Marco Lucien Sesterhenn

Electric engines as an alternative powertrain solution in the urban freight logistics industry

Metropolia University of Applied Sciences
Bachelor of Business Administration
International Business and Logistics
Bachelor's Thesis
23 June 2023

Abstract

Author(s):	Marco Lucien Sesterhenn
Title:	Electric engines as an alternative powertrain solution in the urban freight logistics industry
Number of Pages:	106 pages + 2 appendices
Date:	23 June 2023
Degree:	Bachelor of Business Administration
Degree Programme:	International Business and Logistics
Specialisation option:	Supply Chain Management
Instructor(s):	Head of Master’s degree programme in Procurement, Senior Lecturer, Kaija Haapasalo

This thesis examines the possibilities and limitations of incorporating electric engines as an alternative powertrain solution in urban freight logistics. The research analyses their economic and environmental viability. The results of the research can be utilized by companies engaged in urban freight logistics in the European market, especially in Finland.

The secondary research based on the literature review included an overview of the status of electric vehicles in the urban freight industry, the impact of electric vehicle implementation on companies' daily operations, and a comprehensive cost and sustainability analysis comparing conventional and electric vehicles. The applicability of the theoretical framework was tested with the help of primary research, which was built around two case studies examining the adoption drivers and barriers of electric vehicles when integrated into commercial fleet. The research method used was qualitative as personal interviews with three Finnish representatives of two freight transportation companies were conducted in spring 2023.

The research findings indicate that the feasibility of electric vehicles depend on several factors. They are geographical orientation, business needs, and business models. Based on the research of this thesis, the author´s conclusion is that a significant proportion of urban freight forwarding companies may still find implementing electric vehicles unattractive due to additional costs and more challenging vehicle characteristics compared to combustion engines.

Keywords: Electric vehicles, powertrain solutions, urban freight logistics, last mile delivery, green logistics

Contents

List of tables

List of figures

Glossary

AC-charging	The European "AC" or "alternating current" charging standard sets the standard for slow charging of electric vehicles. It allows charging electric vehicles with 3kw up to 22kw charging speed. (Virta Global, 2022)
AD	Acidification potential are emissions, which can result in acid rain, harming humans and the environment (European Plastic Pipes and Fittings Association, 2023)
ADP	Abiotic resource depletion refers to the over-extraction of minerals, fossil fuels and other non-living, non-renewable materials. (European Plastic Pipes and Fittings Association, 2023)
ADP-fossil	Abiotic resource depletion with fossils refers to the over-extraction of fossil fuels.(European Plastic Pipes and Fittings Association, 2023)
Battery capacity	The battery capacity measures, how much electricity can be charged onto a battery. The battery capacity is measured in kwh and it can be distinguished between net- and gross-capacity.
CED	The Cumulative energy demand of a product describes the direct and indirect energy usage of the product during its whole lifecycle (Huijbregts et al., 2006: 641)
CNG	"Compressed natural gas" is often used as a subsidiary product to petrol/diesel for powering ICE vehicles.
DC-charging	The European "DC" or "direct current" charging standard sets the standard for fast charging of electric vehicles. It

	allows charging electric vehicles with 50kw up to 350kw charging speed. (Virta Global, 2022)
Driving Range/Range	Distance , electric vehicles can travel with one charge, due to the limited battery capacity.
EFV	Abbreviation for “electric freight vehicle”. A vehicle, which is used for freight transport, which is powered by an electric engine.
eLCV	Electric light commercial vehicle
Emission scopes	Different ways, a company emits emissions through their business activities. There are 3 emission scopes to classify companies’ emissions. The first and the second scope are emissions, directly emitted by the company. Emissions in the third scope are indirect emissions.(John and Growcom, 2008)
EP	Eutrophication potential describes the increase of concentrations of nitrates and phosphates which reduces oxygen levels and harms all living beings, including humans, animals and plants (European Plastic Pipes and Fittings Association, 2023)
Environmental impact criteria	Seven different criteria, used to measure the environmental impact of a certain product.
EV	Abbreviation for “electric vehicle”. A vehicle, which uses an electric engine as a source of power.
FREVUE	The “freight electric vehicles in urban Europe” project represents the testing of electric vehicles in different European cities.

GWP	Global warming potential describes the increase of greenhouse gases in the atmosphere, which cause a chain-reaction, leading to global warming (European Plastic Pipes and Fittings Association, 2023)
ICE	Abbreviation for “internal combustion engine”. Used in the context of ICE vehicles which means vehicles using internal combustion engines as a source of power. An ICE is a system, which burns different reactants un order to generate heat and to use this heat for generating power. Examples for an internal combustion engine is a diesel-powered engine. (Proctor, 2023)
LEFV	Electric freight vehicle, which’s weight is 3.5t or below.
ODP	Ozone depletion potential describes the depletion of the ozone layer in the atmosphere, caused by various emissions (European Plastic Pipes and Fittings Association, 2023)
POCP	Photochemical ozone creation potential means the creation of ozone, leading to chemical smogs affecting all living beings, including humans, animals, plants and the ecosystem in general (European Plastic Pipes and Fittings Association, 2023)
Powertrain Solution/ (e-Powertrain solution)	System which generates & transmits power in order to move a vehicle in a certain direction. In the case of an “e-Powertrain solution” the power is generated by an engine, which uses electricity to generate power.(“Powertrain definition and meaning | Collins English Dictionary,” 2023)
TCO	The abbreviation “TCO” means total cost of ownership. The total cost of ownership describes the sum of all direct and indirect costs associated with an economical good (e.g. a

	vehicle in this case). (Castillo Campo and Álvarez Fernández, 2023: 4)
Vehicle routing	Allocating specific routes to specific vehicles in order to achieve a certain goal, which is for freight logistics to bring the freight to a certain place at a certain time.
WLTP	The “Worldwide Harmonized Light Vehicles Test Procedure” is a testing procedure, which aims at measuring the vehicle range with considering its energy consumption. (Nathan Dale, 2021)

1 Introduction

1.1 Background to the topic

One of the major problems, humanity must face in the 21st century is climate change, resulting from human-made environmental pollution. There are dozens of different industries and sectors, in which humanity tries to reduce environmental pollution, as it gets a more and more important topic with its different impacts on the environment and the human. Impacts on the environment are the melting of the polar ice caps or environmental catastrophes, eradicating whole geographical areas. Impacts on the human could be the rise in global temperature levels or the worsening of air quality, especially in areas, which have a high population density.

Various sectors reaching from system-relevant issues to everyday-relevant topics have been targeted by humanity's efforts to mitigate pollution. These sectors encompass a broad spectrum, ranging from the selection of energy sources to be used, to decisions regarding transportation modes and waste segregation techniques. There is not one person, who can make the world to a better place. Therefore, there is need for people to collaborate to decrease environmental pollution. The governments of different countries come together and set different goals in collaboration aiming at the reduction of environmental pollution. These goals must be transposed into national policy by each government to have a real impact. One of the major impacts of environmental pollution on the humankind is the worsening of air quality in densely populated areas. The worsening of air quality is affected by the emission of CO2 into the atmosphere. The main sources of CO2 emissions in the EU is the road transportation sector, measuring 26% of the total emissions, emitted in 2020 as it becomes evident in figure 1.

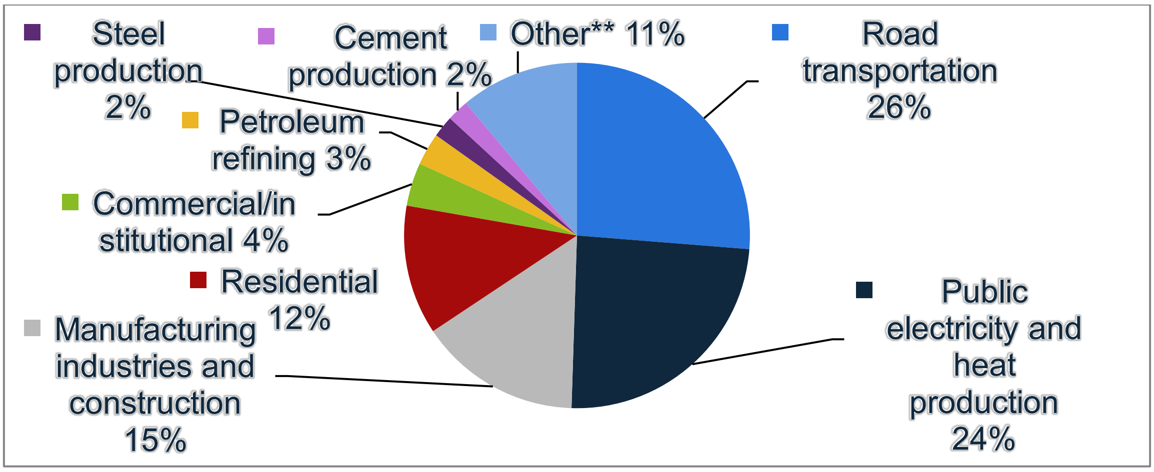

Figure 1: Distribution of carbon dioxide emissions in the European Union in 2020, by key source (Tiseo, 2023)

Unfortunately, traffic is going to increase in the next years, due to many factors. Figure 2 shows the carbon dioxide emissions of the transportation sector worldwide from 1970-2021. It becomes evident, that the emissions, which are measured in billion metric tons are increasing steadily from 1970 to 2020. In 2020, we have a harsh drop, due to the COVID-19 pandemic and its influence on the transportation sector. Nevertheless, from 2021 on, we can see a steep increase again. Therefore, we can say, that without any governmental actions, CO2 emissions from the transport sector will continue to increase steadily. (Statista, 2022)

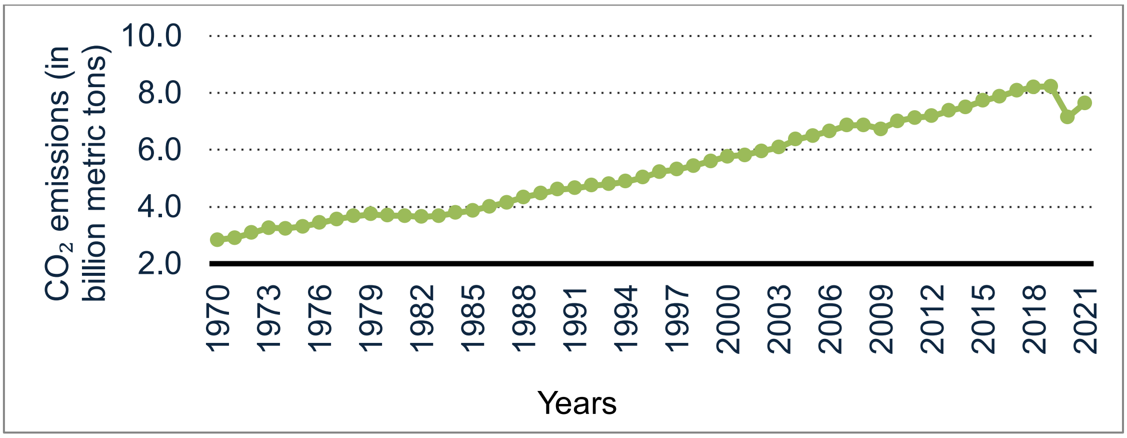

Figure 2: Carbon dioxide emissions of the transportation sector worldwide from 1970 to 2021 (in billion metric tons) (Statista, 2022)

One of the main factors, which influence the increase of transportation is the boom in E-Commerce and the need for transportation of goods. The boom of E-Commerce benefits from the easing of global trade, which took place in the last decades (developments of different trade agreements etc.). Furthermore, E-Commerce is resulting from the development of the internet in recent years. Other factors, contributing to the growth of E-Commerce are the COVID-19 crisis, the current inflation, and the change in buying behaviour of consumers. When looking at the European market, it becomes evident, that the revenue of E-Commerce more than doubled itself in the last 6 years. This development started from 406.2 billion USD in 2017 and landed at a massive 939.7 billion USD revenue, which is prognosed for 2023 as displayed in figure 3. (Beyrouthy, 2022).

