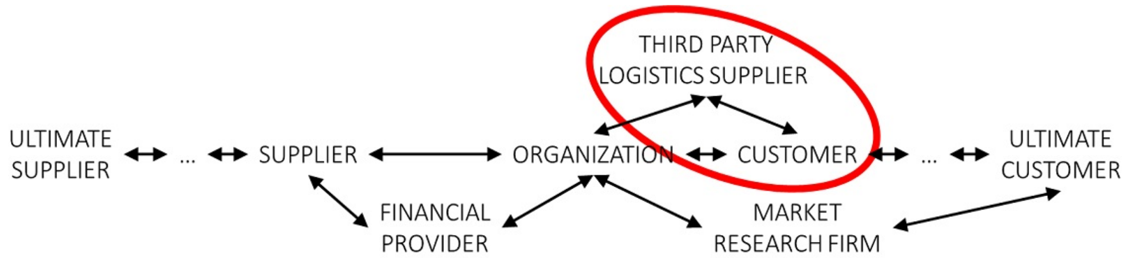

Figure 1: Ultimate supply chain (Mentzer et al., 2001)

The core focus of this thesis was to investigate freight transportation. All other means of transportation were thus excluded from this report. Furthermore, the focus on urban distribution justifies that the tours selected for the study took place mainly in the metropolitan area of Gothenburg, Sweden. Given the unsustainable characteristics of urban distribution, BEVs represent a great opportunity to decrease the adverse effects. As the technology is limited to a specific range and capacity, an urban environment suits these vehicles and the improvement suggestions are most applicable.

There are numerous analyses and examples of light-duty vehicles attending the needs of urban customers. To provide an original approach, thus increase the overall value of this report, these types of vehicles are excluded, and attention is only provided to medium-duty trucks with gross weight between 12-18 tons. Another reason why this type of delimitations was done is that many of the light-duty vehicles serving the urban environment already possess more sustainable powertrains than ICEs. This means that improving the time efficiency regarding a truck drivers' daily routine, who uses a medium-duty truck with a higher capacity and is powered by an ICE, has a bigger impact on the environment.

Another delimitation to take into account is the truck driver and the activities which occur during a normal distribution route. The focus will be to look at what reoccurring events take place. Other random activities that only occur occasionally will thus be excluded from further analysis.

Furthermore, the data obtained through route tracking will be used to evaluate the amount of stops made by the drivers, the average speed throughout the distribution tour, but also total distances. Route optimization calculations are not within the scope of this report.

Regarding the limitations, a significant feature is the time constraint. The time limitations affected the intensity of the empirical study. As the thesis is conducted over a course of a limited period of time, the research subjects were limited to one city and one 3PL, i.e. Company X. Consequently, private transportation, other 3PLs and the distribution in other cities are not discussed.

Even though there exists a vast amount of literature addressing urban freight distribution, the existing time measurements do not involve such a high detail and accuracy as the one involved in this research. Therefore, this limitation did not provide the researchers an opportunity to juxtapose their findings with previous studies. This issue resulted the theoretical framework to address time studies in a general manner.

1.5 Thesis outline

Literature review – This chapter displays the theoretical framework pertinent for the research with the goal to introduce a wider perspective of the study area and portray what needs to be examined in furtherance of fulfilling the research process. It comprises definitions, describes freight distribution and urban freight transportation, including an overview of affected stakeholders with potential side effects and external costs of urban distribution. Thereafter, gives an overview of the current status in electric powertrain technology. The chapter is concluded with an overview of the parameters used for value of time calculations.

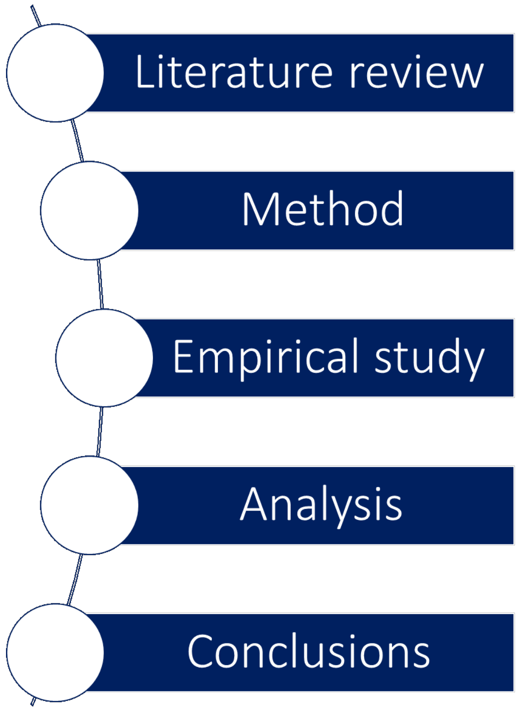

Figure 2: Thesis outline

Method – This chapter presents the design of the research, describing how the empirical study, data collection, and literature review were conducted. This encompasses data collection methods such as time study, route tracking, semi-structured interviews, and company internal document review. Thereafter, the quality of the data is assessed by discussing the reliability and the validity of the findings.

Empirical study – This chapter presents the findings from the interviews with the drivers and managers at Company X. The findings will give an overview of the focus company's current situation as well as the future visions which the company is striving towards.

In addition, the empirical study chapter comprises all the data obtained from timing the daily routine of the truck driver. The activities will be described as detailed as possible to provide better analytical capability. Thereafter, the results will be categorized accordingly. This is the backbone and main focus of the thesis. Furthermore, the range of all the routes will be tracked with a GPS tracker, to achieve a possibility to collate the results with the characteristics of electric vehicles.

Analysis – This chapter focuses on pinpointing the non-value adding activities which can be optimized in order to increase the efficiency of the truck driver's daily routine. The potential effect and feasibility of the proposed list of improvement suggestions will be analyzed. In addition to this, the analysis will contemplate the scenario of replacing current ICE driven distribution trucks with BEVs. This will examine if current distribution routes are already appropriate or need to change in order to adjust to the characteristics of BEVs, mainly limited to driving range. The material presented will be a combination from the literature review chapter as well as the empirical study chapter. This part will also formulate solutions drawn from the analysis.

Conclusion – The final section summarizes and presents the purpose of the study, assesses the quality of the research and presents recommendations for prospective future research.

2

Literature review

This chapter will present relevant literature used for research purposes. The underlying objective is to introduce a wider outlook of the study area. The covered topics will help to outline what needs to be studied in order to fulfill the research purpose. Firstly, the characteristics of freight transportation, and road transportation in specific are described. Thereafter, the main objectives, a typical distribution tour, the performance measures of the urban freight system are discussed. The subchapter also describes the stakeholders and the side effects of urban logistics. Subsequently, the current state of electric vehicles and the advances in all-electric freight distribution fleets are elaborated. Lastly, the parameters for cost calculations of time are presented.

2.1 Freight transportation

As described by the European Commission (1999), the basic function of a transport system is to overcome geographical barriers that prevent interaction between people, businesses or countries. This statement and the definition of transportation includes both freight transport and personal travel (Merriam-Webster, 2016b).

Every day people consume goods: groceries, clothes, furnishings, hygiene products, cars, computers, and many other products are manufactured for people worldwide. Freight transportation enables people to have access to these products, both in terms of location and time (OECD, 2003). Location and time are major parameters related to efficiency and responsiveness. Chopra and Meindl (2013) describe freight transportation as the movement of items in-between different stages along the supply chain (see figure 1). A faster movement corresponds to an increased responsiveness, which often entails poorer efficiency due to lower fill rates. On the other hand, slower movement is generally more efficient, but lacks agility.

The speed of freight transportation is not only dependent on the choice of transport mode. Wandel et al. (1991) present a three layer model of freight transport (see figure 3), stating that the material (freight) flow is dependent on the transport flow, which in turn is reliant on the infrastructure. There is a need of moving an item in the freight flow between processes such as production, assembly and storage (Martinsen, 2011). The transport flow supplies a load unit flow where the item can be carried. In other words, necessary equipment and vehicles are provided in this layer. At the same time, in order to enable transportation movement, there is a need of a functional infrastructure where traffic can take place. A limited infrastructure capacity reduces the speed of transportation as circuitous roads and congestion hinder the accessibility (Lumsden, 2007). Consequently, both the efficiency and responsiveness are affected. In short, the transport market contributes with equipment and vehicles while the traffic market generates the possibility of movement.

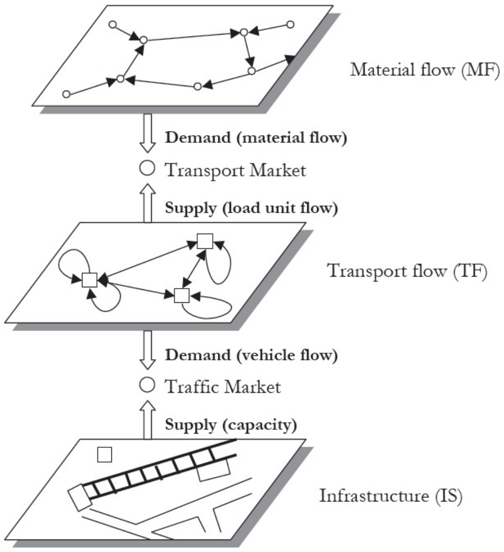

Figure 3: Three layer model (Wandel et al., 1991)

As mentioned in the previous paragraph, freight transportation cannot exist without the required equipment and vehicles. Lindholm (2012a) argues that resources are fundamental necessities to make the movement of goods valuable in terms of time and location. This value of freight transport is increased when certain criteria is guaranteed such as delivering the right product to the right customer in the right quantity, in the right condition, at the right cost, to the right place, and at the right time (Mangan et al., 2008). Lumsden (2007) points out that freight transport is a service that provides certain stakeholders with time and place utility, not only within, but also between organizations.

2.1.1 Road transportation

The global freight comprises millions of employees. In the European Union (EU) alone, over ten million people are engaged in the transport sector. This corresponds to 4.5 percent of the total employment, as the transport sector by itself contributes approximately 4.6 percent to total GDP in the EU. Road transport contributes to 45 percent (in t-km) of the employment share (European Union, 2013). The respective number of professional truck drivers for Norway and Sweden are 30 000 (Søndergaard, 2014) and 56 727 (Statistiska Centralbyrån, 2013). According to All Trucking (2016), there are about 3.5 million professional truck drivers in the United

States (US), with the entire industry exceeding 8.7 million workers. The trucking industry is the essence of the US economy as nearly 70 percent of all freight tonnage is transported with trucks. These figures demonstrate the vastness of the industry with one of every 15 wage earner correlated to the trucking business (American Trucking Associations, 2013).

From a flexibility point of view, road freight is considered as the best transport mode (Behrends, 2015). The road transport market has very low entry barriers. This is partly due to the relatively small investment costs when entering the industry (Roso, 2014). According to Roso (2014), the following table consists of both positive and negative road transport characteristics:

Table 1: Characteristics of road transportation

Positive	Negative
High service	Energy consumption
High reliability	Congestion and land use
Relatively high speed	Road accidents
Flexibility of route choice	Noise
Door-to-door deliveries	Emissions

The positive aspects of using road transport seemingly outperforms the negative effects when companies compare different modes for distributing their goods (den Boer et al., 2009). Companies are progressively interested in responsive transport modes because of the amplified e-commerce business, and the demand of having products just-in-time (Chopra and Meindl, 2013) (see figure 4). Consequently, companies choose to use road freight as their main transport source. It grants a high service level as there is an increased possibility to perform value-adding activities along the road. In addition, road transport is very reliable because of the number of trucks and routes. Flexibility deriving from route availability ensures shorter delivery times. Lastly, the characteristics of a truck entail the potential of performing door-to-door deliveries.

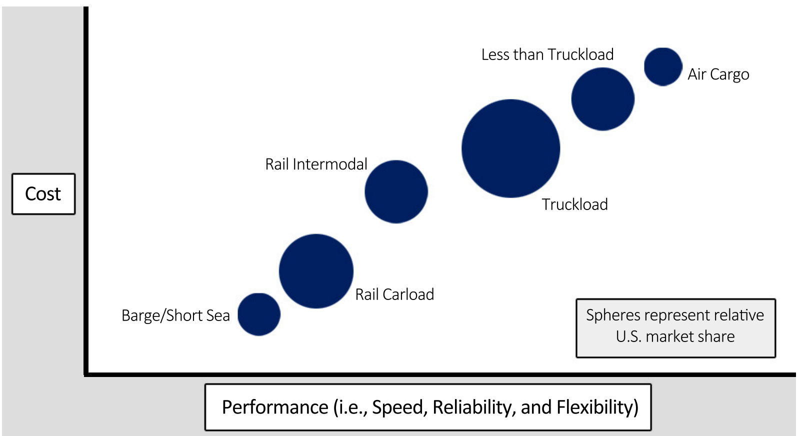

Figure 4: Modal services versus cost (authors' interpretation of Rhodes (2012))

2.2 Urban freight system

According to Chopra (2003) and Muñuzuri et al. (2005), the distribution of goods in urban areas is connected to the so called *last-mile*, which is often said to be the part of the supply chain with the highest costs. The associated freight transport activities in the urban environment are for instance goods movement between industries, warehousing and retail activities, gateway operations such as seaports, truck and train terminals, distribution centers and airports (Rodrigue et al., 2006). Since many industries' production and warehouse facilities are located in urban environments and their transport activities start and end within the urban area, it requires a material freight flow to operate the business (Lindholm, 2012a). Furthermore, urban freight transport also include activities such as home delivery services, goods storage and inventory management, office and household removals and waste handling (Allen et al., 2015). In order to satisfy the need of freight flow, vehicles and other equipment are essential. There exists a need for a developed urban infrastructure to enable the required traffic and transport activities (Wandel et al., 1991).

Urban logistics plays a major role for several reasons. Among one of the most important aspects is that it represents an essential significance to sustaining our existing standard of living. To sustain customer satisfaction of transport operations, the distribution capacity in cities must increase in the same or faster rate than the population growth (European Commission, 2007). The growing importance of urban transport is related to the increasing population and the continued economic growth in urban areas (Allen et al., 2015). Also, it appears as a vital part in retaining and overhauling industrial and trading undertakings in order to provision major capital generating activities. Furthermore, the competitiveness of an industry in a specific region is highly dependent on the efficiency of the freight sector, as cargo distribution and logistics costs have direct impact on the cost of the transported commodities. But it is also conducive to environmental effects caused by movements in urban freight. This relates to visual intrusion, congestion, energy use, pollution, and noise (Hasell et al., 1978, Meyburg and Stopher, 1974, Ogden, 1992). Consequently, matching economic expansion with environmental safeguarding and welfare is of utmost importance to accomplish better living milieus in conurbations (Taniguchi, 2015).

2.2.1 Objectives of urban freight

Six key objectives are addressed to achieve an all-encompassing solution which would satisfy all the affected entities in the urban freight system: economic, efficiency, road safety, environmental, infrastructure, and urban structure (Ogden, 1992). The defined goals and objectives necessitate a collective understanding of what the effects are for the short-term, mid-term, and the long-term future (Holguín-Veras et al., 2015). The complexity of achieving a common goal among all stakeholders is described in chapter 2.2.3.

Attaining economic viability is important as transport demand is closely associated to economic development. Goods distribution flows between and within business regions are connected to the stability of regional and national economy (US National Association of Regional Councils, 1984). The European Commission (2011) has highlighted that freight transport is directly correlated with the growth of the economy. From 1995 until 2008 the annual average progression was 2 percent, which was comparable with the growth of the intra-European Union (EU-27) economy. Moreover, during the economic recession in 2008-2009, freight transport fell 11.2 percent when the GDP in EU-27 dropped by 4.2 percent. Therefore the efficiency of moving goods and low amount of bottlenecks have direct impact on the regions productivity and growth (US National Association of Regional Councils, 1984).

Efficiency objectives relate to the operational aspects of moving the goods. Mitigating transportation operation costs is imperative as it increases the efficiency of the entire supply chain. Generally the costs are generated by the shippers, receivers and transport operators. These costs are vehicle operating costs, vehicle depreciation, terminal costs, and drivers' wages (Hensher, 1977). A more efficient use of labor, terminals and vehicles, offset the significance of these costs. Increasing utilization rates is believed to have substantial economic gains. City logistics involves a broad array of activities and vehicle operations with enormous variations in efficiency and productivity across different tasks. Ogden (1992) highlights that activities involving pick-up and delivery, are identified by low levels of productivity. The productivity is measured by the mean truck speed, the fill rates, and the average shipment size (Crowley, 1980).

The objective of road safety is to decrease the amount of deaths, injuries and property damages caused by the urban road freight sector. According to the National Research Council (2012), fatal accidents involving medium-duty trucks in the USA accounted for 300 cases in 2005. Both transport operators and policy makers have to create unilateral rules to decrease the threat of injury and death.

At present, a large majority of the urban freight vehicles are diesel-powered, which cause several undesirable external effects for the metropolitan area. The specific measures and their effect on the environment are covered in detail in chapter 2.2.4. Thus, creating desirable conditions for alternative drivelines will decrease the impact of these effects (Ogden, 1992).

The infrastructure and management objectives are mainly addressed by the authorities who are responsible for creating a set of rules for land use zoning, traffic regulations, and vehicle mass and dimensions. This involves creating clauses which restrict the usage of trucks with bad environmental performances (Ogden, 1992). For example, the city of Gothenburg has created an environmental zone in the central city to increase the air quality (Göteborgs Trafikkontoret, 2002).

Finally, the urban structure objectives correspond to the interaction between freight facilities and urban structure. Investments into freight facilities have to be aligned with the city's plans since building new distribution centers is costly for the 3PLs.

To fully reap the benefit, it is important that the construction of a new facility would follow the city's future development plans (Ogden, 1992). For example, combining the development plans will provide an opportunity to have good access to the main highways entering the city, thus decreasing the overall driving time.

2.2.2 Typical distribution tour and performance measures

A typical urban distribution tour has significant differences with intercity freight distribution. City logistics are characterized by a significantly lower average speed as the central areas involve a high density setting. This implies specific limitations on the vehicle dimensions. If intercity freight distribution mostly involves trucks with a gross weight above 18 tons, central city is generally served by smaller vehicles.

A typical urban tour (see figure 5) is the route a commercial freight vehicle follows after leaving the distribution center. The route involves loading and unloading stops at the customer sites, but also refueling and other destinations. The driver follows the specific sequence to fulfill the deliveries in the most optimal fashion. After completion, the driver returns to the distribution center to unload the goods for sorting. The trips are distinguished into two distinct trips: the distance between the distribution center and the distance covered inside the service area. The latter is also known as the *Traveling salesman tour* (TST). In the urban context, the tours are normally less than 300 km in total due to the restrictions, i.e. loading/unloading time, average driving speed, number of stops, and fixed work hours. A study in the US shows that warehouse delivery vehicles drive an average of 105 kilometers per day per vehicle (Cambridge Systematics, 2004).

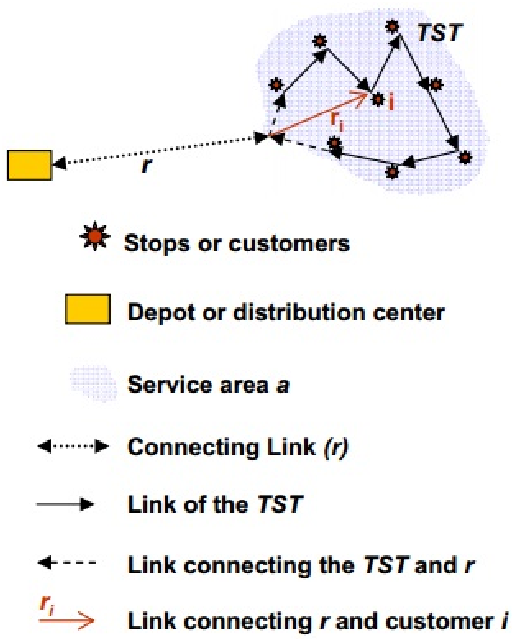

Figure 5: Basic distribution tour (Figliozzi, 2007)

The distribution centers are generally located in low-density suburban areas, which have good connectivity with the highway system. Being connected allows the drivers to deliver goods faster to the service area and reduce time spent in major congestion. An important part of the tour encompasses an analytical study to find the best fit for number of customers served per tour, the proximity of the distribution center to the service area, and the proximity amid the destinations (Figliozzi, 2007).

Since most customers prefer morning deliveries, major part of deliveries are carried out within normal business hours. According to Figliozzi (2010), the division of deliveries was the following: 13 percent of the deliveries executed before 8 AM, 45 percent of the deliveries done before 11 AM, 76 percent of the deliveries took place before 2 PM, and 99 percent of the deliveries finalized before 5 PM. The loading/unloading time for each stops will vary depending on the infrastructural conditions (Holguín-Veras et al., 2013). The presence of a loading bay reduces walking distance to the customer: distribution tours with customers who possess a loading bay will require less time than routes with customers without one. The median stop time in Sydney is 30 minutes and the respective figure for Amsterdam is 21 minutes (Figliozzi et al., 2007).