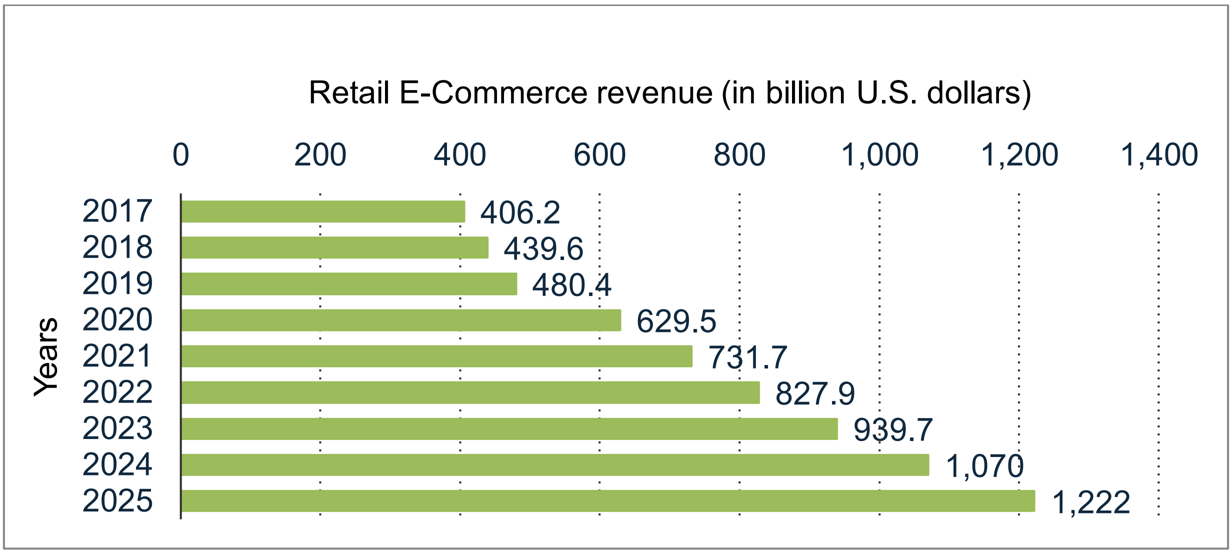

Figure 3: Retail e-commerce revenue in Europe from 2017 to 2025 (in billion U.S. dollars) (Beyrouthy, 2022)

The projected increase of transportation in the future makes actions necessary, which will cut down its impact on the environment. Moreover, not only actions from individuals are important, as the business sector has a much higher environmental pollution rate, especially in freight transport. The major problem are the costs for reducing environmental pollution in the transportation sector. There are high investment costs and following costs, which a business must consider. Due to the existence of an open market in most parts of the world, businesses won't start these actions by themselves initially. Therefore, governmental actions are needed to restrict environmentally harming actions on the one hand and to promote environmentally friendly actions on the other.

In the recent years, many governmental actions aiming at supporting the reduction of pollution have taken place. One of the most influential ones is the Paris Convention in 2015. The main goal of the Paris Convention is to limit global warming to 1.5 degrees compared to pre-industrial levels. The Paris Convention set new standards for the political fight against climate change. For the first time a legally binding agreement was put into place, whilst having 197 states participating in it. While achieving this long-term goal, set in the Paris Convention also several political efforts were conducted on a smaller scale. (Denchak, 2021)

When focusing on the European Union, the most known political effort is the European Green deal. The European Green deal set the long term goal of emitting no net emissions of greenhouse gases in 2050. The short-term goal related to this is to reduce greenhouse gas emissions by a minimum of 55% by 2030. (Wolf et al., 2021: 99)

Nevertheless, governmental actions not only focus on an international scale, but also on a national scale. One of the most known governmental actions limiting emissions was the UK Climate Change Act. This act sets a legally binding goal, which is to reduce greenhouse gas emissions by 80% from 1990 levels by the year 2050. Since committing this act, the UK is often seen as the leader in the fight against climate change.(Lockwood, 2013: 1-2)

Another example is Germany, which is transposing climate protection law into national law. Germany established the so-called “Klimaschutzgesetz”, which embeds different actions into law. The major goals are in short-term to reduce emissions by a minimum of 65%, comparing to 1990 until 2030. In the long-term, Germany wants to be emission neutral. (Deutsche Bundesregierung, 2022)

There are many more examples, but referring to them all is not in the scope of this thesis. It can be concluded, that the governmental actions, imposed in the recent years will have major impacts on the future of the transportation sector. Companies will have to implement alternative powertrain solutions into their vehicle fleets to fulfil governmental criteria. Therefore, the research about the implementation of alternative powertrain solutions into vehicle fleets becomes more important.

1.2 Objectives & Scale of Research

The objective of the research, conducted in this thesis is to present the possibilities and limitations of electric engines as an alternative powertrain solution to conventional combustion engines for companies, which are operating in the urban freight logistics industry.

Electric engines currently represent the most adopted alternative powertrain solution for vehicles. While other technologies such as fuel cells are under development, they have not achieved the same level of implementation as electric engines. Therefore, this research will specifically concentrate on electric engines as an alternative powertrain solution. Despite their widespread adoption, electric engines face a significant challenge in terms of limited battery capacity, resulting in restricted driving range. As a result, they are primarily utilized in densely populated areas characterized by shorter driving distances. However, since densely populated areas contribute significantly to greenhouse gas emissions and suffer from deteriorating air quality, urban freight delivery emerges as the most promising application area for electric vehicles to date. Consequently, this research focuses on exploring the potential and limitations of implementing electric engines as an alternative powertrain solution in urban freight logistics.

Different theoretical models, which are of big importance for businesses in the urban freight logistics industry, were reviewed and analysed. Furthermore, interviews with representatives from two logistics companies, operating in the industry in Finland were conducted. Results of these interviews were utilized when applying the presented theoretical models for the use of the case companies in this thesis. The research focused on small- & medium- sized vans below 3.5 tons. These vehicles are often used in urban freight transportation, due to their size, their payload, and the ability to drive them with a B-license in the EU. Additionally, the scope of the primary research was limited to the densely populated areas of Finland, such as Helsinki, Espoo and Turku.

Given the immediate necessity for numerous enterprises within the urban freight logistics sector to transition towards alternative powertrain solutions in the foreseeable future, this study and its findings possess potential relevance for the broader logistics industry.

The research questions of this thesis are:

- What has the current and future vehicle market to offer to the logistics industry?
  - (a) What are the drivers and barriers for the implementation of electric vehicles into the urban freight logistics industry?
  - (b) How sustainable are electric engines, when using them in the urban freight logistics industry?
- How economically feasible are EVs in commercial usage (cost-perspective)?
- What is the impact of integrating electric engines as an alternative powertrain solution on companies' vehicle fleets?

1.3 Methodology

Different theoretical models, which are of big importance for businesses in the urban freight logistics industry, were reviewed and analysed. Furthermore, interviews with representatives from two logistics companies, operating in the industry in Finland were conducted. Results of these interviews were utilized

when applying the presented theoretical models for the use of the case companies in this thesis.

The research conducted in this thesis was based on secondary and primary data. The secondary research consisted of different journal articles, professional books and online sources. Furthermore, various tools, such as SWOT and TOWS analysis were used to analyse the results of the literature review. The secondary research focused on providing the basis for the case study application and primary research.

The primary research consisted of 3 interviews with 2 representatives of the case companies. The case companies were Posti Oy and another logistics company operating in Finland. Those companies were selected, as they are amongst the most important urban freight forwarders, operating in Finland. The interviews were conducted either in person or via video conferences. The respondents of the interviews have a key role in vehicle fleet management in the respective companies. The interviews consisted of 11 questions respectively. The results of the interviews allowed the thesis writer to gain more sufficient knowledge about the topic in addition to the academic articles and literature researched. The cover letter and the interview questions, which were sent out to the respondents are displayed in appendix 1.

1.4 Limitations of the research

The analysis of the thesis focuses on the possibilities and limitations of the use of electric engines as an alternative powertrain solution in urban freight logistics. Nevertheless, there are some limitations in the research concerning the scope of application.

The secondary research was based on different journal articles and online sources, which were all based on the application of EVs in the European union. Therefore, the feasibility of implementing EVs outside the European Union wasn’t presented in this piece of research. Additionally, it must be stated, that the external influences, impacting the feasibility of EVs are different in all EU countries. Furthermore, the primary research was focused only on the application of EVs in the Helsinki Metropolitan Area by 2 companies. An investigation of multiple different urban areas in different countries with multiple companies would have allowed a more reliable analysis. Additionally, case studies also conducted outside the European Union would have provided the possibility for a wider and more detailed analysis.

However, this study provides a detailed analysis on the feasibility of the implementation of EVs in the urban freight transportation industry of the European Union. Additionally, the research conducted was proven by case study companies, operating in the Helsinki Metropolitan area in Finland.

2 Urban freight logistics industry

2.1 General aspects

To understand the urban freight logistics industry, it is important to understand the concept of freight transport. Freight transport means that goods are moved from one position to another to achieve a certain goal. This movement can happen with the help of all different modes of transportation, such as air-, sea-, rail- or road transportation. The research conducted in this thesis focuses on road transportation. In road transportation, one has to distinguish between short-haul transportation and long-haul transportation. Short-haul transportation mostly happens, when transporting freight in densely populated areas. This is called urban freight logistics.

Urban freight logistics can be defined as follows:

> Urban freight transport and logistics involve the delivery and collection of goods and provision of services in towns and cities. It also includes activities such as goods storage and inventory management, waste handling, office and household removals and home delivery services. (Browne and Allen, 2011)

In today’s market environment, urban freight transportation gains increasingly more relevance, due to various factors, the two main ones being the progressive urbanization and the rise of E-Commerce. As this thesis has an economic focus, it is concentrating on the boom of E-Commerce as an important factor. Through this thriving development, the emergence of new business models is evident and of existential importance. There are different examples for these business models, a few of them being online shops for all kinds of products or even the transportation of important medicines. The important aspect is, that these business models couldn’t exist without a proper urban freight transportation structure. Therefore, many business models, as of today rely on urban freight transportation.

2.2 Important vehicle characteristics for urban freight transport

It is crucial to consider the vehicle characteristics that are essential for urban freight forwarding businesses to carry out their daily operations. The company's ability to meet customer needs and remain competitive in the industry is dependent on having vehicles that satisfy specific requirements. This issue gained increasing significance in recent years due to the introduction of electric vehicles into the industry. Consequently, understanding the requirements that are important for fleet operators is of major significance for this analysis.

2.2.1 Purchase costs

When regarding the vehicle life cycle, the primary aspect to consider is the vehicle purchase price. This vehicle specification is decisive for the purchase decision of commercial fleet operators. This is due to the tight budget specifications. Even though several studies show that a lower purchase price is preferred, whilst the purchase price has a decreasing marginal utility the higher the price is. This means, that fleet operators are becoming less sensitive to purchase price increases, the higher the prices are. As an example, the price difference between two vehicles, that costs 100 000 € and 110 000 €, is seen less important than the price difference between two vehicles, that cost 20 000

€ or 30 000 € respectively. This might be due to the fact, that freight operators, that already have a budget and willingness to spend of 100 000 €, are willing to spend 10 000 € more than those freight operators, which are ready to spend only 20 000 € per vehicle.(Lebeau et al., 2016: 250)

The problem with most EV's, which are suitable for commercial transportation, is the purchase price. It is often significantly higher than the purchase price of the combustion engine, which is the cheaper alternative. This is due to many factors, battery costs and research and development costs being the main ones. The Ford Transit is a popular van model for urban freight transportation. The cheapest version of the combustion engine for the Ford Transit in Germany excl. VAT starts with a price of 37 550 €. On the contrary the cheapest version of an electric powertrain for the exact same vehicle is starting at 59 890 €. This constitutes to a price difference of approx. 59,5 %. The Ford Transit is just an example. However, this price increase constitutes in fact for most vehicles. This is a big issue for freight forwarders, as there is always doubt whether the higher initial price will be offset by the lower operating costs of the electric vehicle. The government often tries to promote EV's by offering a subsidy in a form of a reduction from the purchase price by a certain percentage. This might not be the most feasible tool due to the fact of the decreasing marginal utility. The subsidy will be higher for more expensive vehicles although the higher-priced vehicles don't seem to suffer from the higher price as much as the cheaper vehicle models do.(Ford-Werke GmbH Kundenzentrum, 2023; Lebeau et al., 2016: 250).

2.2.2 Operating costs

Operating costs entail the costs for daily business usage of a vehicle calculated as €/km. They contribute as the second biggest cost element in the TCO analysis after the purchase price of the vehicle. Operating costs seem to have a negative increasing marginal utility. This means, that there is a higher sensitivity to increasing operating costs than to decreasing operating costs.(Lebeau et al., 2016: 250)

A major advantage of electric vehicles are their low operating costs compared to combustion engines. This results from the energy prices on the one hand and from reduced need in maintenance work on the other. The energy costs depend on the geographical location of the business. Therefore, operating costs are differing heavily from country to country. When taking Finland as an example, the energy costs are approx. 0,07 €/kwh (Statista Research Department, 2023a), whilst the diesel price was approx. 1,77 €/litre in May 2023.(Global Petrol Prices, 2023a) In comparison to Finland, Germany had electricity prices of 0.46 €/kwh (BDEW, 2023) and diesel prices of 1.58€/litre in May 2023. (Global Petrol Prices, 2023b)

When comparing fuel costs of two vehicles, one with an ICE and one with an electric powertrain, the significance of different operating costs becomes really evident. The different models of the Mercedes Vito can be used as an example. The “e-Vito” is one of the most popular electrified vehicles used in urban freight transportation. The cheapest ICE Mercedes Vito has a combined diesel consumption of 7.4l/100km and the “e-Vito” has a combined energy consumption of 21.3kwh/100km (Mercedes-Benz AG, 2023a, 2023b). These energy consumptions result in costs of approx. 13,09 €/100km for the ICE version and 1,49 €/100km for the electric version of the Vito (based on the energy prices of Finland). This constitutes to a price difference of approx. 89,8%. The purpose of this comparison is to give a broad idea of the competitive positioning of electric vehicles in terms of operating costs.

2.2.3 Driving Distance

An important aspect for freight forwarders to consider is also the driving distance of the vehicles. (Russo and Comi, 2002) estimate, that 80 % of urban freight delivery trips are 80 km or shorter. In general, a higher range is preferred by vehicle fleet operators. In reality the marginal utility of a higher range (>100km) decreases because most operations in urban freight transportation are 80 km or lower (Lebeau et al., 2016: 251; Russo and Comi, 2002).

Electric vehicles are often seen as non-feasible, as their range is much lower than the range of ICE vehicles. Whilst ICE vehicles will drive approx. 500-700 km depending on the driving profile, the electric vehicles are still often limited to a range of 150-300 km or even less. However, with innovation and development the range of electric vehicles is improving all the time. In the year 2023, already almost all electric vehicles can reach a minimum of 80 km of range on a single charge. Despite of that, the vehicle fleet operators are still sceptical and therefore not yet implementing electric vehicles to a larger degree into their fleets.

2.2.4 Payload

Payload can for example be measured by volume and weight that the vehicle can carry. Concerning the volume, various studies show, that vehicle fleet operators prefer a medium payload, meaning that a too low and a too high loading volume won’t increase utility. However, we must keep in mind, that the needs of the freight forwarders differ heavily, as the specialization in freight is crucial for determining the need for the weight and volume that the vehicle can carry. (Lebeau et al., 2016: 251)

When operating with small and medium-sized vans (<3,5 tons), the required payload isn’t as high as in other industries. Due to the heavy battery in the electric vehicles, the payload is reduced to approx. to 200 - 400kg. However, this reduction in payload capacity can be seen also as a disadvantage and therefore it can worsen the competitive position of the electric vehicles in the vehicle market (Anosike et al., 2021: 10).

2.2.5 Time needed for recharging and refuelling

Numerous enterprises engaged in urban freight logistics possess business models that require certain vehicle standards for the purpose of recharging and refuelling. A substantial number of freight transportation companies rely on the refuelling capacity of vehicles, as these vehicles execute delivery operations throughout the day and are relocated for loading and unloading functions during night-time hours.

Until now, the time needed for refuelling ICE vehicles has not been a problem at all even though there is time needed for driving to the gas station, fuelling, and returning. With EV´s the time needed is more important than ever before. EV’s require not only heavy investments for charging infrastructure, but the charging times are often exceeding 45 min (depending on the vehicle and the charging infrastructure). This puts vehicle fleet operators in an unfortunate positioning, as the adaption of EV’s is often not possible without a change in the business model of the company at the same time. This can make the EV’s unattractive for freight transportation companies.

3 Electric vehicles in the urban freight industry

In the following chapter, the reader is introduced to general aspects about electric vehicles in urban freight transportation, like the status of implementation and the current structure of the vehicle market.

3.1 Status of implementation

First, it is important to know, how the major urban freight logistics players have implemented electric vehicles into their vehicle fleets by 2023.

United Parcel Services (UPS) is one of the biggest players in the transportation industry with a freight revenue of 72 million U.S. dollars in 2021, not only covering road freight transportation, but having road freight transportation as an important pillar of their business model. (Placek, 2022a) UPS is committed to reduce the carbon emissions of their business operations to 0 by the year 2050.(United States Parcel Service, 2022) The vehicle fleet, covering the ground operations of UPS entails approximately 108 000 vehicles. (Placek, 2022b) When looking at the status of implementation of alternative powertrain solutions into its vehicle fleet in 2022, UPS has implemented about 13 000 vehicles with an alternative powertrain solution including approx. 1000 electric and plug-in-hybrid vehicles. (United States Parcel Service, 2022) This amount is about 0.0092 % of electric vehicles and plug-in-hybrid- vehicles of the entire vehicle fleet and therefore corresponds to only a fraction of all vehicles used by UPS.

Deutsche Handels Logistik (DHL) is focusing on long-haul transportation since 80 % of their transportation is long-haul. The image of the vehicle fleet looks a lot different in DHL than at UPS. What comes to developing sustainable transportation, DHL has always been one of the most progressive and ambitious freight forwarding companies. DHL is committed to achieving the EU's zero emissions target by 2050. Therefore, 18% of their short-distance and last-mile delivery fleet was fully electric in 2020. Furthermore, DHL aims at achieving a proportion of 60 % electric vehicles in their short-distance and last-mile delivery fleet by 2030. This would mean having over 80 000 electric vehicles in total. (DHL, 2022; Storch and Scharrenberg, 2023)

The third big player in global freight logistics is Federal Express (FedEx). Its goal is to reach carbon-neutral operations by the year 2040. The ground operations vehicle fleet of FedEx consists of more than 200 000 motorized vehicles. FedEx's ambition is to change the procurement strategy of new vehicles so that 50% of all vehicles they purchase in 2025 will be electric. Furthermore, they want to increase this portion to 100% by 2030. The final target is that the vehicle fleet should be converted to electric vehicles by 2040.(FedEx, 2022)

The Finnish Posti Oyj, is a smaller player but also very ambitious concerning the greening of their transport fleet. The company was granted a sustainable brand index award in 2022.(Posti Group Oyj, 2023a) Concerning their light-duty vehicles (vans < 3.5t), they plan to increase gradually the percentage of electric vehicles until full electrification of their van fleet by 2030. Currently the vehicle fleet of Posti entails approx. 2700 - 3000 vans of which 200 vans are electric.

(Lehmuskallio, 2023) This enables Posti to offer fully electric transportation in the Helsinki Metropolitan Area of Finland. (Posti Group Oyj, 2023b)

3.2 Current vehicle market

One of the reasons for the low implementation status of EVs into commercial fleets is the current vehicle market, which doesn't entail many vehicles, which would be really feasible for commercial use. Therefore, the current vehicle market for potential commercial electric vehicles is discussed more widely in the following. First to examine are vehicles from traditional manufacturers. Additionally, an overview of potential and promising start-ups, which focus solely on light-duty commercial vehicles with electric engines is presented.

In figure 4, the most sold light duty electric vehicles in 2020 sorted by model are presented.

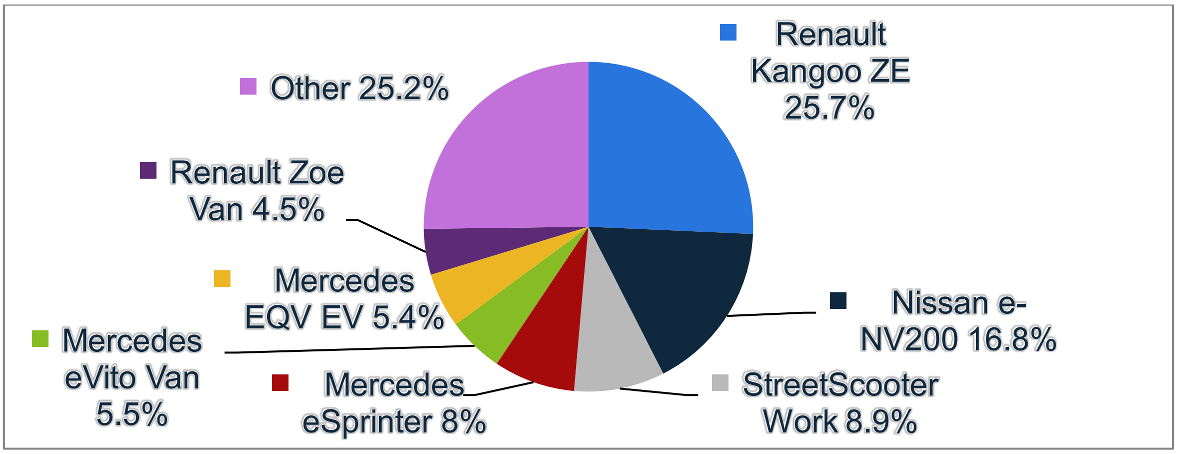

Figure 4: Distribution of electric light commercial vehicle sales in Europe in 2020, by model (Carlier, 2022)

The Renault Kangoo ZE was the model, which was sold the most often with a share of 25.7%. This means, that approx. ¼ of all sold light duty electric vehicles in 2020 were a Renault Kangoo ZE. The Nissan e-NV200 was the next model, which was sold in a high frequency with a share of 16.8% of all sold light duty electric vehicles in Europe. Following Nissan is Streetscooter, which is a LCV developed by DHL, with a share of 8.9%. The rest of the models were nearly all from Mercedes, namely the models eSprinter, eVito Van and EQV. Their share was in total 18.9%. The last category is the Renault Zoe van with a share of 4.5%. Even though the model ZOE had a significant share of 4.5% it is not included in the following analysis, as this vehicle constitutes as a small car, made for passenger transport, rather than a LCV made for freight transport. The last missing 25.2% were distributed to all models, which had a sales share below 4.5%. (Carlier, 2022)

In the following analysis, the manufacturers of the most popular LCV models are presented in further detail. The prices of the vehicles, which are mentioned in the following are without VAT and based on the German vehicle market, unless stated otherwise.