The most frequently enumerated effects in urban freight distribution are vehicle trips, vehicle emissions, vehicle kilometers, and total fuel consumed. Continuous abundant measurements in city logistics studies have identified low load factors and average speeds as indicators of a lack of efficiency of the urban freight sector. Browne's (2004) research has shown that the average load factor is only 45 percent of the entire capacity of the vehicle, and the peak-hour average travel speed was as low as 21 km/h. Moreover, a recent research revealed that 25 percent of urban trips have no cargo, e.g. empty return trips (Holguín-Veras, 2012).

2.2.3 Urban freight stakeholders

Urban freight transportation involves several stakeholders who shape how the value chain looks like. It is important to be able to distinguish various stakeholders and their interests, thus promoting collaboration between different actors. Ogden (1992) highlights that the underlying goal to reach a desired end state involves policy and planning to contribute to minimizing the total social costs of goods transport but also to promote efficiency of the system.

According to McKinnon (2015) there are five larger groups that have the capability of affecting the outcome of urban transportation solutions. These are customers, local government, logistics service providers, inhabitants, and retailers. Out of those, the author emphasizes on three groups which have the strongest power to influence and implement changes to the urban freight system: urban authorities, freight transport companies, and receivers of supplies.

The first group is responsible for creating policy measures which encourage the companies to alter their behavior. The freight transport companies are responsible and capable of impacting the actions by providing economic and ecological incentives. Understandably, the changes derive from the companies' internal benefits, but are also affected by the demand from the firms ordering the delivery. These demands might involve consolidating urban freight by ordering higher vehicle load factor, carrying out off-hour deliveries (Holguín-Veras et al., 2014), improvements in fuel efficiencies, and increasing IT communications for better planning purposes. Lastly, McKinnon (2015) states that the receivers of the supplies have a great deal of influence when it comes to urban supply chains. Holguín-Veras and Sánchez-Díaz (2016) highlight that most receivers base their ordering decisions on economic rationales to maximize their profits. They propose several initiatives to counterbalance the impacts on society and inefficiencies deriving from these activities, e.g. receiver-led-consolidation, which is expected to have the biggest impact. By adjusting their behavior and making them more flexible towards the receiving of goods, the overall urban solution can be more adaptable to sustainable solutions. As this group's sole reason is why these deliveries take place, a demand modification might lead to significant improvements in sustainability.

In addition, Ballantyne and Lindholm (2012) also recognize indirect stakeholders of urban freight transportation who have substantial input for the outcome of freight transport procedures. Potential indirect stakeholders include vehicle manufacturers, commercial associations, drivers of the vehicles, land owners, and many more.

Urban freight transportation is known for its highly complex character, which highlights the necessity for good collaboration. As stakeholders possess a strong interdependence, cooperation is of momentous importance, which necessitates a smooth and open line of communication to mitigate the barriers between various stakeholders (Lindholm, 2014). As can be seen from figure 6, the process of solving a problem in urban freight transportation which has pertinence to all the stakeholders involves several stages, and in general is highly time-consuming to execute.

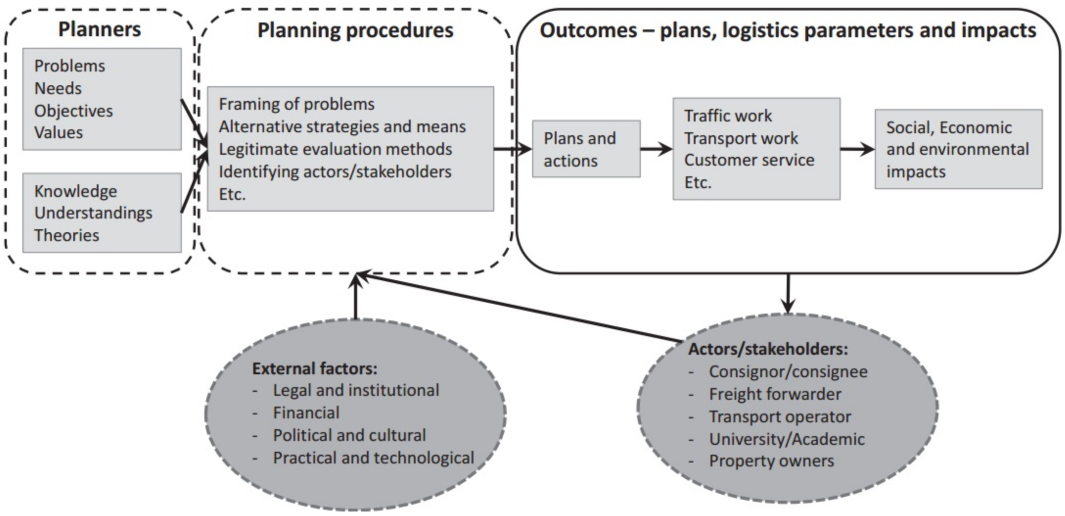

Figure 6: Framing the problem of urban freight transport (Lindholm et al., 2012)

2.2.4 Side effects and external costs of urban distribution

Allen et al. (2015) argue that the modern urban economies require effective freight transport activities. Nonetheless, these activities have both social and environmental impacts as they pollute noise, vibrations and emissions. The movement of vehicles is also a major contributor to visual intrusion, physical intimidation of pedestrians and cyclists, road safety and accidents, and road traffic congestion (Ballantyne et al., 2013).

Cullinane et al. (2012) assert that the most serious environmental challenge is the climate change. As a freight transport vehicle pollutes greenhouse gas (GHG), it is important to consider its impact on the environment, in particular the impact on climate change. Today, trucks are mainly propelled by diesel. The diesel fuel both contains hydrogen and carbon. The incomplete combustion in a diesel engine results in tailpipe emissions of pollutants such as hydrocarbons (HCs), carbon monoxide (CO) and nitrogen oxides (NOx) (Holmen and Niemeier, 2003). In comparison to petrol-driven vehicles, diesel engines emit more CO2 per unit of energy. Nevertheless, because of the diesel engine's better energy efficiency, the overall impact is less than for an equivalent petrol engine (Schipper and Fulton, 2003).

In terms of the particulate matter and nitrogen oxide emissions, the petrol engine outperforms the equivalent diesel engine. Holmen and Niemeier (2003) stress the difficulties of measuring the level of particulate matter. Still, they maintain their statement saying that the level of nitrogen oxide and particulate matter is much higher for diesel engines.

The pollutants emitted by transportation can divided into global, regional and local effects (Cullinane et al., 2012). For the global effects, six categories including 27 GHGs were established in the Kyoto protocol year 1997 (Breidenich et al., 1998). Since then, another category has been added to the protocol. According to McKinnon (2007), in the United Kingdom transport accounts for roughly 25 percent of the total energy-related CO2 emissions, of which 8 percent are connected to freight transport. Out of this percentage associated with freight, 92 percent were attributed to road transportation.

On a regional level, the two main examples of airborne pollutants that can travel by the prevailing winds are acid rain and photochemical smog (Cullinane et al., 2012). Acid rain occurs because of SO2 and NOx emissions. The photochemical smog is produced through a reaction of sunlight with nitrogen dioxide. In other words, diesel and petrol are major culprits for these regional emissions.

The local effects of atmospheric pollution are experienced close to the pollution source, where the concentration level is high. Cullinane et al. (2012) mention six categories in which the gases and particulates that have a high local impact are placed. The categories are NOx, HCs, ozone (O3), particulates, CO, and SO2.

The HCs are a result of an incomplete combustion of organic material. High level of ground-level O3 can contribute to respiratory problems and nausea. According to Fowler (2008), the effects of the O3 might be more harmful to children, asthmatics and the elderly. In addition, according to Amann (2008) there is sufficient evidence to observe a relationship between air pollution exposure of O3 and aggravation of asthma in children. The incomplete combustion of carbon-based fuels causes CO, which affects the human's hemoglobin. High levels of that substance can cause death (Cullinane et al., 2012). Lastly, the fourth category containing particulates appears mainly due to the soot emitted by diesel engines.

Considering the number of local effects when observing urban transportation one can highlight the three issues of noise pollution, congestion and accidents (Cullinane et al., 2012). As stated in Doll and Wietschel (2008), the impact of traffic noise and its effects are primarily restricted to the time of emission. Thus, it is deemed to differ from air pollutants and GHGs. Among others, the effects of traffic noise include annoyance, communication problems and sleep disturbance (Stansfeld and Matheson, 2003). Cullinane et al. (2012) describe traffic noise generated by trucks in three ways, namely propulsion noise from the power train or engine, tire/road-contact noise at higher speeds, and the aerodynamic noise which increases as the vehicle accelerates.

On an EU level, congestion has the largest proportion of the external transport effects that cost the most for society. According to European Commission (2001), road congestion costs approximately one percent of the GNP in the European Union. Furthermore, the vehicles used to serve urban distribution activities share a large impact on the environment as they contribute to the increased atmospheric pollution (Yannis et al., 2006). A French study discussed in Ülkü (2012) shows that the marginal cost external costs associated with urban traffic is ten times higher than inter-urban traffic. Golob and Regan (2001) argue that congestion is perceived as a serious problem for companies focusing on less-than-truckload (LTL), refrigerated, and intermodal cargo. This is mainly due to the congestion's significant impact on routes where delivery times are heavily restricted to the customer requirements. These requirements are for instance affected by time-windows and busy schedules.

Congestion has a great impact on CO2 vehicle emission and fuel efficiency. Barth and Boriboonsomsin (2008) state that there is a rapid non-linear growth in emissions and fuel consumption when the moving speed goes below 48 km/h. CO2 emissions double per mile when the speed drops from 20 km/h to 8 km/h. Moreover, frequent changes in speed, which primarily occur in congested areas, increase emission rates because of the consumption is not only a function of speed but also acceleration rates (Frey et al., 2008).

By studying figure 7, it appears clear that the cost of externalities related to accidents is a major concern. McKinnon (1999) argues that road accidents do not only result in personal injuries, death and material losses for those involved. It also results in delays and general inconvenience for other road users, leading to amplified effects of congestion.

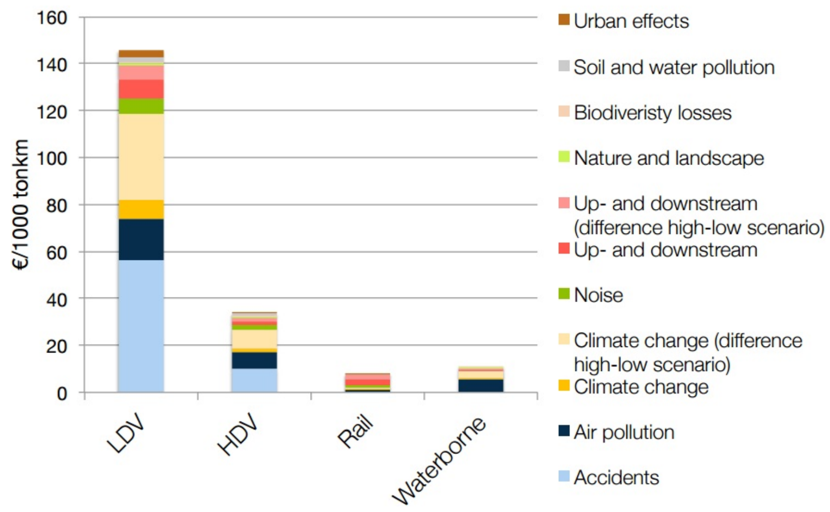

Figure 7: External costs associated with freight transport (CE Delft, 2011)

2.3 Battery electric vehicles in urban freight distribution

BEVs or electromobility is defined as a road transport system where the vehicles are propelled by electricity. Some vehicles are capable of producing their own electricity on-board (hybrid electric vehicles) as others utilize energy provided by the electric grid (Grauers et al., 2013). The batteries are normally charged while the vehicle is parked, but also capture energy from braking. The latter is also known as regenerative braking. It is important to notice that combining ICEs and alternative engines can achieve higher fuel economies for conventional vehicles, but also allow hybrid electric vehicles (HEVs) to use smaller batteries than BEVs.

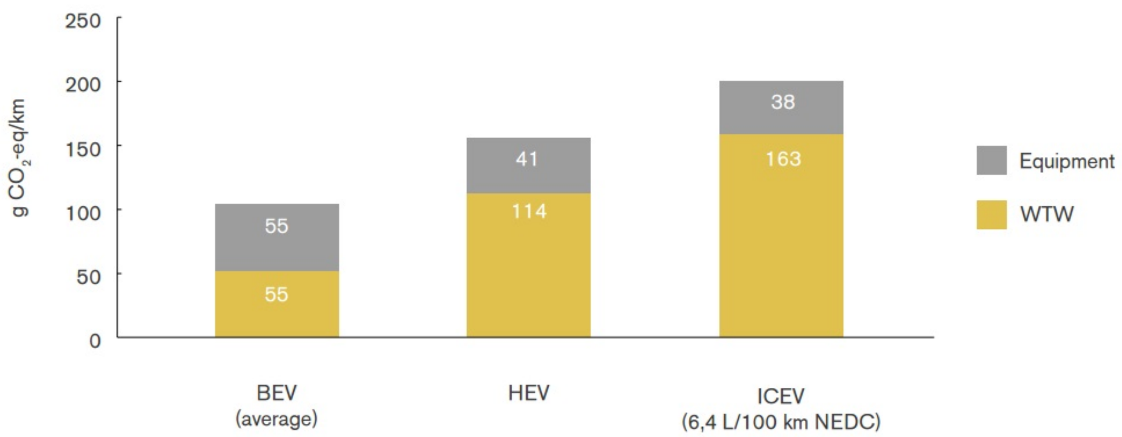

Figure 8: GHG emissions from the well-to-wheels cycle (Nordelöf et al., 2011))

As can be seen from figure 8, both BEVs and HEVs are known for their significantly lower GHG emission rates compared to the conventional ICEs. Out of all the available alternatives, they have the lowest environmental impact. But it is important to notice that the total amount of emissions will depend on the primary energy source. In addition, BEVs can reduce a significant amount of noise in traffic. With speeds below 30 km/h – which is most common in urban environments – the noise can be reduced up to 10 dBs when compared to conventional passenger cars. The gap is even larger when it comes to freight transport where the vehicles produce significantly more noise (Verheijen and Jabben, 2010). Nevertheless, it is important to bear in mind that with speeds over 30 km/h the gap becomes narrower as the tire-road noise starts to dominate. Therefore, with speeds above 30 km/h, the tire selection becomes more important to be able to reduce the total noise emission than the chosen powertrain.

Electric powered vehicles are also capable of regenerating energy through regenerative braking. This implies that there exists a possibility to recover the vehicle's kinetic energy to improve driving range (Gao et al., 1999). The BEVs are also known for its very convenient driveline. This is due to the fact that there is no lag between energy generation and usage as the power goes immediately to the wheels, thus allowing more agile driving (Karlsson, 2015). From an economic point of view, the electric powered vehicles are often subsidized by the government and also include several benefits. For example, often "green" vehicles are provided several privileges within traffic, including free of charge parking and the ability to use the bus lanes. Normally electric vehicles are characterized by higher unit prices when compared to conventional vehicles with an ICE. Fortunately the contrast is decreasing as the production cost of Lithium-ion batteries is dropping (Karlsson, 2015).

Albeit the advantages, BEVs comprise several challenges which withhold the full advancement of the technology. Namely, today the battery's properties are still considered its weak spot. Although the unit price might decrease, it is still considerably high. In addition, the degradation of the battery's energy storage over time causes the lifetime to be shorter than an ICE vehicle (Karlsson, 2015). Also, the production of batteries are highly dependent on limited raw materials (e.g. Lithium), and they can only be obtained from a few specific areas in the world, e.g. Chile, China, and Australia (INN, 2015). From a user's perspective, it is often limited by range and long charging times. Within urban freight distribution, the transport operators are most likely responsible for the necessary investments needed for creating a suitable charging infrastructure (Karlsson, 2015). This causes the technology to be even more vulnerable and undesirable.

Although BEVs are related to several advantages, suitable solutions are generally more associated with private cars than buses and trucks. Nevertheless, there are HEVs on the market which are suitable with their extended range and lower dependability on battery size. For example, Volvo is manufacturing trucks with hybrid solutions (Rosgart, 2015). Volvo in collaboration with several other entities have an on-going pilot project with electric buses in Gothenburg (ElectriCity, 2015). Moreover, Siemens is doing research for building an eHighway, where trucks are powered like trolleys (Cunningham, 2012). Having this in mind, the future for BEVs in heavy- and medium-duty vehicles and buses is promising.

2.4 Advances in all-electric freight distribution fleets

Although the initial invention of electric driveline was already done by Thomas Davenport in 1834, and at that time the technology outsold gasoline cars ten to one, history shows that for the last century the automotive industry has been dominated by ICEs (The Electric Auto Association, 2016). Nevertheless, recent history has experienced an immense surge in development of alternative drivetrains. According to O'Connor (2013), sales of plug-in electric vehicles have gone up by 147 percent between August 2012 and August 2013. As sustainability has become a hot topic during recent years, we are now seeing more and more companies investing in sustainable transport systems (Oswald and McNeil, 2009). These systems can be characterized as accessible, environmentally friendly, affordable, and safe (Russo and Comi, 2012). In general, corporations have started to acknowledge the importance of acquiring a system which is able to address economic, social, and environmental responsibilities (Oswald and McNeil, 2009). Subsequently, an overview of state-of-the-art technologies and their potential is given.

2.4.1 Smith Electric Vehicles

Smith Electric Vehicles is a company that markets and produces a wide range of zero-emission electric vehicles. The company's mission is to manufacture trucks that have higher efficiency and a lower total cost of ownership than traditional diesel trucks. Although they have a wide-ranging array of customers in food & beverage, utility, telecommunications, retail, parcel and postal delivery, military, and grocery (Smith Electric Vehicles, 2016b), the research is delimited to medium-duty freight distribution vehicles. This means that the focus will lie on vehicles with a gross weight between 12-18 tons, thus only including Smith's Newton trucks.

One company that has invested greatly into more environmentally friendlier solutions is America's top selling snack company Frito-Lay. They currently possess the largest fleet of all-electric trucks in North America, with 176 Smith Newton trucks, operating in New York, Ohio, Columbus, and Ft Worth. After investing on electric driven trucks, they have been able to benefit from 75 percent lower fuel costs than diesel. As reported by O'Connor (2013), a Smith truck is roughly $10 000 more expensive than its diesel-powered counterpart, but low maintenance costs and fuel savings will allow a return on investment within three to four years. Furthermore, as the urban environment is sensitive to noise pollution, utilizing these trucks has significant effect as they operate in virtual silence. The technical specifications foresee that these vehicles deliver a top speed of 88 km/h, a payload of over 7 250 kg, and a range of 65-190 km on a single charge (Smith Electric Vehicles, 2016c). A complete recharge should take approximately 8 hours, which can be completed during the night (O'Connor, 2013).

Another company which recently invested in Smith Electric Vehicles is Coca-Cola. The liquid refreshment corporation proclaimed initiating a fleet of 16 refrigerated electric trucks (see figure 9), which will be utilized around the Bay Area, San Francisco. In addition to those, Coca-Cola at present controls a number of alternative fuel fleets, comprising an excess of 650 hybrid and natural gas trucks.

Figure 9: Refrigerated all-electric Smith truck (O'Connor, 2013)

2.4.2 Renault Trucks

Renault Trucks is also known to invest large amounts on environmentally friendlier modes of transport. Recently, during the 21st United Nations Climate Change Conference (COP 21) in Paris, Renault presented two of its newest innovations on behalf of the Ile-de-France French Environment and Energy Management Agency. The first of these is an all-electric 4.5 ton truck, and the second a 16 ton all-electric truck (Renault Trucks Corporate, 2015). The former is going to be excluded because this research will solely focus on medium-duty trucks, i.e. trucks weighing between 12-18 tons.

The largest of these trucks (see figure 10) is currently in the midst of an on-going test period with Speed Distribution Logistique on behalf of Guerlain. The past 18 months of testing have revealed that the vehicle does not generate any emissions or noise during its nightly deliveries to several boutiques in Paris. The vehicle is capable of fulfilling 200 km delivery routes with the support of partial recharges carried out throughout the daily routine. The current routes have been planned so that it is able to perform two partial recharges during the day. The truck also receives a total overnight recharge between 7 PM and 2 AM (Renault Trucks, 2014). Although the exact figures are non-disclosed, records from similar partial recharging solutions are considered adequate. For example, all-electric Volvo buses utilized in central city of Gothenburg receive additional 12km of range from a 6 minute recharge (AB Volvo, 2014, Allenström, 2016). To prevent stoppages during the delivery routine, the daily delivery route is meticulously planned with route optimization programs according to its capacity. The continuing trial period is set to be completed by 2020, when the company intends to present an economically viable zero-emission solution for its clients (Renault Trucks Corporate, 2015).