3.2.1 Renault

Even though the Renault ZOE is a passenger car rather than an LCV made for freight transportation, Renault had the highest share of sold LCV's in the year 2020. The model, which made up the majority of the share was the "Kangoo ZE". This model is a small van, just weighting 1524kg. This was the old version of the "Kangoo", the new version, called "Kangoo Rapid E-Tech" has a higher range but also a higher starting price. Both versions of the Kangoo are rather made for small freight transport.

For bigger freight transport or more freight volume respectively, there is another electric vehicle made for commercial use from Renault. It is the so-called "Master E-Tech", which is a bigger freight vehicle, weighting 2155kg. (Allgemeiner Deutscher Automobil-Club e.V., 2023a, 2023b; Renault Deutschland AG, 2017)

3.2.2 Nissan

Nissan had a share of 16.8% of all sold LCV vehicles in Europe, just with one vehicle model, specifically the Nissan e-NV200. This vehicle is rather a small transport vehicle again, just weighting 1614kg. Therefore, it is suitable only for smaller freight transport. This model, like the Kangoo, also has a newer version available now, being approx. the same weight and having approx. the same costs as the old model. (Nissan Center Europe GmbH, 2023a, 2023b, 2023c, 2023d)

3.2.3 Mercedes

Mercedes had 3 different models listed under the most sold vehicles. The Mercedes EQV, which was also listed as a light commercial vehicle, is made for passenger transport. Therefore, it is not included in the analysis. The model, which was sold in the highest volume was the Mercedes eSprinter. As the name suggest it is the electric version of the popular Mercedes sprinter. This model is available in many different sizes and heights of the ceiling, which makes it very flexible in its usage for freight transport. Another model, which was really popular concerning sold volumes is the Mercedes eVito, which is not available in as many variations as the sprinter is in the electric engine version, but has the perfect size for urban freight transportation.(Mercedes-Benz AG, 2023c, 2023d, 2023e)

Although the market for electric LCV's is developing for the better over time, concerning price, availability and vehicle specifications, it's still not as broadly developed as the market for conventional LCV ICE vehicles. Therefore, there are many promising start-ups in the industry, trying to develop something new and truly unique for commercial fleet operators to adopt.

3.3 Future vehicle market

In the following, the start-up market around LCV's is examined. At the moment, there are some start-ups, which already have vehicles available and in use over the world. On the other hand, there are start-ups, which have just started to develop vehicles recently.

3.3.1 DHL Streetscooter

DHL Streetscooter is as an important start-up in the LCV industry. This company already produces its vehicles and has them up and running mainly in DHL's own vehicle fleet, but also in multiple other vehicle fleets of small third party customers. In the analysis in chapter 3.1, the current status of implementation of electric LCVs in commercial fleets was analysed and DHL stood out as one of the companies, having implemented electric vehicles in bigger scale than its competitors. That is because they bypassed the lack of feasible vehicles on the market by developing their own vehicles. Steetscooter was found as a company in 2010. The first prototype of the model, which was the most sold in 2020, namely the “Work” was first presented in 2012. The mass production of the the Streetscooter “Work” started in 2015, enabling DHL to implement the model into their vehicle fleet. Furthermore, Streetscooter started to sell the vehicles onto third parties in 2017. From 2018 onwards, there was another model introduced by the start-up, namely the “Work XL”. In 2022, the start-up Streetscooter was bought by B-On, which altered the product assortment to a certain degree. (Streetscooter GmbH, 2023)

The vehicle “Work” is the smaller version of the van portfolio. It is available in different variants, called “Work Pure” and “Work Box”, depending on the roof construction and space needed of the customer, to guarantee a maximum level of flexibility. The van model, available by Streetscooter is the “Giga”. This model comes in the same variants, as the model “Work” does, in order to be able to offer a maximum flexibility to customer needs. (B-ON GmbH, 2023)

Overall, the approach of Streetscooter, or respectively now B-On is more on the basis of “Never change a running system” and doing things as simply as possible. They don't try to “reinvent the wheel” but to combine already existing concepts with electric engines as a new powertrain solution.

3.3.2 Maxus

Another important “start-up” in the LCV industry is Maxus. Maxus is a subsidiary company of the Chinese group “SAIC Motors”, which is a production partner of “Volkswagen” in China, therefore it can’t really be seen as a start-up in the conventional way. Instead, it is a young subsidiary found in 2011, which is focusing on electric LCVs. Maxus cooperates with Ikea and Hertz in Germany and operates most of their vehicle fleet. On an international level, Maxus cars are used by postal service providers in countries, such as UK, Ireland, Norway and Australia. Furthermore, also important players, like FedEx are using some Maxus vehicles. (Maxomotive Deutschland GmbH, 2023a)

The vehicle fleet offered by Maxus includes a smaller van, and a larger van. The smaller van is called “eDeliver 3” and can be compared size-wise to the Mercedes “eVito”, which means that this van is rather made either for smaller deliveries or shorter delivery routes. Additionally, there is a larger van in the product portfolio, which is called “eDeliver 9”. It can be compared size-wise to the Mercedes “eSprinter”, which makes this vehicle suitable for bigger deliveries or longer delivery routes.(Maxomotive Deutschland GmbH, 2023b)

3.3.3 Arrival

One more start-up, which is playing an important role in the development process of LCV’s is the British start-up called Arrival. Arrival’s policy is the following:

> At Arrival, we are reinventing both the design and production of electric vehicles for end to end sustainability. Only true innovation of both products and processes can deliver the radical impact we need to combat the worst effects of the climate crisis.(ARRIVAL UK LTD., 2023)

Arrival was founded in the year 2015 and aims at restructuring and revolutionizing the industry for LCV vehicles, which can also be seen from their vision statement, stated above. This start-up can be seen as the Tesla of the industry for LCV’s, as it’s trying to cope with all big manufacturers and out scale them in terms of competition. (Forbes Media, 2023)

Arrival’s van tries to be as convenient and attractive as possible for the driver and the commercial fleet operator, minimizing service needs and being built as easy and simple as possible. The start-up itself states, that the vehicles are outperforming conventional vehicles in terms of costs. A cost saving in operating costs of up to 50%, compared to conventional vehicles is possible. Until now, nothing official about the technical specifications or the pricing is published, but important players in the freight forwarding industry are working closely together with the company and have already heavily invested in the start-up. One example for these investors is UPS, with which Arrival cooperates to build vehicles, which are perfectively aligned with the needs of the businesses. In 2020, UPS already invested a big amount in the start-up in the form of a vehicle order for 10,000 vans, which should be rolled out in the timeframe of 2020-2024. (Tomlinson, 2020)

4 Impact of the implementation of EVs

In this chapter the influence of implementing electric vehicles into vehicle fleet is analysed based on literature review of several secondary data sources. There are impacts on vehicle fleet management, vehicle routing, the way of refuelling and on the satisfaction of important stakeholders like employees and customers. The purpose of the following analysis is to provide better understanding about the possibilities and limitations of the implementation of electric vehicles into commercial fleets.

4.1 Vehicle fleet management

The first and most obvious impact of implementing of electric vehicles into commercial fleet is the change in vehicle fleet management of the business. In general, vehicle fleet management describes the controlling of the business fleet to optimize its efficiency and costs. This is done by a variety of actions, like changing the fleet mix and size or by changing the vehicles used.

The maximum age of vehicles in commercial fleets is often assumed to be a maximum of 10 years (Al-dal’ain and Celebi, 2021: 5). This means, that the vehicle fleet of a commercial business is constantly changing, as old vehicles are salvaged, which are replaced by new vehicles.

(Al-dal’ain and Celebi, 2021: 4) have developed a framework to find the optimal vehicle fleet mix. This is presented in figure 5.

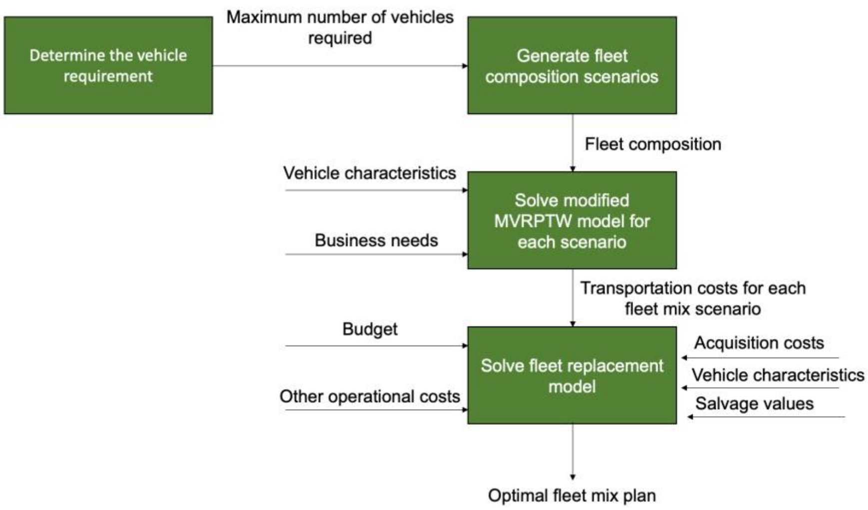

Figure 5: The general structure of the proposed approach for an optimal vehicle fleet mix plan (Al-dal’ain and Celebi, 2021: 4)

The approach developed suggests starting by determining the vehicle fleet requirements, which are needed to satisfy the business needs. Those can be e.g. range, charging speed, purchase costs of the vehicle. The company should determine the maximum number of vehicles required to generate different possible fleet composition scenarios. In the end, the programmed model should be solved for each fleet composition scenario. This model aims at minimizing operational costs, whilst having vehicle characteristics and business needs as input data. Additionally, the model provides the transportation costs for each fleet mix scenario, with which the company can choose the most feasible scenario. With this chosen scenario, the optimal fleet replacement model should then be solved. This fleet replacement model has inputs, such as the budget, operational and acquisition costs, vehicle characteristics and the salvage value. With applying this framework, the company will receive an optimal fleet mix plan in the end.

Commercial fleet operators are currently implementing more electric vehicles into their fleets. However, due to sustainability and budget reasons this change will take several years. This means, that still for some time, the companies implementing electric vehicles have a need to cope with a mixed fleet of ICE vehicles and EVs. This will have both positive and negative aspects for the vehicle fleet operators. A positive aspect is that by continuing the use of ICE vehicles the vehicle fleet operator can balance the deficiencies of electric vehicles like reduced range and payload. Despite this, the impacts of EV´s will be more significant, when the number of ICE vehicles reduces over time. Depending on the fleet mix and the required range due to the geographical location of customers, some businesses might not be able to fulfil their business requirements after reducing the amount of ICE vehicles substantially. This could mean an increased need for the number of vehicles in total (Al-dal'ain and Celebi, 2021: 6).

The size of the vehicle fleet should satisfy business needs and at the same time minimize costs (Campo and Fernández, 2023: 3). When replacing ICE vehicles with EV's the big difference is in vehicle characteristics like range and payload as was already mentioned. This means, that for satisfying the same business requirements, more EVs are needed than in case of just using ICE vehicles. Over time, the renewing of commercial fleets will lead to an increase in fleet size for many businesses (Klumpp, 2014: 10). (Rizet et al., 2016: 506), claim that the impact of replacing ICE vehicles by EVs (1 to 1) will probably produce a congestion in city centres, which wouldn't be bearable. This is due to the fact that there will be need for more EVs than ICEs earlier to satisfy the business needs.