According to the truck's specifications, it will be capable to carry a payload up to 5 500 kg, with an operating range of 120 km (without partial recharge). The battery size is 170 kWh, weighing approximately 2 tons, with a full charging time of about 7 hours. The engine itself is relatively small, with just 103 kW, which is comparable to one of the Tesla Model S. (Kane, 2014)

Among some of the more notable users of these trucks is the French multinational retailer Carrefour, which has been testing them for a few years (Nicolas, 2014), but also the transport operator Deret. Deret is a haulage company that serves duty free shops at the Paris Charles-de-Gaulle Airport. The supervision of the energy supplies for the entire fleet is carried out by the vehicle's energy management system. The system itself is controlled by a dedicated computer, established in collaboration with IFP Energies Nouvelles. By using the preset algorithms, the fleet is capable of performing in the most optimal way, thus, mitigating energy consumption and increasing range (Automotive Fleet, 2015).

Figure 10: All-electric Renault Truck D (Kane, 2014)

2.4.3 Ginaf truck & EMOSS truck

The Dutch origin truck manufacturer GINAF produces predominantly heavy duty off-road trucks, but also vehicles for construction and agronomic work. Although generally focusing on specific off-road transportation vehicles, the company has since 2011 – after being taken over by Chinese Hi-Tech Group Corporation – conducted research in all electric drive trains (GINAF, 2016a). Recently they have developed all-electric urban distribution vehicles with gross weight of 12 tons, a loading capacity of 9 tons, and a driving range of 200 kilometers. The GINAF E-series have the biggest electromotor with 280 kW (GINAF, 2016b). These trucks were developed in cooperation with FREVUE and are being utilized by Heineken Nederland in the city of Amsterdam (FREVUE, 2015, Pink, 2015).

EMOSS truck is another corporation based in the Netherlands. The firm has a long history in electromobility, operating in the industry of electric powertrain development, with its own production and sales departments for electric buses and trucks (Emoss, 2016a). EMOSS's development in the electric truck department has had significant advancements, mainly being driven by recent increase in stricter control of emission pollution, noise regulations and tighter time windows for deliveries. The company's current output range of configurations is very wide with the potential customer given the opportunity to choose battery capacities from 40 kWh up to 300 kWh. This gives the vehicles a range from 25 to 300 kilometers, which is currently one of the highest on the market. At this moment, the customers can choose from three different types of trucks – the 12 ton, the 16 ton, and the 18 ton. Understandably the charging times and payloads vary for different trucks (see figure 11): the largest truck has a carrying capacity of 10 966 kg, the 16 ton electric truck's payload is 9 992 kg, and the smallest alternative can carry a maximum of 6 550 kg. The top speed for all the variants is 85 km/h and the average charging time is between 7-8 hours. (Emoss, 2016b)

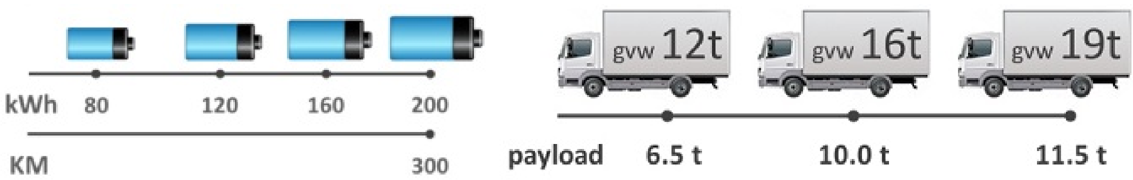

Figure 11: Flexible configurations of EMOSS trucks (Emoss, 2016b)

At present, EMOSS is in its finishing stages with a no-emission urban distribution project carried out in alliance with Hytruck. The research is done in various fields of work, the bigger customers being Heineken in the inner city of Rotterdam and Sligro wholesale foods. The trial period comprises eight trucks in total, four that are based on a 12 ton DAF LF45 framework with battery packs of 120, 160 and 200 kWh. The remaining four vehicles, based on the DAF LF55 chassis, are two 16 ton and two 18 ton e-trucks, each possessing 160 and a 200 kWh battery capacities. (Pink, 2015)

2.4.4 Other companies

Apart from the aforementioned companies, there exist other all-electric freight vehicle manufacturers. The American Zenith Motors and Hong Kong's FDG Electric Vehicles Limited are companies that are experiencing significant growth in their respective fields. The former is a privately funded company mainly servicing hotels, airports, hospitals, governments, commercial delivery and service businesses (Zenith Motors, 2016). The latter is listed on the Hong Kong Stock Exchange and is specialized in solutions for city/rural travelers, city logistics and business travelers. FDG is dedicated to the manufacture of electric vehicles such as coaches, medium and minibuses, commercial vehicles, SUVs and other models. As FDG is a vertically integrated electric vehicle producer they have all the vital departments in-house – R&D, production, distribution and sale of Lithium-ion batteries (Smith Electric Vehicles, 2016a). DHL Express has recently considerably expanded their US electric truck fleet by ordering 45 all-electric delivery trucks from Zenith. The world's largest logistics operator Deutsche Post DHL Group has strict emission targets aiming to improve carbon efficiency by 30 percent during a period from 2007 to 2020 (Cassidy, 2015).

The Chinese-based company BYD is the world leader in the development and sales of new energy vehicles, i.e. about 11 percent of the entire global new energy market (BYD, 2016a), and has a wide array of industries that they operate in. These are IT industry related rechargeable battery business, handset and computer components, assembly services, in addition to new energy vehicles in the automobile industry. Presently, the company has roughly 180 000 employees and 22 industrial parks around the globe (BYD, 2016b). In their automotive departments they mainly focus on commercial electric cars, but also all-electric urban public transportation buses and light-duty trucks. BYD has been working on two different types of trucks – the T5 and the T7 – both with dissimilar carrying capabilities. Reportedly, the T5's range is an outstanding 250 km with a battery capacity of 145 kWh (Drive Clean Chicago, 2016), the top speed is limited to 50 km/h (Ning, 2014), and the gross weight of the vehicle is 7 320 kg (BYD, 2016a). The respective figures for the larger pure electric T7 are 200 km with a battery capacity of 175 kWh (Drive Clean Chicago, 2016), and 10 695 kg (BYD, 2016a). The price tag for North American customers for the all-electric T5 is $90 000 and $88 004 for the larger truck (Drive Clean Chicago, 2016). Recently the company launched the first batch of 35 pure electric vans to serve the DHL International Air Express logistics center (BYD, 2016a).

Notwithstanding, these honorable mentions do not compete in the same market as Renault Trucks, Smith Electric Vehicles, Ginaf trucks, and EMOSS trucks as their products are categorized for light-duty freight distribution or urban public transportation. Hence, these trucks will not be the primary subjects in the analysis of this research.

2.5 Summary of electric trucks

Table 2 provides a good comparison of the existing BEVs on the market. The comparable categories are the gross weight, the maximal payload, the range, and the engine size of the vehicles. Currently, the EMOSS truck is dominating in all the categories. With its 18 ton trucks they are two tons heavier than the closest alternative. Also, due to its bigger dimensions, the payload is up to 10 966 kg, which is roughly two tons more than Ginaf's trucks with 9 tons. Because of its larger carrying capacity, the vehicle is equipped with the biggest batteries, which supplies it with a 300 km range. The second best medium-duty vehicle is limited to a maximum range of 200 km.

Table 2: Comparison of existing all-electric trucks

	Gross weight	**Payload**	**Range**	**Engine**
Smith Electric	12 t	7 250 kg	190 km	120 kW
Renault	16 t	5 500 kg	120 km	103 kW
Ginaf	12 t	9 000 kg	200 km	280 kW
EMOSS	12, 16, 18 t	Up to 10 966 kg	300 km	Up to 300 kW
Zenith	4.6 t	1 724 kg	129 km	62.2 kW
FDG	n/a	n/a	260 km	140 kW
BYD	10.7 t	n/a	200 km	175 kW

2.6 Value of time

Time is a valuable and limited resource for individuals and businesses. Transportation investments and policies can affect the utilization of time in freight distribution. ODOT (2014) claims that travel time is one of three primary types of user costs associated with travel. The other two are costs related to operating the vehicle and safety. These cost factors for travelling can also be applied to transportation.

Kawamura (1999) mentions three methods used in research for determining commercial vehicles' value of time. The most basic evaluation method is the cost savings method. It is based on the cost savings for operators per unit of time. Adding an estimation of the net profit increase resulting from the reduction in travel time is the second method, i.e. the revenue method. Lastly, the willingness to pay method measures the market's perceived value of time under trade-off situations concerning time and money.

The differences between the three methods can be seen in figure 12. The top part of the figure shows the elements included in the cost saving method. This is followed by the revenue method and subsequently also the willingness to pay method including all the required elements.

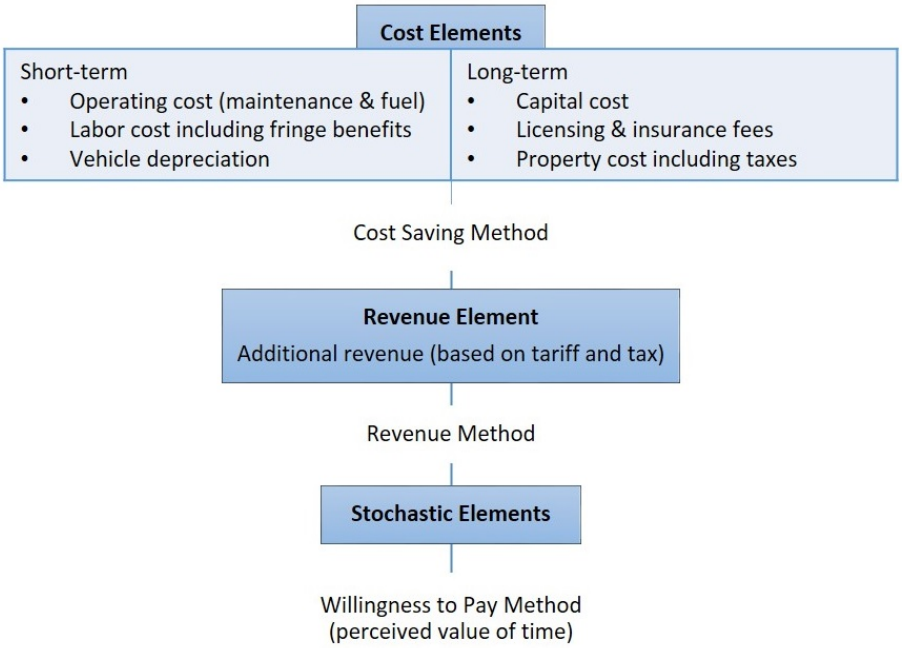

Figure 12: Determinants of Commercial Vehicle Value of Time (Kawamura, 1999)

The cost saving method is used to compute savings or increases in expenditures when altering the transport time. Kawamura (1999) distinguishes between short- and long-term cost savings. The distinction is based on the time span required to realize the savings. While the short-term factors are focused on daily operating costs, long-term factors involve reductions in capital investment costs such as terminals and truck fleets, which require long-term business planning.

The revenue method is used to compute the value of time based on the varying profit that occurs when changing the transport time. Simply described, the method is extracted by adding a revenue element to the cost saving method. The element consists of the additional revenue generated from transport time savings to increase business volumes. Accordingly, the value of time when using the revenue method is affected by the utilization level of the saved transport time.

The willingness to pay method is used to measure the trade-off between time and money a company is willing to pay. This method is more practical than the theoretical revenue method. Kawamura (1999) mentions the possibility of equating both methods if a firm would have perfect knowledge of the aforementioned trade-off. However, as the perceived value of time is subjective, real-world scenarios rarely reflect the theory completely.

Lastly, it is not clear who benefits on time savings in distribution. Although it might benefit the transport operator's productivity it should take into account that it is not certain if other stakeholders benefit from it, e.g. customers, inhabitants and retailers (Zamparini and Reggiani, 2007).

3

Methodology

This chapter will present the research process of the thesis, and what is conducted in order to satisfy the purpose. This is followed by a subchapter which describes the rationale behind the selection of the particular subject for the case study. Subsequently the data collection process will be described, including an explanation of how primary and secondary data sources were collected. Finally, a discussion about the quality of the data is provided. By showing in detail what data sources are gathered and how they are utilized, the reader will have the opportunity to recreate and evaluate the trustworthiness of the research and the outcome.

3.1 Research process

The research process includes the steps of how the project will evolve over time in order to reach the deliverables and subsequently satisfy the research purpose. Figure 13 is presented to illustrate the research process and how the objectives are interlinked with each other. A detailed explanation is provided below.

First and foremost, the objective (RQ 1) of getting an overview of the truck drivers' activities and its associated time consumption in urban distribution to discover potential improvement areas is targeted. At first, an appropriate test subject for the research is selected. Thereafter, a time study is conducted to fulfill the objective of identifying different activities. After executing the field study, the gathered data is compiled and analyzed. This will enable a possibility of analyzing the time consumption of the truck drivers' activities.

After satisfying the first objective, the gathered information will be complemented by interviews with manager-level representatives and truck drivers from Company X. The interviews will give insights into what the associated people think about the efficiency of the current operations and what they believe might support advancements. In addition, a literature review will be conducted to understand what improvements have been suggested previously and their relevance to the research at hand. The input from the interviews and the literature review will allow the authors to conduct an analysis on the potential improvements of time efficiency in the truckers' daily work routine (RQ 2).

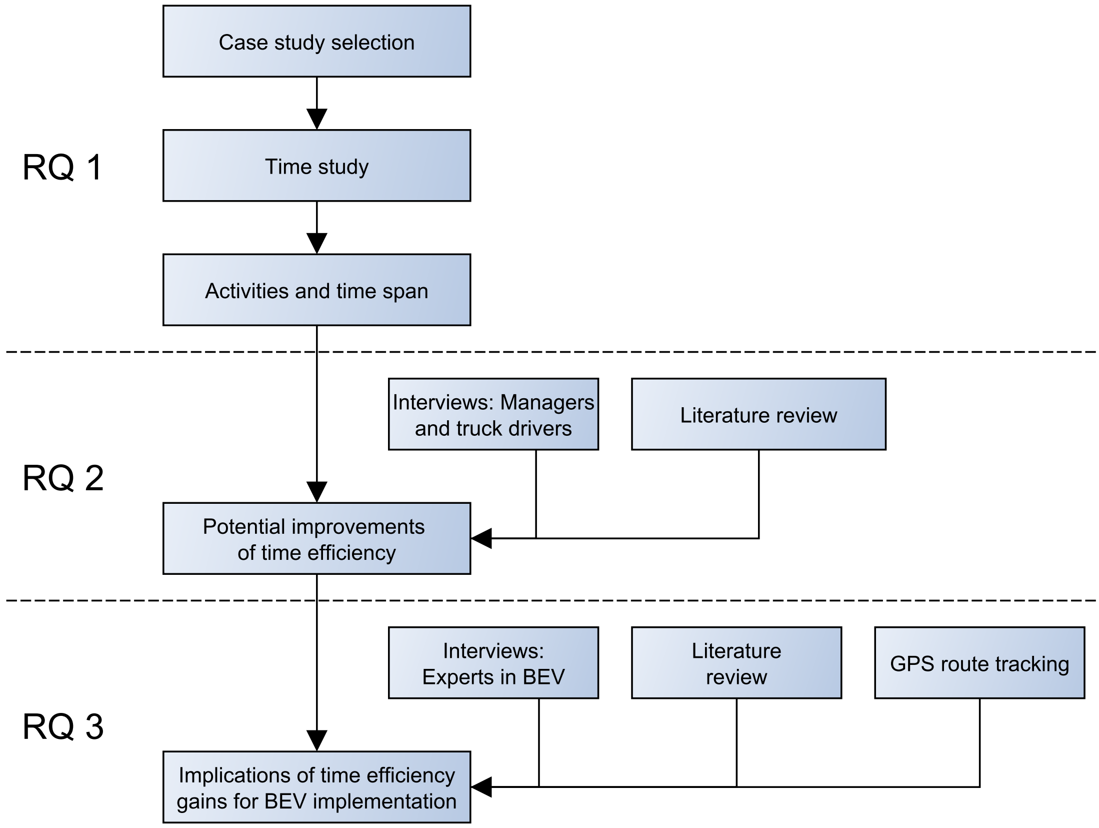

Figure 13: Research process

The obtained information from the previous objectives allow an assessment of the implications of the time efficiency gains for BEV implementation (RQ 3). This is an evaluation of the possibility of exchanging conventional ICEs with electric-powered trucks and what adjustments are necessary to promote a successful change. Qualitative and quantitative data are prerequisites to discuss and assess the feasibility of using new vehicle technology in urban distribution. Therefore, the aforementioned studies will be complemented by interviews with experts from both the academia and industry. In addition, GPS tracking gives excellent comprehension of the characteristics of the distribution tours. It is important to achieve an outlook on the demands as the technology of using electric-powered trucks is limited by driving range. The gathered data will be used to identify and analyze challenges and opportunities, but also to propose potential solutions.

3.2 Case study: Company X

This section presents the rationale behind the decision of the subject for the case study. Volvo's good connections and strong partnerships with several transport companies made it possible to collect data from real world scenarios. Therefore the field research was done in cooperation with a transport service provider. The selection for the particular transport operator involved several criteria. It was imperative that the chosen company would have a large fleet of medium-duty trucks with operations in the urban environment. Preferably, the company would also have a large local market share. This meant that the distribution route would involve a high amount of different recipients. Since Company X met all the conditions, it allowed the researchers to examine the efficiency of their distribution.

Choosing a well-known company with a wide array of customers and commodities provided a chance to focus on specific segments. The goal was to focus on commodities with a similar distribution pattern to provide an accurate overview. The research at hand chose the distribution of consumer goods and daily commodities (pallets and small packages) as the focal commodities. Often the distribution pattern for one commodity cannot be extrapolated to other groups, thus mixed cargo/parcel and post were excluded. Acquiring a comprehensive overview of the characteristics of their distribution tours provided an opportunity to analyze the possibility of a technology shift by utilizing BEVs for urban freight distribution.

3.3 Data collection

In common terminology, research is described as a pursuit for knowledge (Kothari, 2004). Research is done within a preset specific scope, which means that the research process is a systemized exertion to acquire new knowledge (Redman and Mory, 1923). In most cases, the data can be categorized by the source of the information, but also the purpose of the findings. After the research problem was defined, the sources were divided into two types of data, primary and secondary (Kothari, 2004). The former are those which are gathered afresh and for the first time. This means that the collected data is original in its character. The latter are the type of data that has been previously gathered by other researchers and have already gone through the statistical process (Kothari, 2004). The following subsections will describe how the necessary information was gathered for the research at hand in the interest of having a solid basis for the analysis.

3.3.1 Primary sources

The primary sources were considered as the data with the highest input for this research. The methods used for the thesis involve both field and desk research, qualitative and quantitative (Kothari, 2004). The setup of the research foresaw an opportunity to collect data via three different primary sources – a time study, route tracking, and semi-structured interviews (see Figure 14).

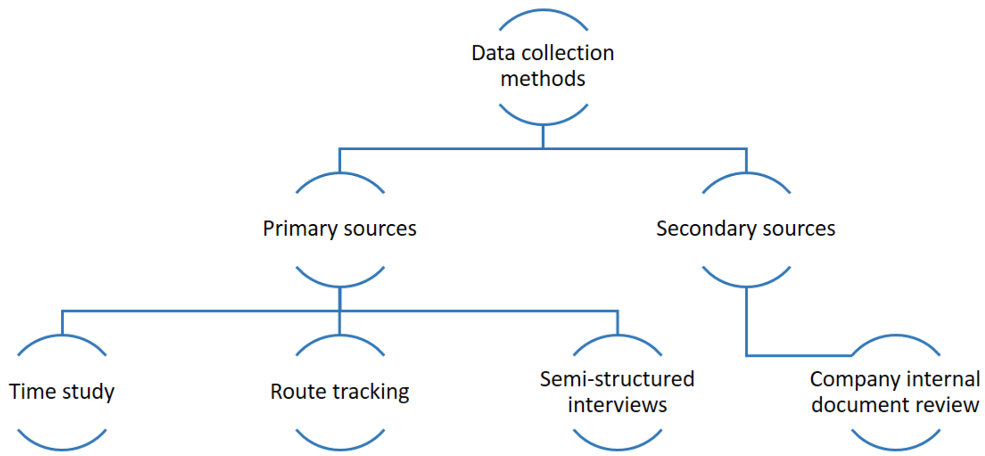

Figure 14: Data collection methods

3.3.1.1 Time study

Salvendy (2001) has defined time studies as follows: "Time study is a work measurement technique for recording the times and rates of working for the elements of a specified job carried out under specified conditions and for analyzing the data so as to obtain the time necessary for carrying out the job at a defined level of performance." Understandingly the underlying goal of the time study is to be able to determine time standards for all activities, and see how much the activity varies from a standard time. By establishing time standards for different activities, it will be possible to collate the standard times with direct and indirect deviations caused by fatigue and/or other personal and unavoidable delays. The cause for such delays can also be related to miscommunication, staff and equipment temporarily been redirected, bad weather conditions, traffic congestion, vehicle breakdown and several other similar reasons (McKinnon et al., 2008).

A time study is the only technique that actually measures and registers the accurate real time taken by an activity. Furthermore, it enables the users to perceive a holistic work cycle, thus making available an opportunity to put forward and set method improvements in motion. In addition, the study is of a relatively simple nature, providing a short learning curve (Salvendy, 2001).

Some of the drawbacks are related to the time requirement. As all the activities have to be intricately documented, the researcher has to follow the worker throughout the entire process. This becomes especially excruciating when a long time frame has been chosen and/or a task with a repetitive character is observed. Furthermore, a time study is only limited to activities with a repetitive nature (Chand, 2014).

To obtain the necessary data for this research, an extensive time study was conducted. The gathered information was used as the main input for the thesis. It comprised following two truck drivers throughout the entire workday for five consecutive days and timing all the activities. The additional objective for the research was that the equipment used needed to be reliable and inexpensive. The reliability aspects comprised features like laptop battery life duration and usability throughout a trucker's daily routine. Generally time studies use four basic elements: a precise and consistent stopwatch, a well-designed time study template, a calculator to calculate the chronicled annotations, and a time study panel. Often video recording is also used.

To avoid unnecessary time expenditure, the researchers decided to align modern technology with knowledge, and created a time study template as an Excel spreadsheet, thus minimizing the amount of necessary elements from four to one, i.e. a laptop. The worksheet (Appendix A) contains all the necessary fields to perform a successful time study: the start time, the end time, the duration, the activity, the description of the activity, the activity code, and the comments. To further secure a successful capture of the necessary data, a wrist watch along with a printed version of the time table was brought along. This guaranteed that the information will be obtained even in the event of a technical failure, such as a computer breakdown.

The Excel spreadsheet is generated in a way that the user only needs to choose the relevant activity code and press *Enter*. By doing this, the worksheet automatically took the end time of the previous activity and activated the start time of the next activity. During that time the duration of the latest activity was calculated. The name of the activity and the respective description was drawn from the premade table (see Appendix B). When the researchers perceived an activity which did not correspond to any of the prelisted activities, it was placed in the *Others* category with a comment explaining what had occurred. The comment provided the researchers an opportunity to later add an additional activity or place it under one of the prelisted activities. Nevertheless, if some events were not with a repetitive manner and/or were not possible to allocate to a specific category, the event remained under the *Other* category. Moreover, the premade activity table was color coded to distinguish different study areas and avoid typing errors. This way of data collection allowed maximal time efficiency and avoided missing relevant data, thus increasing the reliability of the field research. All parameters besides the activity code and comments included a specific formula presented below in table 3.

Table 3: Time study formulas

Start time	=IF(C8<>"";IF(C3="";NOW();C3);"")
End time	=IF(D3<>"";D3;"")
Duration	=IF(C4<>"";C4-C3;"")
Activity	=IF(C8<>"";VLOOKUP(C8;$J$5:$L$33;2;FALSE);"")
Description	=IF(C8<>"";VLOOKUP(C8;$J$5:$L$33;3;FALSE);"")

3.3.1.2 Route tracking

The reasoning behind the route tracking was to obtain information about the distribution trips' characteristics in terms of distance, duration and elevation. The data was collected to determine the feasibility of electric driven trucks for distribution in urban environment.

The route tracking was carried out using two Garmin eTrex 10 devices. Two devices were used for the empirical study to increase the validity of the data. As the data gathering was performed during a period of five working days, the use of two devices enabled to observe two trucks and thus doubled the amount of data collected. The device was placed in the truck throughout the entire distribution trip. Because of the urban characteristics with many streets and tight curves the recording interval was set to level four out of five. This means that the device recorded the location of the vehicle after every 10 seconds or 50 meters had passed. Consequently, the data achieved was sufficiently accurate for the study. In case the level was set to five it had only contributed to larger files and excessive data without additional value. Moreover, since the Garmin eTrex 10 had a maximum limit of 10 000 points (Garmin, 2016), the combination of more detailed data and a longer route could have caused a risk of not having enough memory capacity in the unit. After each distribution trip, the tour log data was exported to a computer as a *.GPX* file extension.

The choice of using the Garmin eTrex 10, and not a smartphone, as a tracking device was based on the vulnerability issue. Due to the fact that one of the main features of the Garmin GPS involved route tracking, it was considered as the more stable option in comparison to a phone, which has many different applications. In addition, the choice of using the GPS device was also supported by its better battery life, i.e. 25 hours (Garmin, 2016).

The starting point for the tracking was at the Company X terminal, marked as an orange house on figure 15. The area within the red circle marks the central city and the focus area of this research. Although the research focuses on urban freight distribution, the routes were designed by Company X to cover some suburban regions as well.

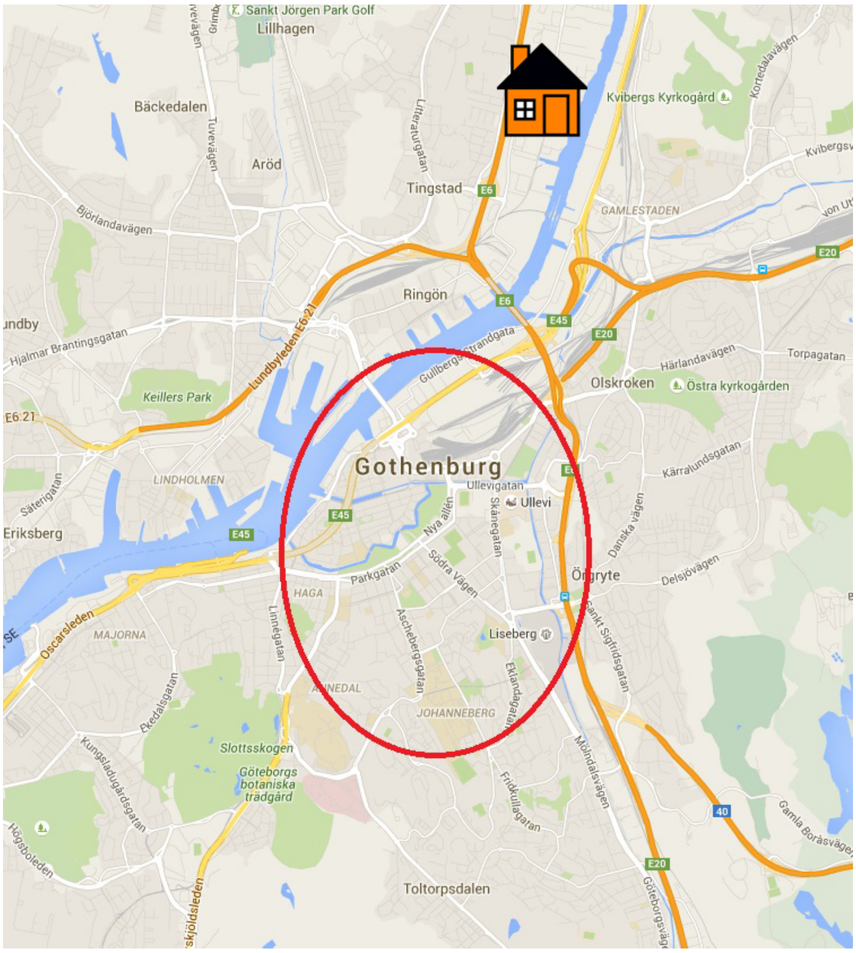

Figure 15: Company X's distribution center and the service area

3.3.1.3 Interviews

According to Merriam-Webster (2016a) an interview is "a meeting at which information is obtained (as by a reporter or pollster) from a person". It is a labor intensive qualitative research method, which takes a great deal of time. In addition to the actual activity of interviewing someone to obtain valuable information, the researcher has to conceptualize the project, establish contact with potential participants, gain access to relevant data, and set up meeting dates. Furthermore, after fulfilling the interview, the researchers have to transcribe the attained information, process the material, and report the key findings (Seidman, 2013). Hence, the interviewing process can be described as a highly demanding process, through which valuable information is acquired not only to evaluate the interviewees, but to comprehend their experience and the meaning of it.

Gill et al. (2008) distinguishes three fundamental types of research interviews: structured, semi-structured and unstructured (see figure 16). Structured interviews are principally a list of predetermined questions with little or no variation. Generally structured interviews do not anticipate follow-up questions for further elaboration.

Therefore, this interviewing style is seen to be as a relatively swift and stress-free way to administer. Nevertheless, as these types of interviews lack in flexibility, they by nature only allow a limited amount of variance in participant responses (Gill et al., 2008). Therefore they are prone to sometimes miss relevant information.

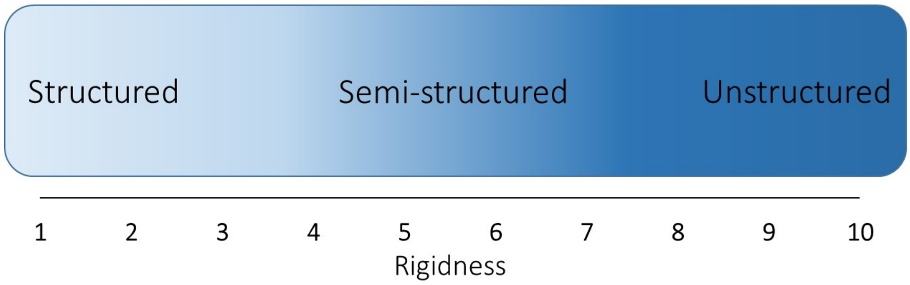

Figure 16: Interviewing styles (authors' interpretation of Gill et al. (2008))

In contrast, unstructured interviews are flexible and allow a high degree of openness. Normally this style does not reflect any predetermined models or philosophies and is executed with minimal or no structure. This type of interviewing technique often starts with an open question and proceeds basing on the received response. In comparison to a structured interview, unstructured interviews are very time-consuming and arduous, and might be difficult to control. Generally this type is used by experienced and influential interviewers who are capable of directing the outcome of the meeting. The most common circumstances where this type of interview is preferred, are situations when nearly nothing is known about the subject area (Gill et al., 2008).

Semi-structured interviews are a combination of both of the aforementioned approaches, combining the rigidness of the structured interview and the flexibility of the unstructured one. In most cases, these interviews comprise of several key questions helping the researchers to make sure that the interview stays within the preferred scope, but also allows them to go more in depth if necessary. This results in an all-inclusive array of responses that are significant for a comprehensive analysis, but also highlights some key aspects which were overlooked and not seen as pertinent prior to the interview. Semi-structured interviews are most frequently used in qualitative research, providing participants helpful guidance throughout the process (Cohen and Crabtree, 2006, Gill et al., 2008).

During the research period various actors with different roles were interview in order to obtain a better understanding of the research area. In addition, the interviews provided an opportunity to discuss the prevailing complications, but also the areas with significant improvement potential. The interviewees were from three distinct branches, but conjointly they would give a comprehensive perspective of the status quo, future development areas, and challenges in their respective fields. Prior to the meeting the targeted actors were researched in order to get a better understanding of their core competences. This allowed the authors of this thesis to create appropriate questionnaires and avoid introducing unsuitable and irrelevant topics, thus increasing the outcome quality of the interview and utilize better time management. All questionnaires were completed and distributed to the interviewees before the interviews took place. Nevertheless, as semi-structured surveys were used, the researchers experienced flexibility and could adjust and/or add questions to the premade version. To increase the value of the interviews, it was highly important to ask clarifying questions to fully understand the answer, but also skip some questions which were answered by a previous response. Distributing the surveys beforehand also allowed the targeted actors to better prepare for the meeting. The authors believe that this increased significantly the quality of the responses, especially since some of the questions were very specific.

The semi-structured interviews took place during April 1st until May 2nd, as shown in table 4. In total 6 face-to-face interviews took place with targeted actors from Volvo Group Trucks, Company X's management, Company X's truck drivers, Chalmers University of Technology, and Viktoria Swedish ICT. The authors got substantial assistance from both the supervisors from Volvo and Chalmers when choosing appropriate interviewees. Furthermore, the respondents were asked to propose additional potential interview subjects during and after the interviews. This allowed to have the best coverage by experts in the industry and academia of the research area. Both authors attended all the interviews, which averted misalignment in knowledge and understandings of the obtained information. The tasks were divided with one researcher leading the interview and the other gathering all the information and following up if all the questions were properly answered. The average duration of the interviews was about 45 minutes.

In table 4, three columns indicate the following information – the time of the interview (Date), the subject(s) of the interview (Interviewee) and the focus area that was covered (Interview topic). As shown in the table, one interview used an interactive focus group setting, comprising of 11 drivers to fulfill the qualitative research. This allowed the group to freely discuss, propose and analyze the questions, allowing the researchers to benefit from a larger array of pertinent responses relevant for the thesis. The input from those meetings had great influence on the analysis part.

Table 4: Conducted interviews

Date	Interviewee	Interview style	Interview topic
01.04.2016	Erik Allenström	Semi-structured	Advances in Volvo's BEV technology
05.04.2016	11 truck drivers	Focus group	Potential improvement areas in urban distribution
05.04.2016	F.N	Semi-structured	Company X's future visions and current standing
05.04.2016	J.V	Semi-structured	Company X's interest in alternative powertrains
07.04.2016	Magnus Karlström	Semi-structured	Prospect of BEVs in urban environments
14.04.2016	Steven Sarasini	Semi-structured	Integration of alternative powertrains in urban freight distribution
02.05.2016	H.S	Semi-structured	Company X's marginal costs and evaluation of value of time

Along with the semi-structured alternative, unstructured interviews were used. As the researchers were located at Volvo Group Trucks Technology facility, this gave them a good opportunity to get additional clarifications from the employees in a swift and effortless manner. These spontaneous unstructured interviews or follow-up meetings took place throughout the entire research period. Their core purpose was to obtain quick guidance or explanations for responses given during the semi-structured interview. Unstructured interviews and biweekly meetings with the supervisor are excluded from the list due to different characteristics. This means that both alternatives did not go through the same level of preparation as the semi-structured option and were more of informal type. Nonetheless, they must be mentioned as they gave significant support and direction in order to fruitfully administer and conduct the thesis.

3.3.2 Secondary sources

To obtain credible quality, it is important to find, analyze, and evaluate potential usability of previous research from the company's internal documents. The thorough review of secondary sources is also done to acquire fundamental understandings and motives behind previous studies. This provided the authors the opportunity to juxtapose the correlation between our findings with previous studies. The secondary sources are essentially of supportive nature and their existence will help the authors avoid duplicating similar research.

3.3.2.1 Company internal document review

In addition to the obtained academic literature, numerous internal documents and researches were used to increase the validity of the research. Furthermore, the review was conducted in order to avoid replicating a study previously composed by Volvo Group Trucks Technology. This is essential as the goal is to provide new knowledge and introduce innovative findings in the urban freight distribution routine. Analyzing previous studies gave noteworthy influence when choosing the main focus and direction of the research. Due to the fact that these documents rather offered a guiding input and were created with a different focus, the documents are considered as secondary sources. Moreover, the internal documents were necessary for understanding in what direction Volvo Group Truck Technology strives towards and how the current state of the research looks like. In conjunction with the aforementioned aspects, the internal document review helped the authors organize and prepare the time study by utilizing and adjusting previously used templates.

Some examples of the mentioned documents are observation protocols, time study templates, category descriptions, internal presentations, and feasibility studies. Moreover, Volvo Group Trucks Intranet (i.e. Violin), has granted access to internal documents pertinent for this research.

3.4 Quality of data

This section comprises a discussion regarding the quality of data. The data quality level of the thesis is determined by targeting the accuracy in terms of reliability and validity. According to Sachdeva (2009), sound measurements must meet the test of reliability and validity. This view on data quality evaluation is shared by Patel and Davidson (2011) who state that the reliability and validity of data depend on the empirical findings and the associated data processing. Sachdeva (2009) claims that the researcher frequently switch between two perspectives, theoretical and observational. In other words, the theoretical part describes how the world is thought to work and the observational part defines the reality of what is really happening. The authors also argue that the reliability and validity of a study are essential building blocks to ensure a match between both perspectives. Before the discussion goes deeper into the details of reliability and validity the authors of this thesis present their own opinion about the weaknesses of the project.

The researchers of this thesis admit it was difficult and time-consuming to interpret and understand the purpose of the problem to be solved. Consequently, a lot of time was spent in the first phases of the project when clarifying any ambiguities and developing the research questions. Moreover, in order to aggregate the data which was collected in the time study the authors established an Excel work sheet. As standardized categories were used the authors of this thesis admit it could have limited the accuracy of data. On the other hand, activities' duration could more precisely be registered and thus increased the quality of data.

Furthermore, the authors concede it was somewhat arduous to interpret the information given by the interviewees, hence, it was hard to pick out the accurate high quality information. With the problems in mind, the authors still feel confident regarding the quality of data, even though some misinterpretations might exist.

3.4.1 Reliability

As stated by Kothari (2004) reliability refers to the consistency of a measuring instrument. A reliable instrument contributes to validity, but a reliable instrument does not necessarily have to be a valid instrument. For instance, a repetitive measurement which continuously gives a marginal error of five percent is reliable but not valid because of the error. Moreover, Kothari (2004) emphasizes two aspects of reliability, namely the stability aspect and the equivalence aspect. The former relates to securing consistent results with repeated measurements of the same measuring object and with the same instrument. The latter aspect encompasses potential errors that occur when shifting between different investigators or different samples. This view reliability is shared by Sachdeva (2009) who mention the importance of having a stable research object.

In this thesis, reliability can be assessed by how well the time study and the interviews can be replicated. The researchers of this thesis created a digital work sheet for the time study, including standardized commands to speed up registration of activities and ensure a stable data collection. In addition, the hardware used, i.e. computers and GPS devices, were identical. The main difference of the equipment was the battery duration. On the other hand, all batteries possessed enough energy to perform the time studies without interruptions. Consequently, one can exclude differences that could had arisen due to battery shortage.

As the instruments used were identical, it is necessary to evaluate other aspects, such as different samples and the human factor of having researchers with different perceptions of activities. To mitigate this risk, the researchers discussed ambiguities to ensure consistent observations and reliable data. Considering different samples, this thesis covers the activities performed by three truck drivers.

Regarding the interviews, Cohen and Crabtree (2006) and Gill et al. (2008) state that standardized interviews have potential to entail high reliability. However, the aforementioned authors also highlight how semi-structured interviews, which are used in this thesis, can be difficult to standardize. This is due to their relatively open framing of questions with a lot of flexibility and freedom for the respondent.

Nevertheless, in order to boost the reliability the researchers of this thesis set up a standardized way of performing interviews. Firstly, the purpose of the interview was presented. Secondly, the actual interview was conducted using pre-set questions and responsibilities were divided between the researchers. Finally, the recap and follow-up process was processed in the same manner for all interviews.

In addition, all interviews were audio recorded to ensure that the researchers fully understood the given answers. Both researchers were present at all interviews, which enabled the possibility of asking questions and interpreting the results individually. In case of any misinterpretation or conflicting opinions among the researchers, a follow-up with the interviewee was performed.

3.4.2 Validity

As previously mentioned in chapter 3.4.1, a reliable measurement does not necessarily mean that it is valid. In contrast, a valid measurement is reliable (Kothari, 2004). The definition of validity refers to the ability of a research instrument to demonstrate a result which corresponds to what the instrument is designed to show. That is, if the instrument observes and measures what it is intended and expected to do (Kumar, 2011).

Jacobsen et al. (2002) distinguish between internal and external validity. Internal validity refers to the accuracy of what has been measured in comparison to what actually was set to be measured. External validity pertain to the level findings can be generalized and transferred to other contexts.

The registration of truck driver activities in the time study was mainly built up on a premade work sheet in the computer. Preset commands helped the researchers to simultaneously register data and observe ongoing activities. Manual registration with pen and paper had been time-consuming and caused a risk of missing out some of the data when the truck driver frequently changed activities. On the other hand, the preset commands restricted the level of detail because of activities being merged even though they were somewhat different. The researchers mitigated the risk of having superficial information by adding more categories to the time study, resulting in an increased internal validity.

The research involved the measurements of three drivers from one transport operator, i.e. Company X. The research is limited to the central city of Gothenburg. Consequently, a compilation of these data inputs represent a specific small part of the total distribution business. Other transport companies might have different procedures and equipment. These factors limit the external validity of the study. Furthermore, cities worldwide vary in terms of size and character. Resultantly, the figures compiled in this study could be used as a reference point for future research on other locations.

Even though it is hard to establish transferability in a qualitative research such as interviews, extensive and thorough description of the research process can increase the degree of transferability (Kumar, 2011). The researchers of this thesis have tried to describe the process in detail. Accordingly, other researchers are given the opportunity to potentially follow, replicate and adapt the results to their context.