Many fleet operators must face this problem of vehicle fleet size at one point in their transition to alternative powertrains. Factors, like the higher purchasing price, the high investment costs in general, an increased need in employees and an increase in working hours are especially important. These problems can require fleet operators to reshape their business model from scratch to have a positive business case.

(Al-dal'ain and Celebi, 2021: 7) also made an analysis of different fleet compositions for a business operating 6 vehicles in total and having geographically random distributed customers. In their research the number of ICE vehicles and EVs was altered to achieve the lowest operating costs possible. Focus of the study was set on the increased driving distance caused by the need to recharge an EV during the delivery operations. The results presented in table 1 show, that operating costs will gradually decrease when using EVs, but on the contrary the distance travelled increases due to the need of recharging during the day. It should also be mentioned that this study does not pay attention to the extra time needed when using EVs, which can have an impact on the operating costs.

Table 1. Results of programmed model for different fleet compositions (Al-dal'ain and Celebi, 2021: 7)

No. of customers	R scenarios	EV's	ICE's	Operation cost	Distance
50	1	6	0	54.89	886.6
50	2	5	1	74.367	830.4
50	3	4	2	98.529	824.05
50	4	3	3	84.338	810
50	5	2	4	126.144	726
50	6	1	5	131.394	718
50	7	0	6	181.249	688.2

4.2 Vehicle routing

Urban freight transport businesses experience additional impacts in terms of vehicle routing when adopting electric engines as an alternative powertrain solution. It is crucial to consider the reduced range and payload capacity of EVs in comparison to ICE vehicles (Melander et al., 2022: 3). Studies show, that the range of EVs often does not exceed 100-150 km (Quak and Nesterova, 2014: 272), and their payload capacity is typically only 55% of that of conventional diesel vehicles (Melander et al., 2022: 7). Consequently, urban freight forwarding companies must reconsider their business models to align with those specific vehicle specifications. Failure to adapt to these requirements can result in a negative business outcome when utilizing EVs (Klumpp, 2014: 3-12).

In general, vehicle routing can be defined as follows:

> The objective (…) is to determine the optimal route set providing tailored services to fit the customers' needs under time, distance, and/or emissions restrictions. (Castillo Campo and Álvarez Fernández, 2023: 2)

As use of EVs is imposing limitations in terms of reduced range and payload, companies must aim at reshaping their route network. This can be done through various actions.

4.2.1 Vehicle routing frameworks

One of the most common actions, when reshaping the route network is to implement highly mathematical vehicle routing frameworks. These are based on certain algorithms, which are fed with real-time company- and vehicle- specific data. The outcome is perfectly planned and scheduled geographic delivery routes which enable business optimization. (Ewert et al., 2021: 518).

(Ewert et al., 2021: 518-519) developed a simple general approach for vehicle routing. This range constraint model constitutes as a mathematical framework making sure that the energy consumption of an operation can't exceed the remaining vehicle energy. Each individual daily business operation is inserted into this range constraint by an algorithm to see, if it can be fulfilled by the vehicle. This depends on its remaining driving range. The assumption of the study made by (Ewert et al., 2021: 518-519) is a mixed vehicle fleet with ICE vehicles and EVs. The EVs should leave the depot fully charged at the beginning of the working day and they shouldn’t be recharged during the day, as the current status of charging infrastructure is not suited for this. The general range constraint approach, used by the vehicle routing algorithm is presented in figure 6.

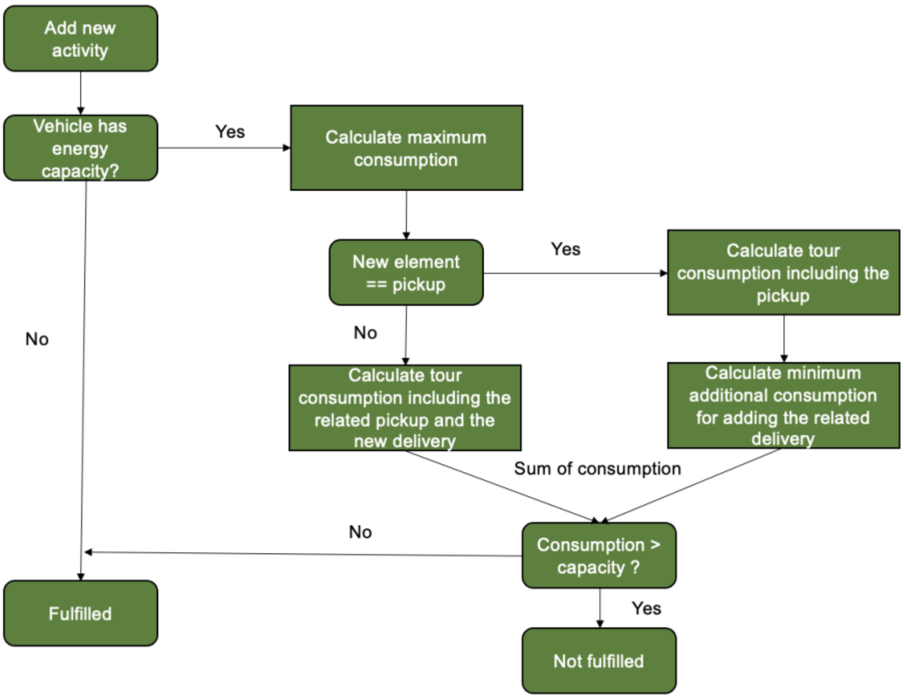

Figure 6: Functionality of a range constraint (Ewert et al., 2021: 519)

The process starts with adding a new activity, which essentially means inserting a next business step into the algorithm. Examples of this can be a delivery of a package. The algorithm checks if the vehicle has energy capacity at all. If not, the operation ends because it can’t be fulfilled. If yes, the goal of the algorithm is to calculate the maximum consumption, which could be incurred by conducting the operation. It must be also checked that the operation contains a new element, which needs to be delivered urgently. If yes the next steps are calculating the tour consumption including the needed pick-up. Because there is need for urgent delivery the minimum additional consumption needed on the same route is calculated and the total consumption is registered. (Ewert et al., 2021: 519)

If the item can't be considered as a new element needing urgent delivery, the only action is to calculate the tour consumption. This calculation is including the pick-up of the good and the delivery schedule for the remaining goods. In the end, the total consumption is also registered here. As a last step, the algorithm checks, whether the total consumption from either of these business operations is higher than the battery capacity. If yes, the operation can't be conducted. If the battery capacity is higher than the consumption on this route, the operation can be conducted. (Ewert et al., 2021: 519). This range-constraint algorithm provides a good example of theoretical routing algorithms for companies using EVs when trying to optimize their daily business operations.

4.2.2 Urban distribution centres and hub and spoke systems

Using mathematically complicated routing frameworks is not the only solution of businesses, to reshape their route network. Rather, there are many different general approaches, which can be used in combination with those routing frameworks.

One of those approaches can be seen in the establishment of so-called urban distribution centres or "mobile depots". Urban distribution centres are facilities, located in urban areas. These are used to consolidate shipments, which's delivery location is in the urban area. These urban distribution centres are linked closely to the big depots, which are placed outside the city. Every day or even multiple times a day, depending on the business needs, shipments from the big depot outside the urban area are delivered to the urban distribution centre by a big truck. After sorting, the shipments are loaded on small- and medium- sized zero tailpipe emission vehicles, such as electric vans to be delivered in the urban area. An example for an urban distribution centre could be the program of the French company “Geodis”, which specializes on modern supply chain solutions. (Geodis GmbH, 2012, 2017; Huskie, 2012)

Another interpretation of urban distribution centres are mobile depots. These are working after a similar principle, whilst providing even more flexibility to the business. Mobile depots are consisting of big trailers, who are equipped with sorting equipment, storage for shipments etc.. They are loaded in the main depot outside the urban area and then they are entirely trailered to the urban area. Therefore, they don’t need to have a fixed location in the city and can be placed according to business needs. After arriving at its final location, small- and medium- sized electric vehicles are picking up the orders from the mobile depot to deliver them to the urban area. An example for a company, operating mobile depots could be TNT Express, which became especially famous with their mobile depot solution in Brussels.(Verlinde and Macharis, 2016: 1251-1257)

Another approach, which is often combined with mathematical frameworks to optimize vehicle routing is a so-called “Hub and Spoke system”. This approach is not only feasible for companies wanting to implement EVs into their commercial vehicle fleets but is rather used on a general basis. Nevertheless, it is supporting the implementation of EVs as problems, like the range and payload problem are minimized.

The hub and spoke system is a general framework which can be used for a variety of industries. In the logistics industry it means that a company establishes many locations, in which consolidation and sorting is done. These are called hubs. Furthermore, many small locations are established, in which the sorted freight is allocated to vehicles, spreading the freight in a specific geographical area. The hub and spoke system is the alternative to a point to point distribution system, in which the freight is directly brought to the customer from the main distribution centre. The structure of a point to point system in difference to a hub and spoke network is displayed in figure 7.

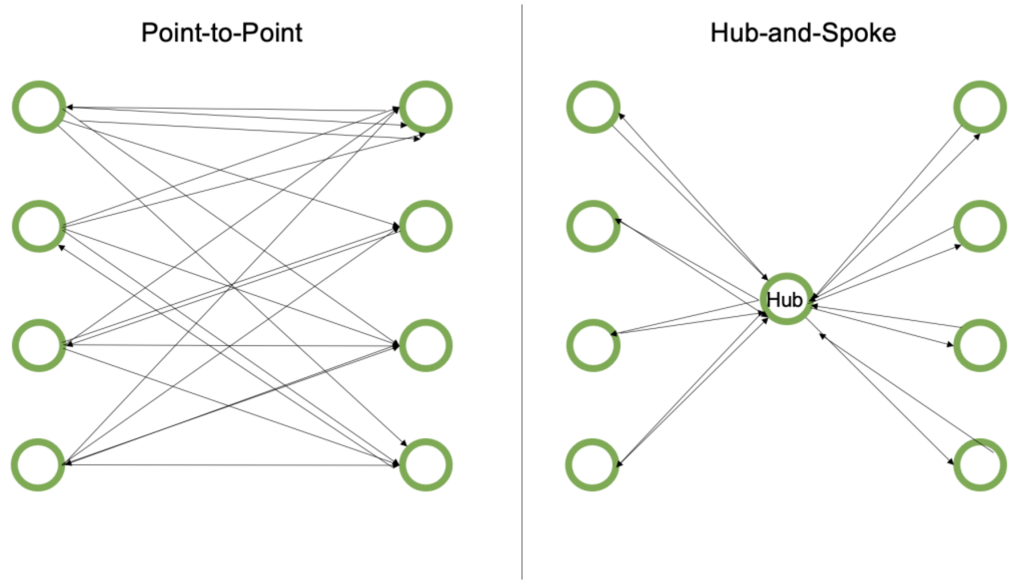

Figure 7: Point to point and hub and spoke models (Abivin, 2019)

The hub and spoke framework minimizes the weaknesses of EVs, as the ways from the distribution centre and the customer are minimized. The vehicles for the final delivery only have to drive between the customers and the spokes instead of between the customers and the hubs. Furthermore, the short distances enable the drivers to drive forth and back the spoke for loading freight multiple times. During the loading time, the vehicle can be charged, which is another positive aspect.