The researchers admit that there are other possible methods of how to approach the purposes of this thesis. The research process used in this thesis is one possible way how to find answers to the raised questions. It can be argued that other research approaches would result in slightly different results. Nevertheless, the authors believe that the methods used throughout this thesis can be considered as an appropriate way to conduct the research.

4

Company X's urban freight distribution

This chapter comprises a description of Company X's urban freight distribution. The first part starts with a brief description of the company, which is followed by an overview of their cost elements. Thereafter, the time study with its associated routes is presented. Finally, improvement suggestions stated by the authors, Company X's truck drivers, and Company X's distribution management, are expressed. The collected data are obtained from desk research and interviews with the company's employees.

4.1 Company X in Gothenburg

Company X has about 25 000 employees and 18 terminals in Sweden. The terminals are divided into two categories based on the handled goods. The first option (pallet terminal) handles part loads, general cargo, and parcels and the second handles light goods, such as letters and unaddressed advertising flyers. Out of the 18 terminals, seven are of the first type while the remaining eleven belong to the second. Company X uses semi-trailer trucks, rigid trucks, postman cars, club cars, electric mopeds, and electric bikes to service the terminals. As the scope of this thesis is limited to pallet distribution in the urban environment, only the first terminal alternative and rigid trucks are included in the study.

In the Gothenburg area, Company X has one pallet terminal that handles approximately 900 outbound pallets a day. Roughly ten percent of those are dedicated to customers in the city center. The distribution management at Company X has assigned the task to three drivers. All drivers have an eight-hour work day and deliver goods in two distribution tours. Consequently, based on the number of delivered pallets and the number of tours, the trucks are seldom fully loaded.

Although the division of trucks in Company X's distribution fleet consists of several brands such as Scania, Volvo, Mercedes, and Iveco, only one brand was used for the city center distribution. All three drivers used Mercedes Atego with a capacity of 18 pallets. According to the drivers, the Atego is used due to its high maneuverability.

4.2 Company X's cost elements

According to the interviews, Company X has a marginal profit of 2-3 percent, a figure which is applicable for all major road transport companies in Sweden. The reason for the low profit margin is the fierce competition within the road transport sector. The industry's relatively low entry barriers have resulted in numerous actors involved in price competitions to sustain their profitability. Meeting with Company X's management revealed that most companies have almost identical cost factors due to using similar vehicles and the transport industry's collective agreement for wages. Table 5 shows Company X's cost per hour for operating its business. The table is divided into three categories: cost of driver, cost of vehicle, and other expenses not directly correlated to labor or material. All figures, besides the fuel cost, were obtained from Company X. The fuel cost calculations are based on the information acquired during the route tracking.

Table 5: Overview of Company X's cost elements

Costs	Amount (SEK/h)
Cost of driver	
Wage + employers contribution	237.5
Cost of vehicle	
Tax and insurance (incl. congestion charge)	11.3
Maintenance	32
Tires	3
Depreciation	25
Fuel (obtained from route tracking)	14.8
Other (towing, collisions, washing, etc.)	12.5
Other expenses	
Overhead costs	25
TOTAL COST	**361.1**

The cost of the driver is 65.8 percent of the total cost, followed by the cost of vehicle (27.3 percent) and other expenses (6.9 percent). The cost characteristics depend on the level of utilization. For instance, while fuel costs are dependent on the level of vehicle utilization, the cost of driver remains the same regardless of use. In general, costs of drivers and other expenses are fixed and vehicle related costs are variable.

4.3 Route tracking

The field research took place during week nine from February 29th to March 4th 2016 in Gothenburg, Sweden. Throughout the research period, three different drivers from Company X were observed (see table 6). All drivers were allocated urban distribution routes, which means that in general the analyzed drivers had similar driving patterns. Nevertheless, as all drivers had different customers, with different areas to be served, the duration for each activity slightly differed.

Table 6: Distribution of drivers

	Monday	Tuesday	Wednesday	Thursday	Friday
Driver 1	✓		✓	✓	✓
Driver 2		✓			
Driver 3	✓	✓		✓	✓

As driver 2 was only observed during one workday, the collected data for drivers 1 and 2 were combined. The researchers believe that this gives a comprehensive and complete overview of the entire workweek, but also allows better benchmarking.

The daily routes were split into two tours, both starting at the terminal. Figure 17 is a visualization of a typical Company X urban distribution route. The morning tour, which is marked in blue text, starts around 7:30 AM after the truck has been loaded with goods. The distance to the city center is approximately 5.5 km with a driving time of 15 minutes. The average driving distance within the service area is 21.5 km before returning to the terminal. In comparison to these figures, the afternoon route (orange figures) starts around 12.10 PM and due to higher level of congestion at that time of day the connecting link takes 20-25 minutes.

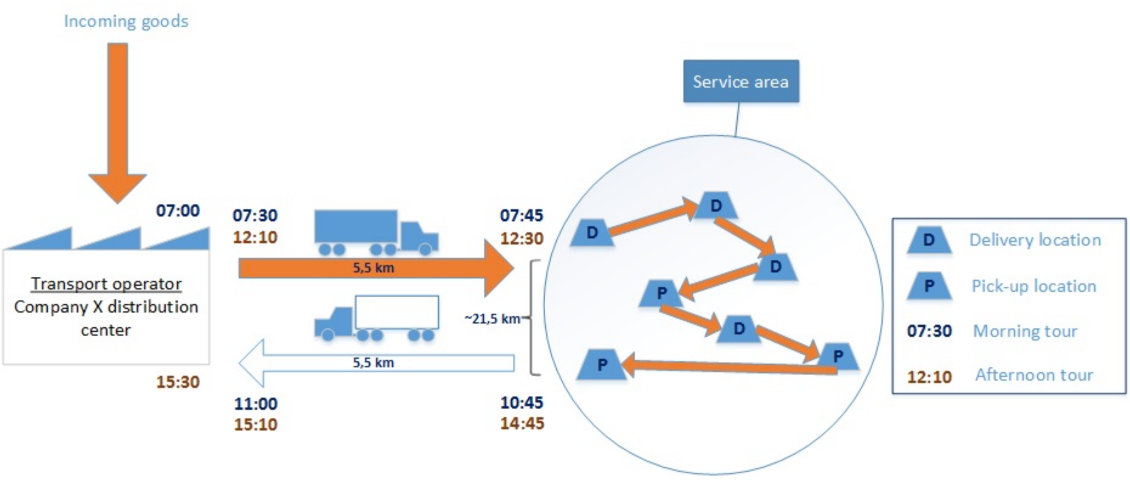

Figure 17: Typical Company X's urban distribution route

The morning tour, which takes place before the lunch break, mainly comprised deliveries of goods, while the afternoon tour had an even division of deliveries and pick-ups. The reasoning for having two tours was because of the lower storage capacity of the truck. In addition, the drivers preferred having lunch at the terminal so they combined their lunch break with the terminal stopover in-between the tours. As the drivers had their lunch break around 11 AM they did not manage to deliver some of the goods from the morning tour and were transported back to the terminal. Thus, unnecessary weight was transported, contributing to increased fuel consumption and environmental impact. Moreover, another reason for having lunch at the terminal was the lack of other alternatives. Available parking for trucks inside the city of Gothenburg was almost non-existent, and since loading zones are used for loading and unloading tasks, parking the vehicle there during lunch was not allowed.

The information obtained from the GPS tracking indicates the total range of each tour, the variation in elevation, and the average driving speed (table 7). Looking at the driving range, drivers 1&2 had a minimum distance of 46.2 km and a maximum of 95.1 km. The maximum range is almost twice as long in comparison to driver 3 who had a minimum range of 43 km and a maximum of 55.4 km. The total climbing and descending figure for drivers 1&2 was 15 893m. The respective figure for driver 3 was 7 394m.

Table 7: GPS route tracking data

	Monday		**Tuesday**		**Wednesday**		**Thursday**		**Friday**	
Drivers	1&2	3	1&2	3	1&2	3	1&2	3	1&2	3
Min elevation (m.s.l.)	-10	-10	-10	-10	-10	-	-10	-10	-10	-10
Max elevation (m.s.l.)	83	30	60	52	79	-	82	42	80	37
Total climbing (m)	2611	1000	1200	982	1554	-	1309	837	1257	776
Total descent (m)	2596	1218	1204	981	1582	-	1324	838	1256	762
Average speed (km/h)	29.1	28.9	34	26.1	33.6	-	23.6	26.8	28.5	32.2
Total distance (km)	90.3	55.4	80.2	45	95.1	-	46.2	43	66.4	53.6

As both drivers had an average of 27 pallet deliveries per day, the difference in distance was not affected by the number of customers, but rather the location of customers. While drivers 1&2's customers were widely spread in the city, driver 3 had the major part concentrated within approximately one kilometer (see figure 24 and 25 in Appendix C). In addition, as the difference in distance corresponds to the proportions in climbing and descending between the drivers, it can be concluded that the topography pattern was similar for both drivers.

Figure 18 is an example of driver 1's distribution route on March 2nd, 2016. It shows the time of the work day on the horizontal axis and the driving speed on the vertical axis. The speed profile obtained through route tracking enables the researchers to evaluate the time efficiency of driving during urban distribution. The graph curve indicates the efficiency of driving activities. The efficiency of other events that took place when the vehicle was at a standstill, such as pick-ups and deliveries, were examined using data from the time study. This shows how both methods supported each other for a more accurate analysis of the urban freight distribution.

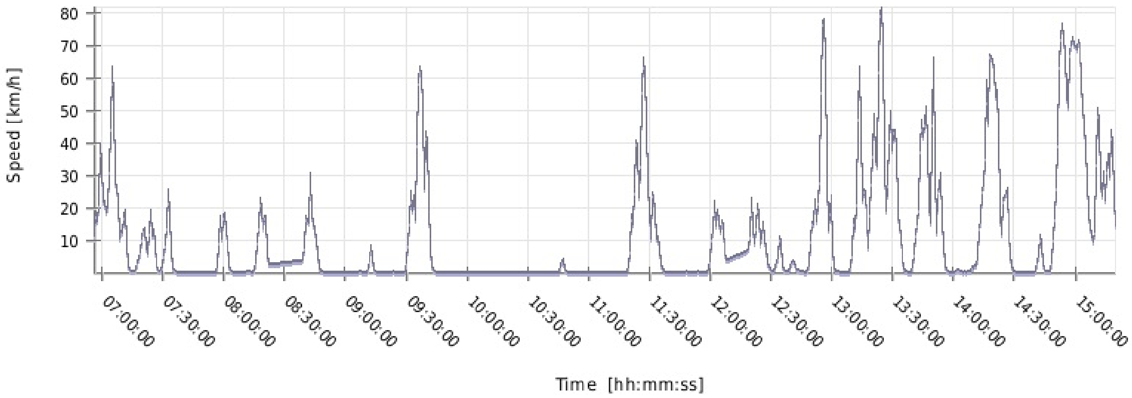

Figure 18: Speed profile of driver 1's distribution route on March 2nd, 2016

4.4 Time study

A total of 4 511 activities were registered in the time study. On a daily basis, the average number of activities observed by the researchers was 441 and 577 respectively. To compare the data, the amount of activities must be put in relation to the average work time of the truck driver. According to the employment contract, a normal work day is eight hours long plus a 45 minute unpaid lunch break. The time study revealed that in reality the average work day (lunch included) for drivers 1&2 was 8h 44min, while driver 3 had a slightly shorter average day of 8h 32min.

4.4.1 Categories and activities

As a truck driver's daily routine comprises several distinguishable activities, it became important to categorize them. The key parameter for classifying the activities was the location where the event took place (see figure 19).

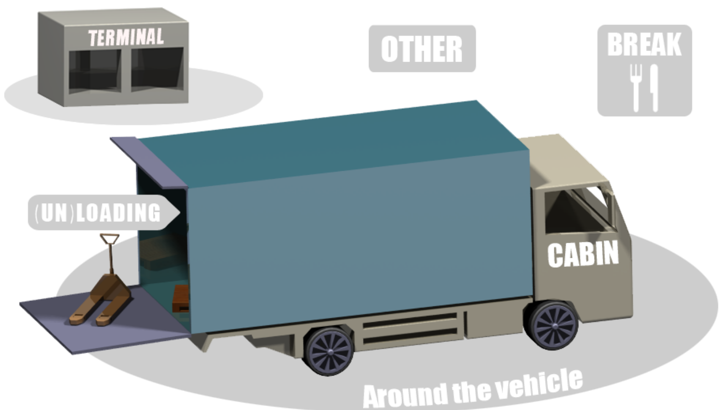

Figure 19: Categorization based on location

Categorizing the activities also made it easier to pinpoint the most time-consuming areas, thus highlighting categories with the biggest improvement potential regarding time efficiency. The total amount of observed activities was 31. An overview of the categorization can be seen in table 8. Four activities took place inside the cabin, ten around the vehicle, seven at the terminal, and seven inside the body of the truck. The latter also includes activities executed on the tail lift. In addition, two activities are related to personal time, i.e. breaks and conversing. These activities are categorized as *Breaks*. Lastly, activities which were unique and did not have a repetitive pattern are grouped in *Other*.

Table 8: Categories and activities of the truck driver's daily routine

Cabin	Around the vehicle	Breaks	Terminal	(Un)loading	Other
Driving	To customer with goods	Break	Route planning	Moving other goods	Other
Park/reverse	From customer without goods	Conversing	Load goods with PJ	Unload truck	
Admin. tasks	Contact customer		Unload goods with PJ	Tail lift down	
P-spot search	Signature		Driving	Pallet jack handling	
	To customer without goods		Load goods with ET	Tail lift up	
	From customer with goods		Using terminal gate	Pick-up/loading	
	Waiting for customer		Unload goods with ET	Secure cargo	
	Use of handheld computer				
	(Un)loading at customer site				
	Walking to/from the cabin				

4.4.2 Results

The time study data is summarized in table 9. The first column is color coded according to the category and comprises all the activities. Red color indicates cabin activities, green - (un)loading, purple - around the vehicle, blue - breaks, orange - terminal, and black is other.

The second and third columns represent daily averages for activities per driver, followed by the combined average and the associated percentage of the total time. Summarizing the average values gives the weekly duration of activities in column six.

Table 9: Summary of daily and weekly duration of activities

Activity	Daily average (Drivers)			%	Weekly
	1&2	3	Combined		Total
Driving	02:55:17	02:10:37	02:35:26	29.9	12:57:11
Park/reverse truck	00:14:10	00:15:57	00:14:58	2.9	01:14:48
Administration inside the cabin	00:08:10	00:05:41	00:07:04	1.4	00:35:19
P-spot search	00:00:00	00:02:18	00:01:01	0.2	00:05:07
Tail lift down	00:10:11	00:11:59	00:10:59	2.1	00:54:53
Tail lift up	00:08:57	00:08:28	00:08:44	1.7	00:43:42
Moving other goods	00:08:19	00:06:09	00:04:34	0.9	00:22:52
Unload truck	00:10:17	00:13:11	00:11:34	2.2	00:57:51
Pick-up/loading	00:04:56	00:08:12	00:06:23	1.2	00:31:57
Secure cargo	00:03:17	00:07:27	00:05:08	1.0	00:25:42
PJ handling	00:05:19	00:10:55	00:07:49	1.5	00:39:03
Walking to/from the cabin	00:18:57	00:14:17	00:16:53	3.2	01:24:23
To customer with goods	00:18:32	00:24:09	00:21:02	4.0	01:45:09
From customer with goods	00:07:19	00:09:54	00:08:28	1.6	00:42:19
To customer without goods	00:08:07	00:10:26	00:09:09	1.8	00:45:43
From customer without goods	00:11:25	00:16:59	00:13:54	2.7	01:09:28
Contact customer	00:09:21	00:11:51	00:10:28	2.0	00:52:19
Waiting for customer	00:26:19	00:09:54	00:19:01	3.7	01:35:04
Signature	00:07:23	00:11:25	00:09:10	1.8	00:45:52
Scan documents	00:05:11	00:07:53	00:06:23	1.2	00:31:55
(Un)loading at the customer site	00:01:07	00:04:25	00:02:35	0.5	00:12:53
Break	01:15:51	01:16:14	01:16:01	14.6	06:20:06
Conversing	00:14:01	00:10:52	00:12:37	2.4	01:03:06
Route planning	00:17:14	00:24:35	00:20:44	4.0	01:43:41
Load goods with PJ	00:09:15	00:23:27	00:15:34	3.0	01:17:49
Load goods with ET	00:15:07	00:05:31	00:10:51	2.1	00:54:14
Unload goods with PJ	00:01:05	00:16:12	00:07:48	1.5	00:38:59
Unload goods with ET	00:09:18	00:00:23	00:05:20	1.0	00:26:41
Terminal driving	00:17:32	00:07:36	00:13:07	2.5	01:05:35
Close/open the terminal gate	00:02:58	00:04:00	00:03:26	0.7	00:17:08
Other	00:07:03	00:00:57	00:04:20	0.8	00:21:40

Note: Times are given in hh:mm:ss

Table 10 describes the duration of a single occurrence of each activity. The minimum, mean, median, and maximum values of each event are given in columns two to five, followed by the standard deviation and coefficient of variance.

Table 10: Descriptive statistics for time study data

Activity	Min	Mean	Median	Max	StdD	CV %
Driving	11.7	439.5	358.6	3176.4	383.1	87.2
Park/reverse truck	2.6	43.2	30.0	425.2	50.2	116.1
Administration inside the cabin	2.0	37.0	17.8	422.7	54.9	148.3
P-spot search	7.6	30.8	29.4	82.4	21.2	68.7
Tail lift down	1.3	16.3	14.9	45.8	8.7	53.5
Tail lift up	2.4	14.4	14.0	43.4	5.3	36.9
Moving other goods	3.0	21.5	15.8	95.3	17.7	82.3
Unload truck	2.1	27.9	21.1	139.0	23.2	83.4
Pick-up/loading	4.0	23.8	21.1	80.8	12.7	53.4
Secure cargo	4.4	20.1	18.8	87.5	11.6	57.7
PJ handling	2.7	15.8	11.7	366.5	25.3	160.6
Walking to/from the cabin	2.6	21.5	15.5	336.8	24.9	115.8
To customer with goods	2.8	39.7	27.1	430.6	43.8	110.2
From customer with goods	3.2	31.1	22.9	144.8	25.9	83.4
To customer without goods	2.9	27.7	17.7	177.6	30.7	110.9
From customer without goods	2.2	28.4	18.6	272.0	33.6	118.2
Contact customer	3.6	104.8	36.3	2038.2	246.1	234.7
Waiting for customer	3.9	64.2	29.1	1183.5	133.0	207.0
Signature	6.3	38.4	33.8	194.0	25.8	67.2
Scan documents	2.8	31.7	21.3	192.2	33.3	105.3
(Un)loading at the customer site	6.9	66.4	41.3	318.7	81.6	123.0
Break	24.9	1282.9	394.1	4027.3	1515.8	118.2
Conversing	1.9	40.1	25.4	232.6	41.4	103.3
Route planning	4.3	74.6	40.7	975.4	104.6	140.2
Load goods with PJ	8.6	87.5	53.5	522.2	94.2	107.6
Load goods with ET	8.2	154.1	106.3	929.6	183.5	119.1
Unload goods with PJ	12.7	175.4	75.5	1105.6	256.0	146.0
Unload goods with ET	27.3	180.0	79.4	915.1	238.9	132.7
Terminal driving	2.0	70.9	34.5	2540.1	258.2	364.0
Close/open the terminal gate	4.0	25.0	23.4	81.2	14.5	57.8
Other	19.7	167.1	166.2	384.6	107.7	64.5

Note: Times are given in seconds

The total activity time spent per driver for each category was computed to compare and evaluate the work routines. This data can be extracted from tables 9 and 10, but a clearer visualization is compiled in tables 16 and 17 (see Appendix D). According to the tables, each of the activities of driving and break represents more than five hours per driver per week. Drivers 1&2, had a total number of eight activities with a weekly total duration between 1-5 hours. The respective figure for driver 3's is six. Finally, the biggest share of activities took less than one hour. The corresponding total amount of activities for drivers 1&2 and driver 3 were 20 and 23. In total, 30 activities were registered for drivers 1&2 and 31 activities for driver 3. The difference is due to the fact that drivers 1&2 did not have any occasions when it was necessary to spend additional time looking for a parking spot as the parking spots were generally vacant or the drivers continued with another customer. An overview of all activities with the associated time spans is presented in table 11.

Table 11: The weekly duration of registered activities with associated time spans

	> 5 hours	1-5 hours	0-1 hour	Not registered
Drivers 1&2	2	8	20	1
Driver 3	2	6	23	-

Tables 16 and 17 in Appendix D indicate that there are notable time differences in most of the activities. This corresponds to the variances in table 11. Obviously, this is highly influenced by the fact that driver 3 was observed one day less.

Since the observation period differed for both researchers, it is important to weight the results, making them equally comparable. The activity time per day is aggregated for each driver and divided with the sum of work days. As stated in table 6, drivers 1&2 had five working days while driver 3 only had four. The updated results give a better overview of how much time each activity took for both drivers. The results signify that a strong majority of the activities took more time for driver 3 than the other drivers. Nevertheless, the daily work patterns are still in the same range.

To better envision the differences in work patterns, an elaborate comparative chart is provided (see figure 20). The chart visualizes the average time spent per activity per driver per day. The duration is placed on the vertical axis while activities can be seen on the horizontal axis. The categories are sequenced from left to right: activities inside the cabin, (un)loading, around the vehicle, breaks, terminal, and other. Blue bars represent drivers 1&2 and orange bars driver 3.

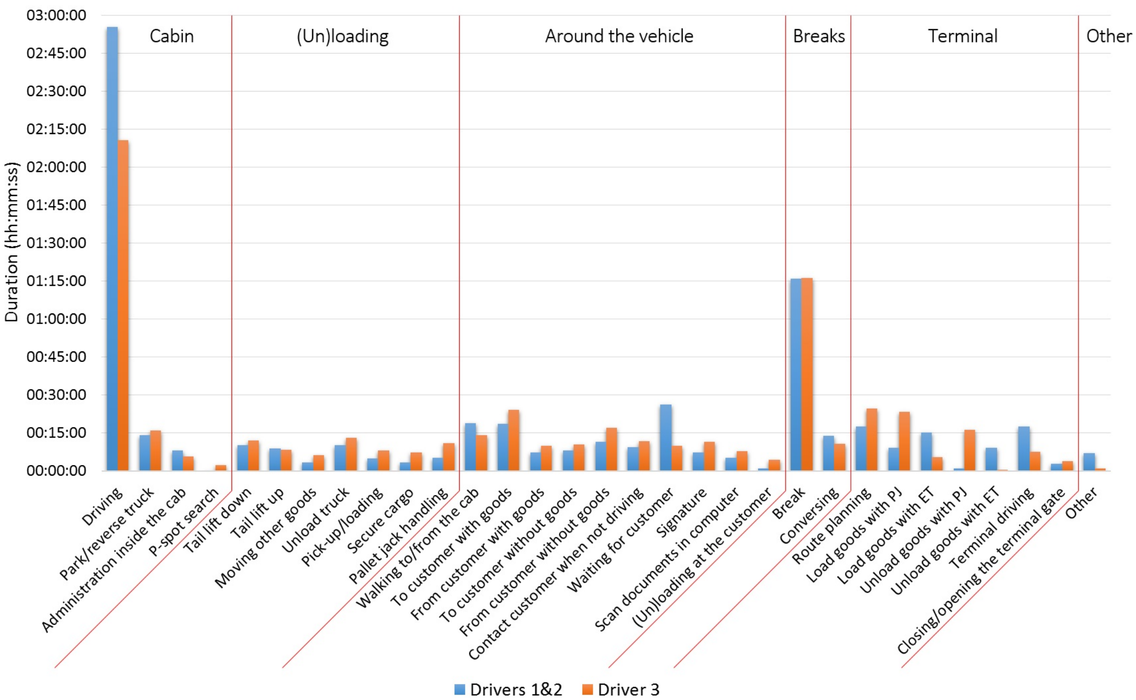

Figure 20: Comparative chart of the drivers

It is clear that driving and break activities account for the vast majority of the day. The biggest absolute differences were in *Waiting for customer* and the activities at the terminal. The former is different because during two workdays driver 1 arrived at the customer too early. As most shops have specific opening times, the driver was unable to use that waiting time to serve other stores. These two occasions significantly increased the total amount of waiting time for drivers 1&2. The latter are considerably dissimilar for the drivers as different types of pallet jacks (PJ) were used. Driver 3 mostly used a manual PJ but drivers 1&2 mainly used an electric-powered pallet jack (ET), which increased the speed of the activity.

Figure 21 further indicates that the daily work patterns are relatively analogous. The opaque colors represent drivers 1&2 and half transparent colors show driver 3. For drivers 1&2, 37.5 percent of the entire workday was dedicated for cabin related activities, 21.6 percent for activities surrounding the vehicle, 17 percent for personal time, 13.8 percent for terminal activities, 8.8 percent for loading and unloading activities, and 1.3 percent for other unspecified activities which did not have reoccurrence. The corresponding figures for driver 3 are 30.2, 23.7, 17, 16, 13, and 0.2 percent. Figure 21 also displays the daily mean duration for all the categories. The collected data for drivers 1&2 shows that activities inside the cabin take 3h 17min 37s, followed by activities around the vehicle with 1h 53min 41s, and breaks with 1h 29min 53s. Activities in the terminal, (un)loading, and other take less time with 1h 12min 54s, 46min 16s, 7min 3s, respectively. The corresponding figures for driver 3 are 2h 34min 33s, 2h 1min 11s, 1h 27min 6s, 1h 21min 43s, 1h 6min 21s, and 57s.

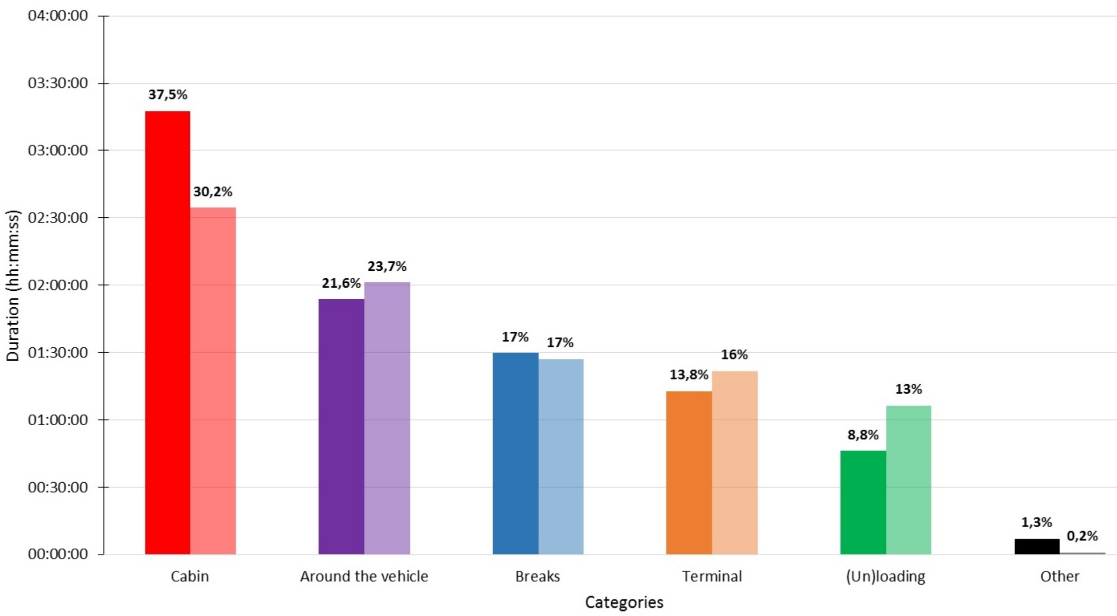

Figure 21: The division and daily mean duration of categories

It clearly shows that there was a significant difference between the two groups (drivers 1&2 and driver 3) under the cabin category. A calculation for the daily average duration for driving shows that the drivers 1&2 experienced 25.5 percent more driving than driver 3. This is greatly influenced by the fact that drivers 1&2 also served customers outside of the normal service area. For example, even though most of the pick-ups and deliveries were in the *Inom Vallgraven* area, drivers 1&2 also served districts such as Mölndal, Billdal and Hovås.

The *Other* category also showed significantly dissimilar results for different drivers, a 76.4 percent deviation from the daily mean. However, it is important to highlight that this category only encompassed 0.8 percent of all the activities throughout the entire week. In addition, (un)loading activities had a 17.8 percent absolute deviation for both drivers. All the other categories had relatively low deviation from the daily mean result: around the vehicle 3.2 percent; breaks 1.6 percent; and terminal 5.7 percent. This further acknowledges and supports the researchers' initial assumption that the daily routine patterns look relatively analogous.

4.5 Interviews

Interviews were conducted with employees from Company X and experts in the electric driveline technology. The former are directly related to carrying out the urban freight distribution, including both the management and the operational level. The purpose of the interviews was to understand the existing challenges as well as how they address them. The latter were targeted to obtain an understanding of the current state and the advancements of the technology in electric powertrains.

4.5.1 Interviews with Company X

In the recent past, Company X has experienced an increase in demand for parcel deliveries. According to the interviewed managers, this trend is connected to the amplified e-commerce business. The first quarter in 2016 shows that parcel deliveries have increased by 16 percent whereas pallet distribution has declined by 8 percent. Although the numbers indicate a change in customer demand, the management at Company X is not entirely certain whether it is a temporary or a permanent shift. The management believes that due to the higher number of smaller shipments, the relevance of smaller vehicles in urban freight transportation has increased.

Company X's drivers feel that the management is not interested in investing in new high quality equipment. Although they believe that the current tools are decent, they envisage significant savings potentials in equipment with higher quality. The current investments are only done for the short term. For example, the company has mainly invested in non-electric PJs, which are cheaper but have worse ergonomic features. The main problem in the central city is the lack of oversight around the vehicle when driving. They point out the risk of operating close to the pedestrians and cyclists. The drivers also emphasize problems regarding the handheld computers. Their current experience indicates that the handheld computers are too slow, thus limiting their performance and affecting the service level.

4.5.2 Interviews - experts in electric driveline technology

A common understanding among the experts is that the electronic driveline technology for medium-duty trucks is at an early stage of demonstration. The high battery cost of a BEV limits the potential of a more rapid expansion for the technology. The interviewed subjects emphasized the importance of decreasing the unit price of a battery as the battery accounts for the biggest cost of a BEV. Decreasing the unit cost would significantly lower the price per BEV. On the other hand, if the BEV producers lower the cost by reducing the size and capacity of batteries, it will have an adverse effect on the vehicle's range.

It seems that most problems concerning BEVs are connected to the battery. One of the interviewed subjects claimed that the charging infrastructure is the main challenge when implementing BEVs in urban freight distribution. The other interviewees believed that the biggest obstacle rather lies with the driving range. The interviewees back the belief that the current battery capacity is sufficient for serving urban distribution routes. By increasing the mileage, the number of necessary investments in the charging infrastructure is minimized as they only need to charge the vehicle at the distribution center. Thus, the charging infrastructure is not considered as the main focus area. In addition, the experts also believe that there needs to exist a certain safety margin in battery capacity to minimize the impact of weather and varying topography.

Another common understanding among the experts was the reduced environmental impact of BEVs, specifically the benefits of not having any tailpipe emissions in the city. Nevertheless, one of the interviewees highlighted that BEVs cannot be automatically considered as a zero emission option. It is imperative to consider the source of the electricity to promote sound environmentally friendlier solutions.

Finally, the contribution to the reduction of noise pollution from using BEVs was shared by all interviewees. It was stressed how the low average speed in the urban environment enables the benefits deriving from BEV's smooth and quiet driveline. On the other hand, having noiseless vehicles close to pedestrians and cyclists might increase the risk of collision. Nevertheless, the interview subjects stressed the ergonomic factors of noise reduction for both drivers and local residents.

4.6 Improvement initiatives

To improve the work conditions and increase the time efficiency for truck drivers' daily routine, a list of improvement suggestions was composed. The list creation process involved different collecting techniques for each respondent, the drivers and the management of the transport operators. In addition to the aforementioned parties, the authors also generated suggestions of their own to have an external perspective. The total amount of suggestions gathered and created throughout the research was 41, the sum of the figures in the parenthesis (see table 12). The aggregate quantity is lower because some suggestions overlapped. Moreover, as some of the suggestions were too grandiose, rather implausible, and outside the scope of this research, the total measure of used recommendations was narrowed down to 26.

The suggestions were grouped according to what category they would address. Initiations in the vehicle category comprise changes that can be modified with the specifications of the urban freight truck. Navigation related suggestions comprise activities which can reduce the time spent on planning the daily route or to lessen driving time. The assisting tools category encompasses machineries supportive to the driver, i.e. handheld computers, PJs. The last category involves changes which are mostly initiated by the public sector.

Table 12: Division of proposed recommendations

Category	**Vehicle**	**Navigation**	**Assisting tools**	**City logistics**
Drivers	6 (13)	2 (4)	2 (3)	3 (4)
Management	1 (1)	3 (4)	1 (1)	0 (0)
Authors	3 (3)	3 (3)	2 (3)	0 (2)

The ideas from the truck drivers were gathered through a focus group meeting, involving 11 participants. An open atmosphere throughout the interview allowed the researchers to gather numerous thoughts; the total sum of all proposals from the drivers was 24. Personal one-on-one interview meetings were conducted with people from the managerial level. Respective figures for management and authors were 6 and 11. Nevertheless, not all suggestions were original in nature and had to either be withdrawn entirely or merged with similar types.

5

Analysis

This chapter discusses the suggestions gathered from the interviews with the drivers and the management of the transport operator, as well as the ideas produced by the authors. This unveils the details on how initiatives from all the entities might improve the overall experience and economic performance by increasing safety levels and the daily time efficiency of the truck drivers. The analysis will also discuss the option of utilizing BEVs in urban freight distribution, how certain parameters affect the plausibility of a successful change, and what needs to be adjusted to have a smoother transformation. Finally, this chapter will introduce prospective future research areas which might change the fulfillment of urban freight distribution.

5.1 Proposed initiatives

In total 15 initiatives are presented and their rationale explained. The list is not by order of importance, but is organized in the following categories: vehicle, navigation, assisting tools, and city logistics. The classification is based on the aspects which the initiatives aim to improve.

5.1.1 Vehicle

The vehicle initiatives address features which would improve the operational characteristics of the trucks. These improvements are mainly of the engineering type – thus directed towards the truck manufacturers – and focus on adjusting the dimensions, the maneuverability, safety, and security of the vehicle.

1. Better oversight

According to the time study, driving and parking activities encompass 32.7 percent of the entire work day. Decreasing the total time of those activities will significantly increase the truck driver's time efficiency. The current average total time spent during one week on the aforementioned activities is 14h 11min 58s, which corresponds to a weekly cost of 5 127.4 SEK per driver for the employer. All three parties suggested that by having better oversight of the surroundings of the vehicle, it would be possible to eliminate a significant amount of non-value adding time.

Common issues highlighted by the drivers, state that in urban environments the movements of pedestrians, cyclists and private cars cause a lot of difficulties. Understandably, the drivers aim at avoiding collisions, but the chaotic urban traffic makes it problematic. One of the solutions identified in the focus groups was the installation of a rearview camera. A rearview camera on the top of the body of the vehicle provides the drivers a considerably better oversight of its surroundings when reversing or parking. Due to the dimensions of the urban freight vehicles, operating without having a decent rearview means that the drivers do not possess any knowledge on what takes place behind the vehicle. Although many of the medium-duty trucks already have a rearview camera, the main issue resides with the location of the camera as most of them are located in the lower part of the truck. The lower part of the truck does not provide a good angle for reversing and misses important details, such as the distance to the loading bay. For example, when a truck is reversing, the lower setting for the camera shows good overview of everything around the height of one meter, but misses out on everything above it. This means that objects located above one meter continue to be a source of threat for collision, e.g. roadside roofs, streetlights, railings. As of now, the drivers utilize the mirrors to notice these obstacles, which cause the drivers to spend more time on parking. Therefore, locating the camera on the upper edge of the body allows the driver to sidestep those occurrences, operate in a more rapid fashion and increase overall safety for pedestrians.

To further increase driving efficiency, the management and authors believe that the vehicle could have sensors around the entire chassis. The sensors would allow the driver to have a 360 degree visualization of the surroundings. This will become especially useful during parking in tight conditions. Often both drivers had to maneuver below the Nordstan and NK shopping centers where the goods reception area is located. The area is confined by narrow passages and strict maneuverability. By having sensors around the vehicle, parking will be considerably faster and less stressful. Creating only 5 percent more efficient driving and parking activities, the transport operator can experience a weekly time saving of 42min 36s which corresponds to 256.4 SEK per driver. Assuming that the average life span of a medium-duty truck is 257 495 km (Antich, 2006), and that the weekly distances remain the same as during the time study, the total savings potential for the entire life cycle is 206 605 SEK. This shows that improvements regarding driving and parking should be highlighted as even a slight modification has substantial influence.

The challenge of implementing these initiatives is mostly monetary. The transportation industry is confined by small margins, which set strict limitations on investments. The interviews revealed that the companies generally opt for vehicles with basic interior design without special accessories.

2. Decreased turning radius

Analogously to the aforementioned initiative, the following is related to the activity with the highest time consumption – driving. During the focus group meeting with Company X's drivers, one of the proposed suggestions was connected to the maneuverability of medium-duty truck. The drivers suggested that decreasing the turning radius of the vehicle would ameliorate the central city driving experience, thus improving both driving and parking. As the load capacity (i.e. 18 pallets) sets certain limitations on the dimensions of the truck, the focus is to modify the extent to which the vehicle can maneuver. Both this and the first initiative are capable of yielding good results with small changes. The adjustment would result in an overall reduced time consumption, with less stress for the drivers, and an increased driver's satisfaction.

Nevertheless, changing the maneuverability of the vehicle might be difficult with today's technology. An in-depth analysis for the research and development in enhanced maneuverability technology is needed to support a rational investment plan in this action. Moreover, from an economic perspective, the suggestion could turn out to be too expensive of an investment for Volvo and Company X.

3. Adjustable mirrors

Another proposal was highlighted by the drivers to address maneuverability issues. This issue of mirrors hindering maneuverability while delivering or picking up goods was observed several times during the time study. In addition to decreasing the turning radius, the dimensions of the trucks could be adjusted. Although light-duty vehicles could improve these parameters, the total amount of transportation vehicles in the urban environment would significantly increase if the demand stays at the same level. Therefore, another solution was considered. A new concept for the wing mirrors was proposed to adjust the dimensions of the relatively large freight distribution vehicles to better suit the narrow streets found in city centers. The new concept foresees that truck manufacturers would produce tighter wing mirrors. Currently, the turning circle (wall to wall) for a 16 ton Mercedes-Benz Atego is 18.4 m with a circumference of 115.6 m, with the mirrors extending the cabin up to 40 cm on each side (Mercedes-Benz UK Ltd, 2016). By having 15 cm tighter wing mirrors, the turning circle can be reduced to 18.1 m with a circumference of 113.7 m. This is a 1.6 percent decrease in the turning radius.

Nevertheless, having smaller or tighter mirrors can cause reduced visibility for the driver, thus leading to worsened driving experience and safety. As they are a vital part of the drivers' daily routine, it is imperative that these aspects would not be affected. An advancement of the previous suggestion is to use foldable mirrors. This means that the wing mirrors could be folded from within the cabin during situations when the driver has to pass through a constricted street. By folding the mirrors, the turning circle can be reduced to 17.6 m with a circumference of 110.5 m, which provides a 4.4 percent decrease in the turning radius. Although the visibility and oversight is reduced by collapsing the mirrors, it can be offset by using sensors.

The sensors will give the driver a decent control over the vehicle, and unnecessary collisions can be avoided.

Again, this suggestion is confined by the truck manufacturers' willingness to develop new concepts. Also, due to economic reasons the solution will only be attractive for the transport operators in case the option is included in the standard vehicle equipment.

4. Improved accessibility

To further optimize time efficiency, while increasing driver safety and ergonomics, the drivers highlighted that adjustments to the cabin height are necessary. Although generally the drivers are strongly associated with driving trucks on roads, it is important to notice that drivers also engage in other activities. One of these activities involves ascending to or descending from the truck's cabin, which can be as high as 1.5 m. The authors observed during the time study that climbing into the cabin took an unnecessarily high effort and time. A recent study revealed that non-traffic accidents accounted for 92.6 percent among truck drivers in Denmark during 1993-2002 (Shibuya et al., 2008). As it is today, the drivers need to open the door above the ergonomic power zone (Howard and Welsh, 2007), which significantly increases the risk factor for musculoskeletal disorders. This is directly linked to the awkward postures the drivers experience over the course of the work day when reaching for the door handle. An answer would be to lower the cabin to a more suitable height. As the drivers already have had previous experiences with different truck brands, they stressed that vehicles with a lower cabin led to better user ratings. Hence, this is something the truck manufacturers might want to look into. Furthermore, as some alternative powertrains (e.g. electricity) have lower demands regarding space for the engine, lowering the cabin should be technologically easier to achieve than with conventional vehicles.

Another solution would be to increase cabin accessibility by implementing advanced stairs. Similarly to the foldable mirrors, these stairs could extend outside the body of the vehicle during exiting and entering the vehicle. This will allocate the biggest effort of entering the cabin to the legs and decrease the burden on arms and shoulders. Nevertheless, this solution might seem unattractive for truck manufacturers and may become difficult to achieve as it involves high investment costs, but also due to the low impact on increasing the time efficiency. Especially, as the former proposal is supposedly easier to achieve. All in all, it is important that the truck manufacturers could improve the fit between the demands of work tasks and the capabilities of the drivers.