In conclusion, these methods rule out some issues of EVs. These include the low driving range as the ways from the urban distribution centre, mobile depot or hub to the customers are short. Furthermore, the payload issue is addressed too, as the vehicle can be loaded multiple times a day with new shipments, as the way to the depot or hub is kept short. This makes EVs more attractive for the use in urban freight transport companies. Nevertheless, those solutions are not feasible for all companies and all geographical areas, therefore it requires a sufficient analysis of those factors beforehand.

4.2.3 Influence of ambient temperature

Ambient factors are becoming especially important when using electric vehicles in urban freight transportation. These factors can relate to e.g. ambient-temperature, driving behaviour, traffic, geographical location and topography. They can impact the driving range of the EVs and that way also the vehicle routing and economic feasibility of EVs in commercial use.

Temperature is one of the most influential factors, impacting the energy consumption of EVs. (Yuksel and Michalek, 2015: 1-2) found out that when operating EVs in warm or cold climates, the driving range can decrease by up to 41% compared to mild climates. This factor is especially important, as the case study companies, presented in the later course of this thesis are operating in Finland. This means that they must cope with extreme cold climate conditions.

In their study, (Rastani et al., 2019: 125-135) investigated how ambient temperature affects electric vehicle route planning, identifying various factors contributing to increased energy consumption. In colder climates, decreased battery efficiency and high energy demand for heating can lead to a 60% rise in energy consumption, while hotter climates can result in a 20% increase due to intensive air conditioning usage. (Rastani et al., 2019: 125)

The impact of the decreased driving range on the optimal vehicle routing is displayed in figure 8. The explanatory model was planned with one depot, equipped with a charger, two customers to be addressed and one external charging station. Aspects, such as loading capacity of the vehicle and time-window constraints have not been considered. (Rastani et al., 2019: 126-128)

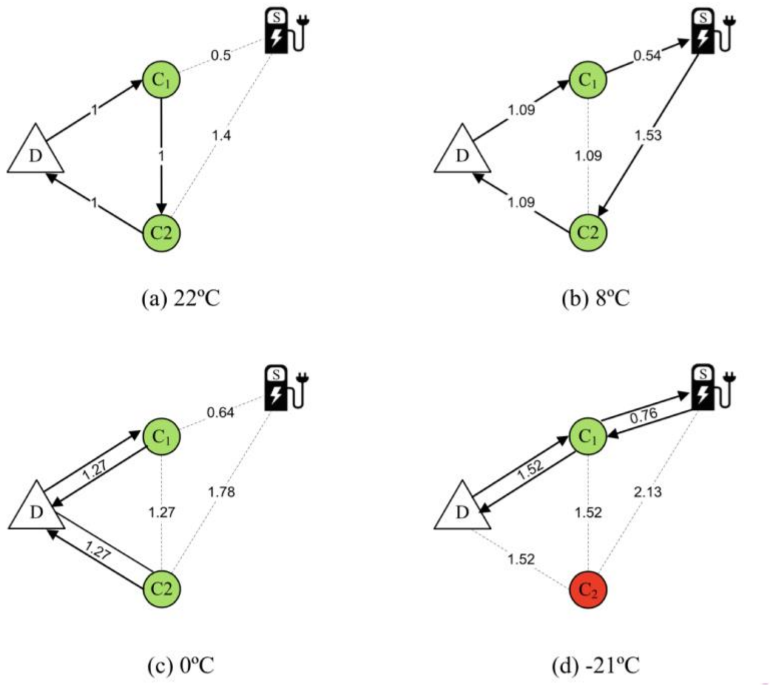

Figure 8: Optimal route plans that change according to varying temperatures (Rastani et al., 2019: 128)

In their study, (Rastani et al., 2019: 126-128) conducted four cases to assess the effects of varying ambient temperatures on electric vehicle operations. The first case (a) was carried out under optimal operating temperature conditions (22 degrees Celsius), resulting in a distance driven and energy consumption of 3, without the need for recharging. In the second case (b), lower temperatures (8 degrees Celsius) increased the demand for heating and decreased battery efficiency, leading to an energy consumption of 1.09 per distance driven. Charging in-between operations was required to complete the route, with a total distance driven of 3.9 units and an energy consumption of 4.25 units. Case (c) involved an ambient temperature of 0 degrees Celsius, necessitating the use of two electric vehicles, each assigned to a specific customer. The total energy consumed in this case was 5.08 units. Finally, in case (d), the extremely low temperature rendered proper vehicle operation unfeasible. While a dedicated EV could serve customer 1, the additional distance travelled to the charging station and back to the depot incurred unnecessary costs. Customer 2, on the other hand, could not be served due to the excessive distance to the recharging station or depot, making the use of EVs impractical. (Rastani et al., 2019: 126-128)

Another important case study, conducted by (Rastani et al., 2019: 131-135) was also testing the impact of temperatures on driving range of EVs and thereby on the vehicle routing. The case included 12 small-sized businesses with various customers. The case was conducted for cases of 5,10 and 15 customers for each business. Three temperature levels were analysed, namely 8-,0, and -21 degrees Celsius. The results of the case study are displayed in table 2. (Rastani et al., 2019: 131)

Table 2. The influence of ambient temperature on route plans in small-size businesses (Rastani et al., 2019: 131)

Ambient Temperature	Nr. Of feasible business cases	Number of cases in which a bigger fleet was needed	% increase in vehicle fleet size	% increase in energy consumption
8 degrees Celsius	34/36	3/34	4%	12%
0 degrees Celsius	21/36	6/21	15%	40%
-21 degrees Celsius	15/36	10/15	46%	81%

The amount of economically feasible business cases gradually decreases, as temperatures go down. With an ambient temperature of 8 degrees Celsius, nearly all business cases are feasible, whilst with -21 degrees Celsius just approx. 50% of all business cases is still feasible. The same can be seen with the number of cases, in which a bigger vehicle fleet was needed. Furthermore, the need in a bigger vehicle fleet size shows exactly the effect, which was discussed in 5.1.2. Due to the lower range at low temperatures, it needs more EVs to satisfy the same business requirements as before. During 29 degrees difference, the number of EVs needed to satisfy the same business needs as before increased by 42%, which is nearly half of the total vehicle fleet. Lastly, we can see that the energy consumption also increases significantly with lower temperatures. Starting from a 12% increase in energy consumption in the mild climate scenario, the energy consumption increases up to additional 81% percent. At this point, even the sustainability can be questioned, as much more energy is used just because of the lower ambient temperatures. This case study was conducted in a region with hot climate in southern Turkey.

4.3 Charging

Another important impact on businesses, which decide to implement EVs into their commercial fleets, is charging and refuelling. Refuelling conventional ICE vehicles had not been a big issue, as the process just takes a few minutes. The driver drives to the nearest gas station and refuels the vehicle. In the era of using EVs the most important and most polarising topic is recharging. Although the technology has been advancing in the recent years, recharging EVs still remains an important factor to consider. The charging process takes a while, depending on a wide spectrum of factors. These include the vehicle characteristics, the ambient temperature, the charging infrastructure used, the geographical location of the business and the energy supply available. Therefore, the charging of the vehicle imposes one of the most important factors for businesses to consider when implementing EVs.

4.3.1 Charging infrastructure

When implementing EVs, commercial fleet operators must consider the investment needed for the charging infrastructure. Public charging infrastructure is no option for business use as 2023. This is due to unreliability and the low density of the public charging network. Therefore, companies must invest into their own charging infrastructure. (Melander et al., 2022: 3)
This imposes financial pressure on companies, as the building of infrastructure constitutes a major investment and brings some issues with it. The costs for charging infrastructure can be distinguished into 4 different types of costs.

First, there are costs for the infrastructure itself. This means the costs for the chargers and everything relating to it. The costs for AC chargers can vary from

300$ to 6500$ depending on the business needs. Furthermore, the costs of DC chargers can amount up to 40,000$. The next immense cost factor is incurred for the installation of the charging equipment. As this is individual, depending on the circumstances of the business's real estate and the location etc., the price can't be estimated. Although it can be assumed, that the installation costs are amounting to the second biggest cost factor. Furthermore, there are so-called "soft costs", which also amount to a substantial costs factor. These are the costs incurred for receiving the needed permits from the state to install the charging infrastructure etc. Lastly, software costs must be considered. These depend on the charging infrastructure provider and the charging stations used. (Nick Zamanov, 2022)

4.3.2 Recharging time

One of the most prominent challenges introduced by EVs relates to their long recharging time, which can have substantial influences on commercial enterprises. This factor depends on the vehicle characteristics and the charging infrastructure of the businesses. The most important vehicle characteristics thereby relates to the vehicle ability for AC or DC charging. If the vehicle only supports AC charging it can be assumed, that charging takes approx. 300-360 min for commercial vehicles (11kw speed for approx. 66 kwh battery capacity). If DC charging is supported by the vehicle, a charging time of approx. 30-45 min can be assumed (80kw charging speed for a 50kwh battery). (Carlier, 2022)

To resolve this issue, it needs vehicles that allow fast charging on the one hand, whilst on the other hand, charging models are required, which allow the companies to schedule charging in advance.

4.3.3 Charging models

In literature, there are often descriptions of 4 different scenarios, with which businesses can reduce the impact of the restricted range of EVs. The first one would be reducing the scope of services, which would reduce income etc. This would cancel out adopting EVs in businesses in the first place. The second one would be modifying transport operations. This would mean adapting the business model to the restrictions, incurred by EVs. This is popular amongst businesses, as it reduces additional operational costs in the long term. The third one would be modifying the vehicles or collaborating with vehicle manufacturers. This is rather costly and requires a certain degree of exclusivity. Therefore, it can only be considered as a viable option for the big players in the freight forwarding business (such as UPS collaborating with Arrival). The last option would be to use a charging strategy, such as e.g. opportunity charging. In the end, it requires a combination of different aspects, such as modifying transport operations and adopting charging strategies, to produce an optimal outcome. (Teoh et al., 2018: 1-18)

In the recent years, charging strategies, e.g. opportunity charging became more popular with businesses. Such strategies are developed for minimizing the influence of the complicated charging aspects of EVs. The aim is to find the best way of recharging and to minimize the negative facets of EV charging for businesses. Furthermore, the business objectives should be achieved, whilst providing maximum sustainability. These frameworks are also called charging strategies and are defined as:

> (…) the approach adopted by the carrier to integrate charging services into the EFV operation (Teoh, 2022: 173)

Various authors emphasize the imperative nature of employing suitable charging strategies in relation to EVs. Insufficient consideration of charging strategies for EFVs can potentially lead to the alteration of logistics practices, the extension of work schedules, the expansion of fleet sizes, and a non-ability to fulfil orders. (Quak et al., 2016b: 1507-1515; Teoh, 2022: 157-174; Teoh et al., 2018: 10-18)

The design of the charging strategy depends on different factors. Examples for these factors could be e.g.: the location of the battery whilst charging, the motion of the vehicle whilst charging, the charging interface, the charging power and speed and the charging mode. (Teoh, 2022: 171-172)

The charging strategy, employed by the business heavily influences the value of EFVs for the carriers. Good charging strategies increase the capability of EFVs and thereby increase the value of the purchase. This will also lead to a re-purchase of the business. (Teoh, 2022: 171) Furthermore, the choosing of a charging strategy can affect financial costs and the profitability of using EVs. (Teoh et al., 2018: 17-18)

Nevertheless, the charging strategy must also be designed in a way, that it satisfies the operational and financial requirements of the business. There are some general considerations, on which more or less all charging strategies are build up on. One of them is the assumption, that charging is always planed. Although of the high degree of planning, drivers should also optimize routes themselves in special situations, e.g. traffic congestion, forced detours etc.. (Teoh, 2022: 173-174)