5. Increased safety

The following initiative has similar touch points with the previous section. The main difference is that this section includes the safety of the drivers and other road users, while the previous section only contained the ergonomic aspect of the driver.

Urban distribution entails numerous loading and unloading activities throughout the distribution route. Since parking is generally on the right side of the road, the driver needs to exit the cabin on the left side of the truck where the traffic is. This can impose a significant safety threat as 29.8 percent of all truck drivers jump out of the truck cabin, often without checking if another vehicle was passing (Heglund, 1987). This issue could be mitigated by installing an indicator that warns other road users when the driver is about to exit the cabin. That solution could involve a flashing warning light located outside of the cabin or on the back end. It is important that the sign would differ and stand out from the usual indicators.

The drivers and the authors highlight that currently the drivers must pick up their mobile phones when calling or receiving calls. The authors perceive this as a safety risk for both the drivers and other people as the attention is divided. This is particularly relevant as it is entirely prohibited to use the phone when driving. To relieve the problem a voice controlled Bluetooth hands-free setup in the cabin should be implemented. Resultantly, the driver can pay more attention to the driving and simultaneously keep two hands on the wheel. No additional activities are necessary as the mobile device is automatically connected with the vehicle when entering the cabin. Since the driver does not need to stop the truck to call or receive phone calls, this solution provides an opportunity to increase time efficiency.

The following suggestion was addressed by all three parties. To improve the driver's safety the ability to share traffic information among the drivers is valuable. By sharing information, drivers can avoid prevailing risks in traffic. For example, they can register and warn other drivers about bad road conditions, narrow passages, bad bridges, fallen trees, and many other similar occurrences. A potential alternative is to place a monitor in the center console inside the cabin. The driver is now able to observe traffic conditions in real-time. All warnings sent to and from other drivers and/or the dispatchers would pop up on the screen instantaneously. This solution would thus increase the safety of drivers as they are able to avoid undesirable roads.

6. Tail lift

As of today, tail lift activities from Company X's urban freight distribution comprise 3.8 percent of all activities' time, i.e. 1h 38min 35s throughout an entire work week, and account for 593.3 SEK per driver for the employer. This is a vital part during loading and unloading, thus increasing the performance of the tail lift will have notable impact. Various improvement suggestions regarding the tail lift's operations were proposed by all the actors. Most importantly, the speed is thought to be the biggest drawback, especially during morning hours and winters, when the apparatus is still 'cold'. The median value for lowering the tail lift was 14.9 seconds and rising was 14 seconds. The tail lift had to be closed every time the driver moved away from the truck. The time study indicated that only big shopping centers, i.e. NK and Nordstan, and a few bigger customers had a secure separate goods receipt area.

To offset the weight of non-value adding activities, a suggestion was proposed to move the buttons farther from the back end of the truck. One of the main reasons why the tail lift is currently so slow is associated to safety. To avoid getting the driver's limb or head stuck between the tail lift and the body of the vehicle, the legislation foresees that the speed of the lift is limited. If the buttons are located farther from the opening, the aforementioned threat is avoided. This change acts as a *poka yoke*[1] solution, increasing the safety level and allowing the tail lift to be faster, thus reducing overall operation time.

The authors put forward that the entire activity could be remote controlled. This allows the driver to already start moving towards to customer while the tail lift is being raised. Hence, the activity is done during another event (i.e. walking), which grants a more time efficient work day as well as increasing the safety of the cargo. Since cargo safety involves great significance for the transport operators, an additional alternative is presented in the next section.

7. Temporary automatic security roller shutter

As mentioned before, lowering and closing the tail lift constitute a significant division of the work day. The authors highlight that temporary automatic roller shutters could be installed to improve the time efficiency. This solution is an advancement of the aforementioned remote controlled tail lift. Similarly, the shutter would be activated with a remote and the back end of the truck will be closed while the driver is walking towards the customer. The technology is similar to the ones used by retail stores to cover their shop front or windows after closing (see figure 22). It is believed that the security shutter is sufficient to deter abusers and thieves during the short time of absence. Now the driver does not have to spend time closing the tail lift after every single delivery. It will have an even higher value when several pallets of goods have to be transported to a customer with no easy access or goods receipt area. Furthermore, the temporary shutter could be installed under the ceiling inside the body of the truck. As the fence is thin, the ceiling would only need a set of two guide grooves and a small motor to power the retraction and lowering of the shutter. This might decrease the total height of the storage area, but will be a marginal reduction for the total load capacity. The idea and the necessity of it was approved by the drivers, who felt that this solution would be both faster and more ergonomic than the current solution.

[1]Poka yoke – the concept is based on the same idea as "fool-proofing", an approach devised mainly for preserving the safety of operations (Shingo, 1986)

Figure 22: Retail and shop front roller shutter (Alutech United, 2016)

5.1.2 Navigation

The navigation initiatives address features which would improve the operational characteristics as well as the delivery sequencing. These improvements are mainly of the operational type – thus involve investments for the transport operator – and focus on better time utilization, smarter driving, and route planning.

1. GPS navigation

One distinct characteristic of Company X's urban freight distribution was that none of the drivers made use of a GPS navigation system. As it is today, the drivers undergo training by job shadowing a colleague over a course of few weeks. This allows the new employee to understand the basics of the profession, but also provides him an opportunity to get acquainted with reoccurring customers. Company X has dedicated three drivers for the goods distribution in central city, which means that part of the destinations are reoccurring, i.e. Nordstan, NK, Partihallarna. Nevertheless, there are several factors that deviate, which have a substantial impact on the total driving time and safety, i.e. congestions, accidents, closed roads. To curtail these deviations and increase average driving speed, a GPS navigation system could be implemented. The dispatchers would be responsible for keeping the system updated by persistently managing the changes. The drivers are duty-bound to inform the dispatchers through the system of any changes in traffic conditions. All of the information will be managed by the aforementioned touchscreen monitor placed on the center console. The navigation system will be of great help the drivers avoiding congested areas by continuously calculating the fastest route to the next customer. During the time study, one of the drivers got stuck in a traffic jam caused by an unforeseeable accident, thus increasing the usual driving time by 37 minutes, which is equivalent to 222.7 SEK in additional costs for the employer. If a navigation system would have been utilized, the initial route would have been redirected. To make the system even more accurate, it could be integrated with the world's largest community based traffic and navigation app Waze. This is already very common amongst Uber drivers, who use it on a daily basis to avert problematic areas.

The navigation system would also significantly increase the speed of locating the exact location of the customers' goods receipt area. During the focus group meeting several drivers mentioned that often the access to the loading bay is impeded or difficult to locate. Less time is wasted on searching for the loading zone as the drivers constantly update their customers' location in the system. During the time study both researchers experienced several occasions when the drivers did not find the correct location. Therefore they had to pull over to call the customer for supplementary instructions on how to reach them. Some drivers admitted that they often had to use navigation applications on their personal cellphones to pinpoint the location of the customer. Ideally, the system could involve an application through which the information could be shared by multiple 3PLs and receivers, further increasing the accuracy of the information. This also provides an incentive for the receivers as the delivery accuracy is increased and the goods are delivered on-time. Nevertheless, achieving cooperation among several 3PLs and customers, and establishing a common operating platform might comprise several technical and financial difficulties.

2. Pre-advice on upcoming customers

Almost all the early morning deliveries during the field study took more time because the driver arrived before opening hours or the customer was late. In some cases, this caused the drivers to wait outside the store up to 21 minutes, which relates to 126.4 SEK on a non-value adding activity. The weekly total amount of time waiting for the customer was 2h 27min 24s, which constitutes as 5.7 percent of the total working time. This corresponds to 887.1 SEK per driver. The median value for each waiting time was 29.1 seconds during the observation period. If the driver had known this beforehand, he could have allocated that time for another customer. These inefficient time utilization situations are wasteful as the driver cannot do any value-adding activities during that time.

To offset these wasteful events, the touchscreen monitor could also comprise pre-advice information on the imminent customer. This involves being able to send the customer a signal prior to arrival but also the aforesaid information regarding the exact location of the goods receipt area. Signaling the customer beforehand will smoothen the process and allow the customer to be prepared for the delivery. In case the retail store is not ready to receive the goods, the driver will know to skip that customer and proceed to the next delivery. Although, this solution requires to set up an IT system which would be equally used among all commercial customers. This might be difficult to achieve as different stores might use services from several carriers. Unable to apply the same solution for all the participants might constrain the potential gain.

3. Route planning and sequencing

Currently, the daily route planning is entirely done by the driver. He receives an entire list of deliveries from the dispatcher when arriving at the terminal. Thereafter, he walks to his loading bay and checks the goods adjacent to it. Only after scanning and confirming that all the goods are in a correct state, he creates the loading sequence based on how to distribute the commodities. The sequencing is based primarily on his existing knowledge on where the customers are located and their respective opening hours.

The routes could be preplanned by the dispatcher to decrease the time spent on planning the route. After implementing the change, the driver only needs to check the goods before loading them. The time study revealed that the drivers spend 1h 43min 41s weekly on route planning at the terminal, which constitutes as 4 percent of the total work time and 626 SEK in costs per driver. As checking the integrity of the goods only takes a fraction of that time, the duration is significantly decreased. Nevertheless, to avoid overloading the dispatcher, it is imperative that a software is utilized to create optimal routes.

The forklift drivers at the terminal could complement the aforementioned suggestion with sequencing tasks. The terminal operator could already sequence the goods before the truck drivers check the goods. This could further improve the time utilization at the terminal.

5.1.3 Assisting tools

The assisting tools initiatives address features which would improve the operational characteristics of the supplementary tools the drivers use during distribution. Similarly to the last category, these initiatives are of the operational type – thus involve investments for the transport operator – and focus on decreasing non-value adding activities.

1. Handheld computer

The weekly time spend on the handheld computer was 3h 1min 27s, which corresponds to 1 092 SEK per driver. This time includes three different activities which all involve using the handheld computer; route planning, scan documents with handheld computer, and signature. In total, the figure accounts for 7 percent of the entire work week. A suggestion highlighted by all three parties involves improving the performance of the handheld computer. The current below par performance has impaired the service level during several administrative tasks. Moreover, the user cannot carry out other activities while the device is processing the information. The drivers argue that the computer is too slow and has a complex interface. Simplifying the interface will provide the drivers easier and faster navigation through the menus. Furthermore, the number of erroneous entries will be reduced by having a simpler interface. As technology has evolved significantly, the solution for this issue is a ‘low-hanging fruit’. Although this involves the 3PL investing in new handheld computers, the potential gain is believed to exceed the investment costs.

2. Electric pallet jack

The time study indicates an aggregate time of 4h 22min 40s associated with walking to and from the customer. The figure represents 10.1 percent of the entire work week and 1 580.8 SEK in costs per driver. The drivers highlighted the necessity for an ET, specifically with rubber wheels. Currently only one of three drivers at Company X used an ET. Unfortunately it had plastic tires, which is not best suited for cobblestone streets and uneven surfaces in the city center of Gothenburg. In these circumstances the ET was extremely noisy and unstable. Proper equipment would definitely improve the working conditions as the drivers frequently deliver the goods on foot. In addition, the use of suitable equipment allows the driver to reduce the effort of balancing the goods while moving. The increased ergonomics result in a decrease in strain injuries. The battery will be charged overnight when it is in an idle state.

Results from the time study shows that 39min 3s is spent on pallet jack handling inside the body of the truck. This is 1.5 percent of the total time and 235 SEK in costs per driver. This time solely represents the time to secure the PJs. Theoretically, by using electric alternatives, the time spend could be eliminated entirely. The automatic break in the electric motor prevents the ET from moving when not in use. Consequently, the total usage time can be decreased as the driver does not need to secure the ET after usage unlike the non-electric alternative, which has less rolling resistance and must be secured before driving the truck.

Solutions regarding securing the PJ need to be considered when investments in electric alternatives are not desired. Currently, the PJ is attached with a strap to the wall in the back of the truck. However, leaving the strap in its fixed position requires additional time-consuming movements. The authors realized that attaching a magnet to the PJ’s handle could decrease the time used on securing the PJ. As Company X’s trucks had metal mounting points in the walls, the PJ could be fastened to the wall without a strap. This solution would enable a possibility to place the PJ anywhere along the walls inside the truck. Nevertheless, because the non-electric alternative still necessitates some handling activities, the magnetic solution has a lower improvement effect on time efficiency than the ET.

5.1.4 City logistics

The city logistics initiatives address features which would improve legislation in urban transportation. These improvements are mainly standards – thus are aimed at customers, transport operators and public authorities – and focus on developing guidelines for loading zone signs, and analyzes potential solutions regarding bus lanes and loading zones.

1. Visible loading zone signs

The visibility of the signs indicating the location of the loading zones at the customer site is a common issue stated by the drivers. Currently, 57min 26s is spent weekly on finding the loading zones and getting in contact with the customers. This is the equivalent of 345.7 SEK in monetary figures per driver for the employer. The drivers believe that the authorities could encourage the companies to have more visible signs. By increasing visibility, the drivers can spot the destination without problems. Ideally this would minimize the total time spent on driving. This is especially relevant when new customers are served and the exact location of their goods receipt area is unknown. It would also be beneficial when the destination comprises many loading bays. These settings are very common with larger shopping centers, i.e. Nordstan. As of today, there is no specific information shared with the drivers on which loading bays should be used. Not finding the correct loading bay is extremely time consuming and stressful due to the narrow passages in the goods receipt area. This is also beneficial for the receivers as the time spent at malls is decreased, resulting in better use of space and higher capacity of the receiving area. As the 3PLs and customers could come to an agreement by agreeing to a specific set of guidelines, this suggestion will avoid involving the public authorities. It is believed that the parties will experience faster results when an agreement is achieved between the transport operators and the customers as pushing through legislation is extremely time intense. The effects of this solution need to be understood by both parties to obtain successful implementation. The difficulty of capturing the interest and approving common guidelines might be considered as the biggest challenge with this initiative.

2. Access to bus lanes

Another suggestion stated by the drivers involves changes in legislation. The drivers stressed how driving convenience and time savings could be obtained by allowing distribution vehicles to use the bus lanes. According to the route tracking, the daily driving distance and time were influenced by detours caused by areas where only public transportation was allowed. Figure 23 illustrates two cases where the vehicle drove significantly more than it would if it had the chance to use the bus lanes. Driving towards the Inom Vallgraven area (red lines), the driver drove 170 meters instead of 70. In the opposite direction (green lines), the contrast was even bigger – 215 meters instead of 70. Due to the aforementioned inconvenient city center driving environment, these detours not only contribute to longer distances but also increase the environmental impact. If trucks get access to the bus lanes congestion can be avoided for all users and driving will become both faster and smoother since less detours are needed. A smoother driving pattern without multiple stop and start occasions would also reduce the level of emissions. Understandably the biggest demand occurs during peak-hours when the average driving speed is lower than normally. Nevertheless, it is important that the bus lanes are not overcrowded by the 3PL's. To avoid such an incident the permission would only apply for specific times so that the public transportation would not be affected. Finding the perfect balance is the biggest challenge for legislators.

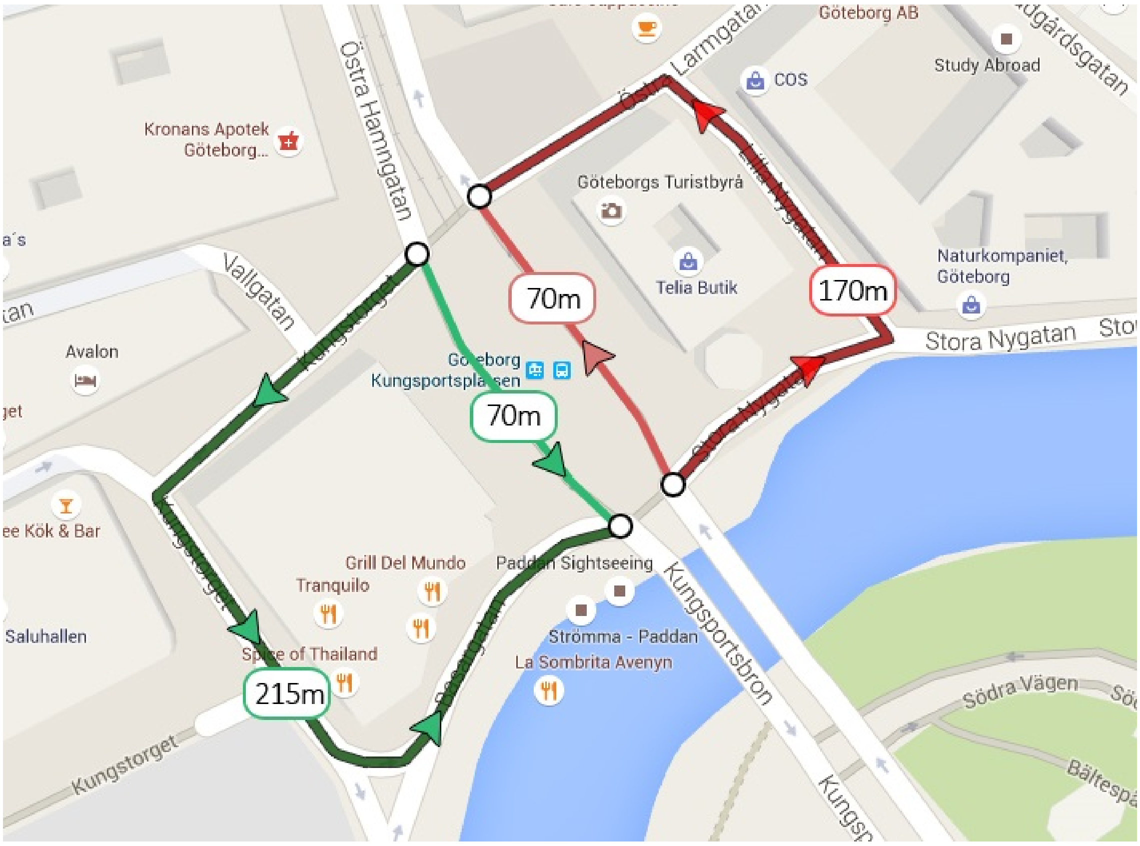

Figure 23: Detours in the city center

3. Sensors for loading zones in the city center

The field study shows that time spent on searching for a vacant loading zone and parking contributed to 1h 19min 54s per week, which is 3.1 percent of all the activities and corresponds to 480.9 SEK per driver. A suggestion emphasized by the drivers is to implement sensors at loading zones in the city center. The idea is based on the fact that loading zones in the city center are often occupied by other vehicles, forcing the drivers to change their delivery sequence. During the time study, both drivers experienced such an occurrence once a day on an average. Consequently, the time used to search for parking increases the driving time and mileage.

The purpose of the idea is that the drivers would have some insight into the availability of certain loading zones. The sensors could be connected to the Internet or the internal system, and send out notifications whether the loading zones are available or occupied. At a later stage, the system could implement a time table. This will allow the companies to pre-book a time slot in advance. These changes would facilitate the drivers' route planning throughout the day. Nevertheless, the latter suggestion requires a thorough study of the usefulness prior to implementation.

5.2 Summary of proposed initiatives

Table 13 summarizes the classification, the type, the responsible fulfiller, and current weekly costs and time spent on activities related to the proposed initiatives. The classification involves four different categories: vehicle, navigation, assisting tools, and city logistics. Seven of the initiatives were of engineering type, seven were operational, and two involved new standards. Seven of the initiatives are directed to the truck manufacturers, seven to 3PLs, three to public authorities, and one to receivers.

Table 13: Comparative table of the initiatives

Initiative	Classification	Type	Fulfiller	Cost	Time spend
Better oversight	Vehicle	Engineering Operational	Truck manufacturer	5 127.4	14h 11min 58s
Decreased turning radius	Vehicle	Engineering	Truck manufacturer	n/a	n/a
Adjustable mirrors	Vehicle	Engineering	Truck manufacturer	n/a	n/a
Improved accessibility	Vehicle	Engineering	Truck manufacturer	n/a	n/a
Increased safety	Vehicle	Engineering	Truck manufacturer 3PLs	n/a	n/a
Tail lift	Vehicle	Engineering	Truck manufacturer	593.3	1h 38min 35s
Temporary automatic security roller shutter	Vehicle	Engineering	Truck manufacturer	n/a	n/a
GPS navigation	Navigation	Operational	3PLs	222.7	37min
Pre-advice on upcoming customers	Navigation	Operational	3PLs	887.1	2h 27min 24s
Route planning and sequencing	Navigation	Operational	3PLs	626	1h 43min 41s
Handheld computer	Assisting tools	Operational	3PLs	1 092	3h 1min 27s
Electric pallet jack	Assisting tools	Operational	3PLs	1 580.8	4h 22min 40s
Visible loading zone signs	City logistics	Standards	Customers / 3PLs (Public authorities)	345.7	57min 26s
Access to bus lanes	City logistics	Standards	Public authorities	n/a	n/a
Sensors for loading zones in the city center	City logistics	Operational	Public authorities	490.9	1h 19min 54s
Note: Weekly times and costs (SEK)					

The table shows that the initiative with the highest weekly cost reduction potential was related to the better oversight initiative. This is mainly due to driving being the activity with largest contribution to time spent. For some of the activities, the weekly cost and time spent was not available as the initiative improved the driver's experience in other parameters than time. These initiatives possess significant improvement potential in adjusting the dimensions, the maneuverability, safety, and security of the vehicle. Furthermore, these initiatives provide better route planning and smarter driving.