On a general basis, it must be distinguished between so-called “schedule based”- and “trigger based”- charging strategies. In the further context of this analysis, these terms are referred to “SCS” and “TCS”. The SCS are based on precise planning beforehand, whilst the TCS are spontaneous actions, resulting from a specific happening. In practice, both strategy types should complement each other to reach an adaptive strategy. Although, TCS are rather spontaneous and should just be used in emergencies, therefore they are disregarded in the following analysis. The conceptual framework, which underlies all charging strategies is displayed in figure 9. (Teoh, 2022: 166)

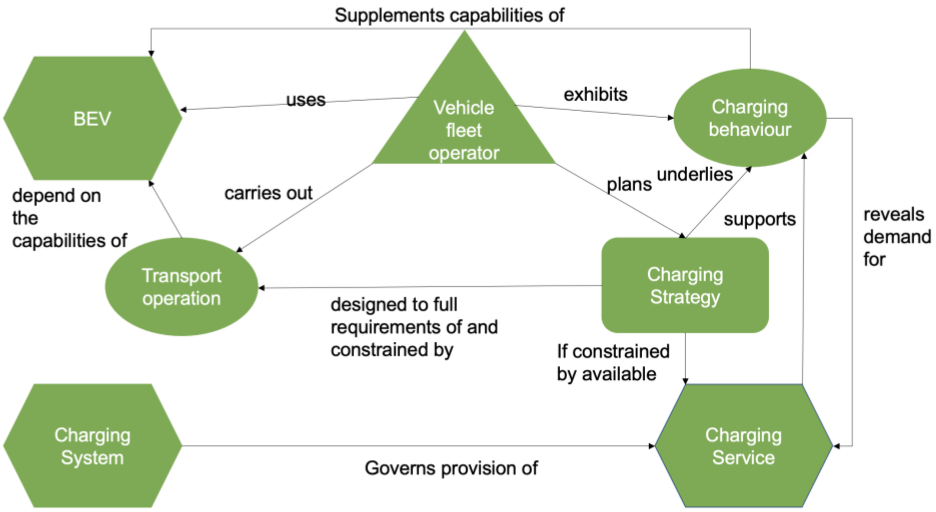

Figure 9: Conceptual framework for charging strategy (Teoh, 2022: 165)

To decide on a specific charging strategy, the so-called vehicle operating cycle is defined. This operating cycle includes different business-use factors, which must be considered, such as driver activity, vehicle activity and vehicle location. Based on this, the choice of either SCS or TCS or complemented strategies for the business to use is possible. (Teoh, 2022: 164-166)

Schedule-based charging strategies or short SCS are considering the charging of the EV happening at a planned point in time. Most developed charging strategies are based on this assumption. Three strategies, which are used often are the downtime charging strategy, the opportunity charging strategy and the intrusive charging strategy. (Teoh, 2022: 167-171)

One example for a schedule-based charging strategy is the downtime charging strategy, which constitutes as the most common and most simple charging strategy. The charging of the vehicle is conducted, while it is parked for a long time, which is usually at night at the depot. This means, that the charging is incurred, when the vehicle is not in use, so the daily business operations are not interrupted by charging. The fact that the charging is conducted at night, when there is a big timeframe, in which the vehicle isn't needed enables the companies to use slow AC chargers. The negative aspect of this strategy constitutes that as many chargers as vehicles are needed. Furthermore, the daily driving range is restricted to the battery capacity (Teoh, 2022: 167-168). This constitutes a major problem, as it can make operations more expensive, as there is a high variability of daily energy requirements. Furthermore, there are high costs, when running out of battery during operations. Therefore, expensive batteries must be bought, which can’t be utilized to their full potential in many scenarios. (Tario, 2014) Buying vehicles with different battery sizes would partly solve the problem, but this would directly be connected to a high bureaucratical effort. (Teoh, 2022: 168)

Another example for a schedule-based charging strategy is the opportunity charging strategy, or short “OC”. This strategy is rather popular amongst freight forwarders, as it proves itself as very effective. The goal of this strategy is to charge in a certain way, so that the operational schedule isn’t impacted because of recharging. This is done through the point in time, on which is charged. The charging is done simultaneously with the required transport tasks, such as loading, unloading, shift brakes etc.. The charging in opportunity charging can be distinguished into three different types of charging. Stationary, quasi-dynamic and dynamic. Stationary refers to charging, whilst loading, unloading, taking a break, delivering goods or conducting a shift-change. The quasi dynamic charging refers to charging conducted in short time periods, e.g. while moving slowly when decelerating, accelerating or creeping. At last, there is the dynamic charging, which is conducted while the vehicle is moving via e.g. an overhead catenary system. (Teoh, 2022: 168-169)

Opportunity charging can increase the daily driving range while maintaining the operational efficiency of the business. It is also suitable for multi-shift operations, in which the vehicles are used at night too. It doesn’t add detours or extends operational time. Another positive aspect is that vehicles can share charging stations, which eliminates the need for having as much chargers as there are vehicles. (Teoh, 2022: 173-174) Additionally this strategy reduces the purchase costs of EVs, as smaller battery capacities become also feasible. Depending on where the drivers charge the vehicles, no additional logistics facilities are needed, which creates a dependence on public charging infrastructure on the other hand. If the businesses decide to use their own charging infrastructure, fast chargers must be implemented, which incurs higher costs. This fast charging additionally degrades the battery capacity faster in the long term. (Teoh et al., 2018: 10-18)

Different authors, such as (Teoh et al., 2018: 10-18) research on the real efficiency of implementing opportunity charging on businesses with the help of real-world conducted case studies. The case study considers different types of OC in the business cycle. No OC, OC during break and shift change, OC during loading activity, OC during unloading activity and OC while driving on the highway. All those stages are complementing the conventional overnight stationary charging of the vehicles. The case study was conducted with two different companies in different industries. One of them specializes on freight transport, transporting mail and parcels, whilst the other company is in the furniture business. For our research, only the courier express parcel company, transporting mail and parcels is of relevance. Furthermore, both companies used different vehicles with different payloads and battery capacities, as this is what the OC model suggests doing. The study assumes, that the companies only use public charging infrastructure, which is 100% available all the time. The financial outcomes of both companies using all 4 types of OC analysed are displayed in figure 10.

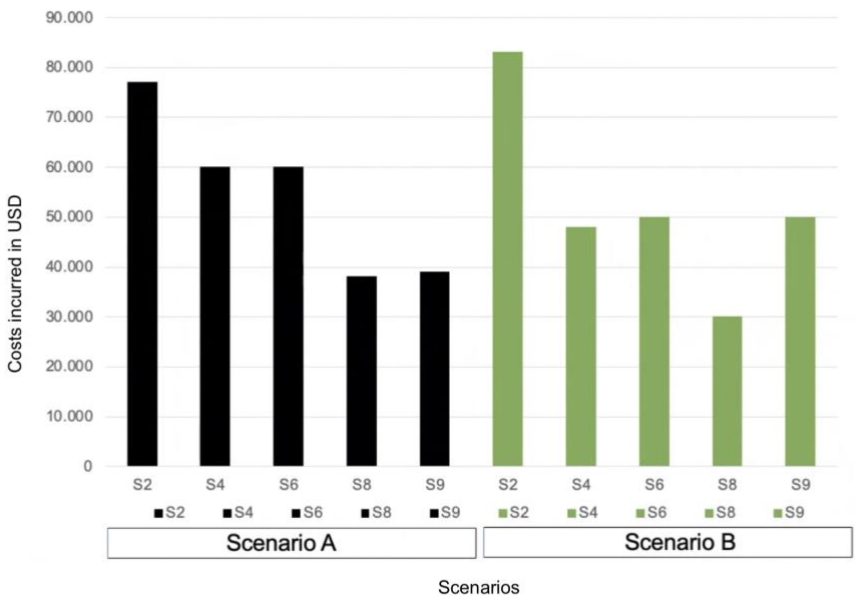

Figure 10: Cost difference breakdown of Cases A and B (Teoh et al., 2018: 14)

The cases A and B refer to the tour structure. Case A entails just 1 depot and therefore many cross-docking locations. In difference to that, Case B refers to 3 depots and therefore no cross-docking stations. The costs entailed in the analysis are apparent on the right-hand side of the diagram. (Teoh et al., 2018: 14)

Scenario 2 refers to the situation, in which no OC was used at all. It becomes evident, that no matter of the tour structure, this is always the most expensive option. This proves the effectiveness of OC to a certain degree already. In Case A, the costs incurred, while not using OC at all are approx. 77,000$, while in Case B they are approx. 83,000$. (Teoh et al., 2018: 14-15)

In case A with having many cross-docking locations, scenarios 4 and 6 incurred the second highest costs, following the non-use of OC in scenario 2. Scenario 4 thereby describes the OC during break and shift change. Furthermore, Scenario 6 describes the OC during loading activity. Both scenarios incurred a cost of 60,000$, which is already better than the costs incurred for scenario 1, where no OC was used, but still high. Scenario 9 was then the next option, which incurred even lower costs of approx. 38,000$. This option was using OC, while driving on the highway, which would be possible e.g. with an overhead catenary system. The last and cheapest option for Case A was Scenario 8, which is OC during unloading activity. This incurred costs of approx. 36,000$, which constitutes to a cost decrease of approx. 53%. (Teoh et al., 2018: 14-15)

In case B, the company just has 3 depots and no cross-docking locations. In this case, the results look similar to case A. Scenarios 6, 9 and 4 (OC during loading activity, OC while driving, OC during break or shift change) are the second most expensive options, with costs of 50,000$, 55,000$ and 48,000$ respectively. Thereby, it becomes evident, that those options are never feasible for urban freight transportation. The cheapest option is again Scenario 8, which is OC during unloading activity. In this case B, it incurred even lower costs as in case A with approx. 30,000$. This constitutes to a cost decrease of approx. 63%. (Teoh et al., 2018: 14-15)

In conclusion, it becomes apparent, that OC is a viable option for commercial fleet operators. It eliminates different disadvantages of EVs and allows the companies to conduct “business as usual”, whilst enjoying the advantages of EVs. The only major disadvantage, which must be stated for OC is the high investment needed for fast charging infrastructure and the thereof resulting fast battery degradation. Nevertheless, the potential costs savings of using OC and the fact that business operations can be conducted as usual will amortize the high investment costs over a short timeframe. Although it has to be kept in mind, that the usability of OC must be evaluated for each individual business case, as it is possible, that the higher investment costs won’t be offset by cost savings. (Teoh et al., 2018: 17-18)

4.3.4 Role of battery degradation

Depending on the charging model chosen by the company, there is another factor, influencing the feasibility of EVs. This is battery degradation which describes the loss of battery capacity over time due to the recharging of the battery (increasing charging cycles). Charging cycles describe a charging operation, by which the battery is charged from 0 to 100%. The loss of battery capacity leads to a reduced range, which impacts vehicle routing and the economic feasibility. Battery degradation is not avoidable, as the battery is a consumable product. This degradation can happen faster or slower depending on the recharging behaviour.

The average age of vehicles in commercial fleets is estimated to be a maximum of 10 years. (Al-dal'ain and Celebi, 2021: 5) If it is assumed, that the vehicle is charged just once a day (1 charging cycle per day) and there are 280 working days a year (6-day working week) this already amounts to approx. 280 charging cycles a year.

(Millner, 2010: 349-356) has made research on battery degradation. The motivation of his research was to find the real battery degradation and its potential impact on vehicle routing and commercial feasibility. The outcome of Millner´s case study about calculating the capacity loss of battery cell on real-world data is presented in figure 11.