5.3 Effect of introducing BEVs

As BEVs have certain differences when compared to conventional ICEs, introducing BEVs in urban freight distribution requires attention to evaluating driving characteristics with current distribution patterns. BEVs' shorter driving range requires the distribution route to be shorter or the ability to recharge during distribution. Today, the former is most plausible as there does not exist a well-functioning charging infrastructure at the customer sites. The battery has to be charged overnight to facilitate the drivers' ease of functionality. This foresees that the battery capacity is sufficient enough to cover the daily distance. This will solely depend on how long the distribution routes are for different 3PL's. However, adjustments need to be implemented if the battery capacity falls short from the necessary.

Route tracking indicated that the daily mean driving distance was 63.9 km and the maximum 95.1 km. The existing technology in all-electric medium-duty trucks have driving ranges between 120 and 300 km, which shows that current BEVs are able to address the urban freight distribution demands in Gothenburg. If necessary, the daily route can be split into two distinct trips so the driver is able to recharge the vehicle during the lunch break, giving it more leeway with additional range. This also offsets the need to invest in costly infrastructure to charge the vehicle several times during the day. Understandably, the figures might differ in larger cities where the distance between the service area and the distribution center (the connecting link) is longer. In such cases if the range is not sufficient, another solution would be to integrate two different drivelines which act as a range extender, known as HEVs.

The biggest influencers of the driving range are the battery type and the battery size, but also the weather conditions, topography and the driving pattern. Many experts emphasize that there exists a trade-off between the size of the battery and its usefulness. Although a bigger battery might extend the performance, this will limit the dimensions of urban freight vehicles. Bigger batteries contribute a significant proportion to the gross weight, which decreases the percentage of the payload per total weight. As the urban environment sets concrete restrictions regarding the weight and the size of the vehicle, most 3PL drivers will agree that an agile vehicle is preferred to a bulky alternative. However, the research showed that there exists a wide array of BEVs with different gross weights, carrying capacities, and dimensions, thus giving the 3PLs the opportunity to customize their truck fleet according to their specific needs. According to the interviews, current distribution is constrained by capacity rather than weight or time.

The driving pattern has significant impact on the driving range. Driving at a constant speed is advantageous *stop-start* driving patterns. The urban freight distribution is characterized by congestion, traffic lights, numerous deliveries and pick-ups. On an average, each stop during a delivery took roughly 10 minutes. This sets certain limitations to the possibility of charging while delivering the goods. However, as BEVs are capable of regenerating power while breaking, the driving range is less affected by the urban traffic patterns. Conventional ICEs do not possess such an option, causing that driveline to be more vulnerable to the aforementioned traffic conditions.

The urban freight vehicles are also influenced by weather conditions and the topography. It is known that cold temperatures have a bigger impact on decreasing the driving range than warm weather. This is related to the fact that during cold periods, the vehicle has to use additional energy to heat the cabin. Moreover, using the radio and other devices further decreases the battery performance. According to the Köppen climate classification, Gothenburg is dominated by warm and temperate oceanic climate with the average winter temperatures at one degree centigrade (Climate Data, 2016, Kottek et al., 2006). Due to the mild weather conditions, the range of the vehicle is not significantly affected, which further highlights the suitability.

As distribution tours normally comprise notable variations in elevation, topography plays a significant role in vehicle performance and fuel consumption. Naturally, in comparison to flat and downhill driving, uphill driving triggers an increment in fuel consumption. BEVs have a noteworthy advantage over the ICE as it is capable of regenerating lost energy while rolling downhill. Nevertheless, the landscape in Gothenburg is not very hilly with the highest peak at 102 meters. The conducted route tracking indicated that the daily average climbing was relatively low, i.e. 1 281 meters, because the city center is located at a low altitude.

5.3.1 The production cost and lifetimes of BEVs

The attractiveness of a BEV for the potential customer will depend on several attributes. Besides the aforementioned driving range, the initial investment into electric-powered vehicles is higher than conventional vehicles. This is correlated with high production costs of the batteries and investment costs for the charging infrastructure. In addition, the shorter lifetime of a BEV's battery might undercut the suitability when compared to ICEs.

Although these issues are perceived as problematic, it is important to consider the evolution of the technology in the near future. The associated high cost is because the technology has not yet reached mass production. Once the public interest and know-how increases, the unit price will drop. A good example of decreasing unit price via economies of scale is the present business model of Tesla. A massive Gigafactory is being built to cut down production costs and make it a more feasible alternative for the potential customer (Tesla, 2014). It is believed that a similar path can be taken in the freight industry as well. According to the literature and the interviewed experts, the cost and lifetime of the battery are of core importance as it represents the greatest cost of a BEV. The increased flexibility in today's production community allows the feasibility of having more customized vehicles. Thereby it creates the possibility of optimizing the battery size according to the need of the user. Furthermore, in many countries the purchase of environmentally friendlier vehicles is financially subsidized and often involves several benefits, such as free parking, permission to enter the environmental zones, and a permit to drive on the bus lanes. This further increases the attractiveness of BEVs.

5.3.2 Externality aspects of BEVs

Seemingly, the environmental aspect of introducing BEVs is perceived as the most significant benefit. The interviewed experts stressed that many bigger cities are experiencing significant issues regarding emissions and noise. It can be regarded as the future solution in urban transport distribution since BEVs have a very low level of noise pollution and emissions. Nevertheless, the lower noise level affects the safety of urban citizens. As the BEVs are close to noiseless at slow velocities, pedestrians in the urban environment face the risk of not noticing approaching vehicles. Accidents and noise are the two biggest issues associated with road transportation. Improving one aspect may impair other aspects. Therefore the technology must be developed in such a way that lower noise levels do not increase safety risks. For example, it is possible to produce a temporary noise that warns the pedestrians but has lower noise impacts than an ICE truck.

The environmental effects of BEVs are not always as well-performing as often thought. When evaluating the environmental impact, the primary energy source is a fundamental aspect to consider. For instance, if coal power plants are used as the primary energy source of electricity, the total amount of emissions caused by BEVs will in a life cycle analysis perspective be remarkably larger than using renewable sources such as solar or wind power. Consequently, assessing the entire WTW process is essential when rating the environmental performance of BEVs. This is also the reason why the interviewed experts avoided describing the BEVs as an emission free option. The energy production must be conducted outside urban areas before being transported to charging stations in the cities. Nevertheless, this is not considered as a universal solution since production sites with high levels of emissions may still not be eliminated. The solution would only shift the local impact to another location. The regional effects, that is acid rain, photochemical smog, and the global effects of GHG emissions, remain exactly as before.

Finally, it is necessary to have a well-developed logistics system for the transport and storage of batteries. It is required to have an efficient logistics system to mitigate the risk of facing unusable batteries since the batteries are vulnerable when they are not used or recharged within a certain period of time. According to the interviews, carrying out long distance shipping of batteries at slow speed can cause problems. Consequently, to utilize a sustainable solution, it is strongly advised that the production of batteries is done locally. This will minimize the effort of transporting the batteries.

5.3.3 Operational benefits and challenges of BEVs

To perceive BEVs as a viable alternative to ICEs in distribution, it is important that the operational aspects do not worsen when vehicles are replaced. The potential benefits of using BEVs in urban freight distribution are based on reducing the environmental impact. The BEVs can be used in indoor settings due to their low noise and emission levels. Therefore, the BEVs can open new possibilities for door-to door deliveries. The aforementioned time study revealed that a weekly aggregate of 4h 22min 40s is spent on walking to and from the customer, which represents 10.1 percent of the entire work. As the vehicle can be driven right to the receiver, less walking activities are necessary. This increases both efficiency and responsiveness of urban transportation. These solutions could be used in bigger malls with an open layout, e.g. Nordstan. Nevertheless, it is important to bear in mind that this solution will only be feasible if it is executed during off-hours. The presence of pedestrians and shoppers will deter the plausibility as it will not be safe nor convenient to drive.

BEVs have a substantial impact on the plausibility of off-peak hour deliveries (OPHD). Company X's management expressed openness to new solutions and believed that the company would not have any issues delivering higher amounts during evenings. Due to BEV's notably lower noise emission, transportation activities will create less disturbances. In case unassisted drop-offs are used, the customer will not need to employ additional night shift workers to receive the goods. The drivers can easily use a separate access in which the receiver provides a delivery locker outside of the establishment (Holguín-Veras et al., 2012). Furthermore, traffic is significantly lower during off-hours, which reduces the amount of *stop-start* occurrences. This provides a smoother driving experience, which helps sustain a higher range. The challenges with OPHD involve the need for additional work shifts if staffed OPHD is used. Also, an increase in security threat undercuts the benefits. Company X's management also believed that the bleeping sound during reversing causes distress in residents close to the loading zone. Although OPHD has several benefits, convincing the receivers and carriers to change their operations takes time and effort.

To achieve the best outcome, the truck drivers need to adapt their habits to the characteristics of BEVs. This involves both driving experience and refueling activities. As the charging can be executed at the terminal, customer location or at a nearby charging station, the drivers do not need to spend time on refueling at a gas station. On the other hand, frequently plugging and unplugging the charging cable becomes an additional activity and can be deemed as time consuming. The conducted interviews revealed that when the driver forgot to plug in the cable for overnight charging, the vehicle was unusable the consecutive day. To circumvent this risk it might be necessary to assign this responsibility to an existing employee to check that all the vehicles are properly charging. The different structure of the BEVs also calls for the workshops and mechanics to adapt and gain additional knowledge on the new technology. Since BEVs have substantially less moving parts, and more wiring and electronics, maintenance work is very different from the ICEs.

Lastly, noise pollution inside the cabin is also decreased with the all-electric vehicle because they do not have loud engines. The entire driving experience is thus thought to be very different from the conventional option with less noise, higher torque and without a need for a gear box. The risk of damaging goods is also reduced as the acceleration is smoother.

6 Conclusion

This study focused on the time efficiency of urban distribution activities and the feasibility of BEVs in urban environments. Firstly, all activities were identified and their respective purpose recognized. Thereafter, the activities were analyzed and classified into different categories. This provided the ability to examine the optimization potential of those activities to increase time efficiency for truck drivers as well as how to realize these improvement initiatives. Lastly, the current distribution routes were juxtaposed with the existing technology in all-electric medium-duty trucks to evaluate the suitability and what is necessary to facilitate a successful change.

The time study on truck drivers' urban distribution activities envisage that in total 31 distinct activities were identified, which were categorized into five groups. The categorization was based on the character and the location where the activity took place. The time study indicated that the biggest share of activities took place in the cabin (34.3 percent) with driving as the major contributor (29.9 percent). Other categories' respective figures were 22.5 percent on activities around the vehicle, 17 percent on breaks, 14.8 percent on terminal activities, 10.6 percent on loading and unloading activities, and 0.8 percent on other activities.

Formulating improvement initiatives in four different classifications from three different perspectives revealed the type of initiative and who had the largest influence of fulfilling the initiative. For most initiatives, their efficiency factor and economic figures were also revealed. The initiatives were extracted from the interviews with experts in BEV technology from the academia, and Company X's managers and drivers, supplemented by the authors' own inputs. Vehicle related initiatives showed that almost all of the suggestions where of engineering type, which allocates the responsibility of fulfilling them to the truck manufacturer. Assisting tools and navigation related initiatives were all of operational type and should be addressed by the 3PLs. City logistics associated initiatives were standards and of operational type, and are directed to public authorities as well as 3PLs and receivers.

The urban distribution driving patterns and characteristics obtained from the route tracking revealed that the existing medium-duty BEVs are capable of fulfilling distribution tasks in Gothenburg, Sweden without any adjustments. The range of all the BEVs is more than twice as high as the average recorded driving distance. Furthermore, there exist vehicles with different payloads between 12-18 tons, allowing the 3PLs to choose the most suitable for their operations. Using BEVs provides significantly better environmental performance as well as several operational benefits, such as lower noise pollution. Nevertheless, it is important that the truck drivers adapt their habits to the characteristics of BEVs to experience the best outcome.

All in all, the research highlights the importance of understanding the demands of different stakeholders and satisfying them in an all-embracing way. The researchers believe that the findings can help truck manufacturers (e.g. Volvo Group Trucks) improve the fit between 3PLs' demands and the truck solutions combined with environmental goals. The value of this research is notable as there were previously almost non-existing enquiries in this field.

6.1 Future research

As the research was confined by certain limitations, the authors believe that subsequent studies in the similar field could further elaborate the findings and incorporate more parameters.

Firstly, a similar study could be done in other cities as well. It is believed that the results could be very dissimilar from the ones highlighted in this report. The amount and division of activities in urban freight distribution in bigger cities might differ significantly. The authors also believe that future studies could use several 3PLs and investigate if there exists notable alterations in the way they conduct their distribution. By collecting information on several carriers and cities, the results can be benchmarked to give supplementary insights into what are the biggest influencers.

Secondly, the future study could integrate route optimization calculations. The meetings with Company X revealed that it is not very common among carriers to calculate the most optimal routes. As the driving activity took roughly a third of the entire work time, this is definitely something that should be investigated. The calculations could also be collated with the initiatives proposed in this research.

Lastly, as technology continues to evolve and reach new heights, the near future might comprise a very different execution of the urban freight distribution. One of these advancements is related to creating a safer and more efficient transportation system by using autonomous vehicles (AVs), which partially or fully drive themselves, meaning that ultimately no driver will be required at all. According to a recent interview with Elon Musk, he firmly believes that fully automated vehicles will be seen as the new "normal" in two years if the same pace of technological developments continue (Korosec, 2015). As AVs have great potential of reducing the amount of crashes, but also congestion and its associated costs, and improve land use, the deliveries and pick-ups could be fulfilled by driverless vehicles. (Anderson et al., 2014). Therefore, the future studies could analyze the potential gains and challenges of introducing AVs for urban distribution.

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A

Time study worksheet

Table 14: Time study worksheet in Microsoft Excel

No.	Start time	End time	Duration	Activity	Description	Activity code	Comments
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
17							
18							
19							
20							
21							
22							
...							
Note: Times are given in hh:mm:ss							

B

Activities and description

Table 15: Activities and description in the time study worksheet

No.		Activity	Description
1		Driving	Driving between locations
2		Park/reverse truck	Parking or reversing the truck
3		Searching for available parking	From having arrived at the customer until the parking begins
4		Administration inside the cabin	Administrative work inside the cabin
5		Tail lift down	Open tail lift
6		Tail lift up	Close tail lift
7		Moving other goods	Restructuring of goods during (un)load
8		Unload truck	Unload truck during the work day, not at terminal
9		Pick-up/loading	Load truck during the work day, not at terminal
10		Secure cargo	Securing the loaded cargo
11		Pallet jack handling	Handling the pallet jack
12		Walk to/from the cabin	Walking to and from the cabin
13		To customer with goods	Walks to the customer with goods
14		From customer with goods	Walks from the customer with goods
15		To customer without goods	Walks to the customer without goods
16		From customer without goods	Walks from the customer without goods
17		Contact customer	Phone call or doorbell, not driving
18		Waiting for customer	Waiting, depending on the customer's work
19		Signature	Signature by the driver or customer
20		Check in documents in computer	Checks in documents in handheld computer
21		(Un)loading at the customer site	Pallet handling at the customer site
22		Break	Including lunch break
23		Conversing	Talking to people
24		Terminal - route planning	Checks lists, decides routes and loading sequence
25		Terminal - load goods with PJ	Loading at the terminal using a pallet jack
26		Terminal - load goods with ET	Loading at the terminal using a motorized vehicle
27		Terminal - unload goods with PJ	Unloading at the terminal using a pallet jack
28		Terminal - unload goods with ET	Unloading at the terminal using a motorized vehicle
29		Terminal - driving	Driving within the terminal area
30		Close/open the terminal gate	Both at the terminal and the customer site
31		Other	Non-repetitive activities

C

Company X's driving routes

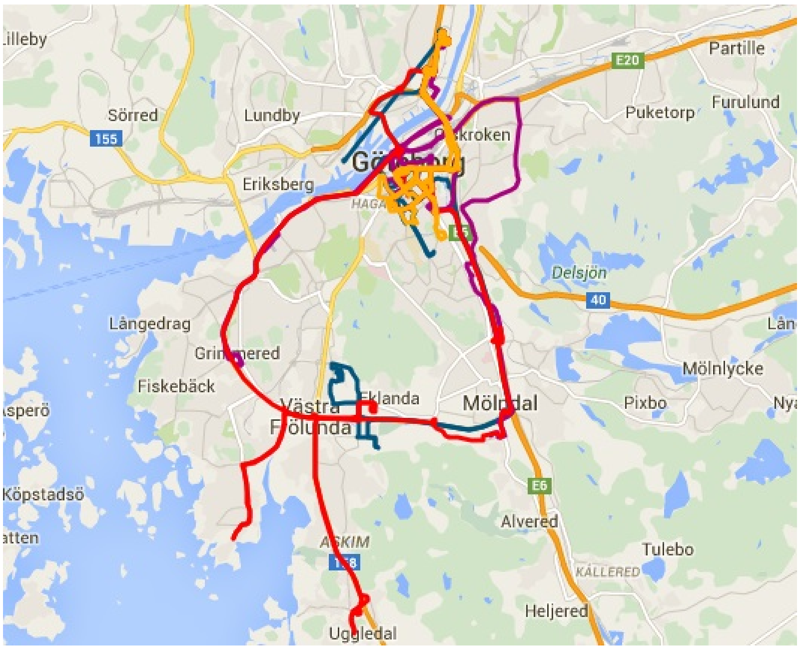

Figure 24: Routes for drivers 1&2

Figure 25: Routes for driver 3

D

Statistics for drivers

Table 16: Statistics for drivers 1&2

Cab		Around the vehicle		Breaks		Terminal		(Un)loading		Other	
Activity	*Duration*	*Activity*	*Duration*	*Activity*	*Duration*	*Activity*	*Duration*	*Activity*	*Duration*	*Activity*	*Duration*
Driving	14:36:27	Contact customer	02:11:34	Break	06:19:17	Route planning	01:28:18	Unload truck	00:51:25	Other	00:35:13
Park/reverse truck	01:10:50	Walking to/from the cab	01:34:47	Conversing	01:10:06	Driving	01:27:38	Tail lift down	00:50:54		
Administrative tasks	00:40:50	To customer with goods	01:32:40			Load goods with ET	01:15:34	Tail lift up	00:44:45		
		From customer without goods	00:57:07			Unload goods with ET	00:46:31	Pallet jack handling	00:26:37		
		Waiting for customer	00:46:47			Load goods with PJ	00:46:15	Pick-up/loading	00:24:41		
		To customer without goods	00:40:36			Using the terminal gate	00:14:51	Moving other goods	00:16:33		
		Signature	00:36:54			Unload goods with PJ	00:05:24	Secure cargo	00:16:26		
		From customer with goods	00:36:33								
		Use of handheld computer	00:25:55								
		(Un)loading at the customer site	00:05:34								

Table 17: Statistics for driver 3

Cab		Around the vehicle		Breaks		Terminal		(Un)loading		Other	
Activity	*Duration*	*Activity*	*Duration*	*Activity*	*Duration*	*Activity*	*Duration*	*Activity*	*Duration*	*Activity*	*Duration*
Driving	08:42:28	To customer with goods	01:36:36	Break	05:04:54	Route planning	01:38:19	Unload truck	00:52:42	Other	00:03:46
Park/reverse truck	01:03:48	From customer without goods	01:07:56	Conversing	00:43:29	Load goods with PJ	01:33:49	Tail lift down	00:47:54		
Administrative tasks	00:22:45	Walking to/from the cab	00:57:06			Unload goods with PJ	01:04:47	Pallet jack handling	00:43:41		
P-spot search	00:09:12	Contact customer	00:47:24			Terminal - driving	00:30:25	Tail lift up	00:33:54		
		Signature	00:45:39			Load goods with ET	00:22:03	Pick-up/loading	00:32:49		
		To customer without goods	00:41:42			Using the terminal gate	00:15:59	Secure cargo	00:29:49		
		From customer with goods	00:39:38			Unload goods with ET	00:01:30	Moving other goods	00:24:36		
		Waiting for customer	00:39:34								
		Use handheld computer	00:31:32								
		(Un)loading at the customer site	00:17:38								