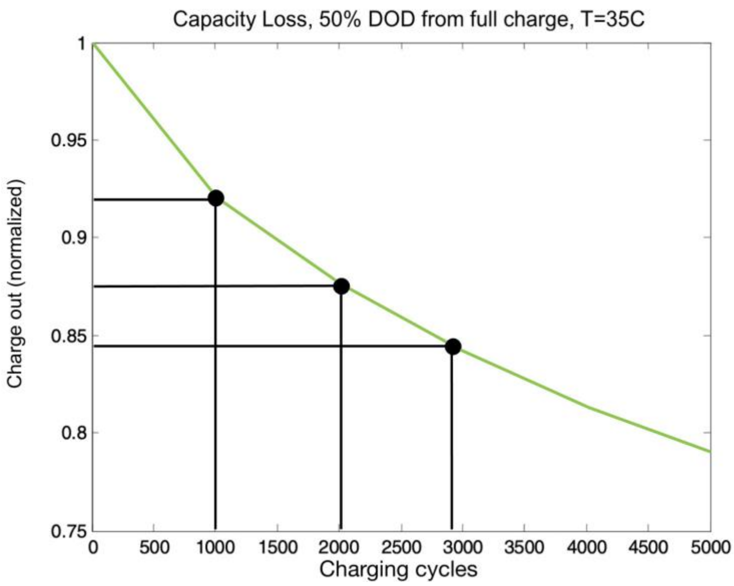

Figure 11: Capacity loss in simulated cell using exponential model (Millner, 2010: 353)

The assumptions of the case study was a state of charge of average 75%, a 50% variation in the stage of charge and an ambient temperature of 35 degrees Celsius. State of charge describes the amount of charge on a certain point in time. Furthermore, an 50% variation in the state of charge describes, that the level of charge varied from e.g. 100% to 50%. In the graph, the battery capacity loss over a certain amount of charging cycles can be seen. The results imply, that the battery capacity amounts to just approx. 92% after 1000 charging cycles, which corresponds to 3.5 years of use. Furthermore, after 2000 charging cycles, the battery capacity drops to approx. 87%. This constitutes to a decrease of battery capacity of 13% in 7 years of use. In the end, the battery capacity will decrease to 83% after 3000 charging cycles, which constitutes to a usage of 10 years. (Millner, 2010: 353)

Therefore, it can be assumed, that after 10 years of usage, the vehicle battery lost 16% of its capacity. For exemplary purposes to show the effect of battery degradation, the Mercedes eVito is sufficient. This model has a WLTP range of 180km. As the WLTP range isn’t holding up to real world standards, the normal procedure is to subtract additional 10% minimum. This leaves a range of 162km.(Allgemeiner Deutscher Automobil-Club e.V., 2023c; Nathan Dale, 2021) After a use of 10 years and a deduction of battery capacity by 16%, this would leave a driving range of approx. 136km. This would still be sufficient for most urban delivery operations, as it is estimated that 80% of urban deliveries have a distance of 80km or less. (Russo and Comi, 2002) However, this can impose limitations and capacity issues in businesses, which should be considered beforehand. Additionally, the battery depletion can lead to a reduced resale value. This factor is not known as of today but does create some doubts in the company anyways.

4.4 Customer & Employee satisfaction

The last important impact on urban freight transportation businesses, when implementing EVs into the commercial fleet is the influence on customer and employee satisfaction. Delivery is one of the most important elements of logistics consumer service and acts therefore as a driver for consumer loyalty. (Dadzie et al., 2005: 53) Furthermore, employee satisfaction acts as an important variable, influencing employee efficiency and business success. These aspects are especially influenced by factors relating to the day-to-day business operations, e.g. delivery-windows, working shifts etc. Thereby, EVs play an important role, as their efficiency in the day-to-day operations impacts those factors. EVs can't keep up with the characteristics of ICE vehicles in the area's of payload and range. Therefore, it can be necessary for the business to extend delivery time windows to fulfil the same operational requirements as before. This change in operational behaviour can impact the customer and employee satisfaction.

4.4.1 Consumer perspective

Fast delivery, selecting a delivery timeframe and choosing the place for delivery are amongst the most important factors for consumers when ordering online. (Chevalier, 2022) The focus of this thesis remains in the delivery timeframe selection, as the delivery time windows can be impacted through the implementation of EVs.

If the business would decide on extending the delivery timeframe, this could impact customer satisfaction to a large extend. Regular business hours in Finland don't exceed 9 p.m. usually. (Posti Group Oyj, 2023c; Postnord Oy, 2023) If extending the business hours to e.g., until midnight, this would incur different difficulties, impacting customer satisfaction. An example of this is that the average Finnish person goes to bed at 00:03h. (Woollaston, 2015) This would mean that delivery drivers wouldn't be able to deliver parcels, as customers are already asleep. Furthermore, there would be the possibility to increase deliveries in the morning. This on the other hand would also mean missing many customer deliveries, as most of them are working.

It is important to state that the importance of on-time home deliveries depends on the geographical location. Statistics in figure 12 show, that the top 3 most popular delivery options, chosen by the Finnish customers don't involve home delivery. The top 3 most popular delivery methods include picking up parcels on various locations, such as a parcel machine or a distribution point. Furthermore, the delivery of packages to mailboxes is also popular. These top 3 most popular delivery methods already take up 82% of customers. Only the last 15% of customers prefer receiving deliveries to their homes or workplace.(Clausnitzer J., 2022)

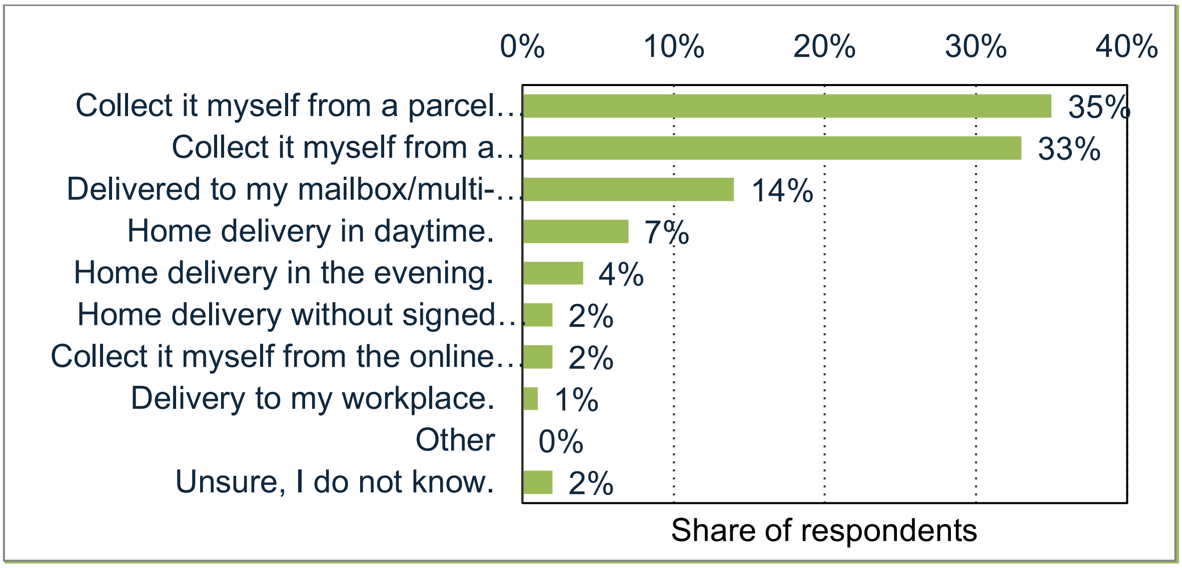

Figure 12: Preferred methods of delivery in Finland (2020) (Clausnitzer J., 2022)

Therefore, it can be assumed, that in the Finnish market, the impacts of using EVs on customer satisfaction through longer delivery time windows can be disregarded. However, it is an important factor to consider, as in other countries customer preferences may differ from Finland.

4.4.2 Employee perspective

Another important stakeholder group are the employees. From various studies, it becomes evident, that for Finnish employees, the work-life balance is amongst the most important factors. (Statista Research Department, 2023b)

If the business was to extend the business hours due to the decreased operational performance of EVs, it can be assumed, that employee satisfaction would decrease, as work life balance shrinks. This could lead to extensive impacts on the business, as the factors of employee satisfaction and employee efficiency are closely linked. Results of a survey of Society for Human Resource Management (SHRM) to 664 000 employees globally shows this correlation. The results indicated that companies with high employee satisfaction have 52 % more operational compared to the companies with low employee satisfaction. In general, one could say, that engaged and satisfied employees tend to be the top performers of the company, which improves the company´s profitability.(Shmailan, 2016: 2-4)

Based on the studies presented above, it wouldn’t be a good strategy to increase business hours in the urban freight forwarding businesses since this might lead to lower employee satisfaction and therefore to lower employee performance.

5 E Powertrain vs combustion engine powertrain

Given the significance of cost competitiveness and environmental performance for commercial fleet operators, a comparative analysis is conducted to evaluate the performance of EVs and ICE vehicles in these regards.

5.1 General cost aspects

One possibility to find out, which technology is more cost competitive, is to conduct a cost analysis between conventional vehicles and EVs. Therefore, it is important to understand, which type of costs are generally incurred in vehicle fleet management. (Kleiner et al., 2015) have made research on the cost competitiveness of EVs and provide detailed cost structures for vehicle fleet management. An example of a cost structure is displayed in figure 13.

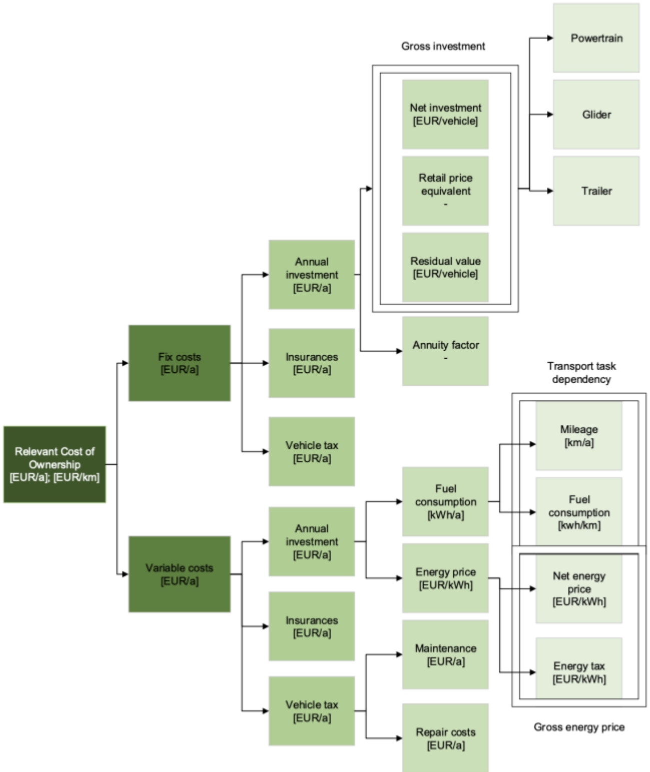

Figure 13: Relevant cost of ownership approach (Kleiner et al., 2015)

As the figure displayed is too detailed for the purposes of this analysis, only the important points are explained. The total cost of ownership, being the most important variable is defined by

> The sum of all the annual fleet direct costs (CT) incurred through the ownership period of the vehicle and the installed energy infrastructure per year (…) (Castillo Campo and Álvarez Fernández, 2023: 4)

The total cost of ownership results of the fixed and variable costs per year. The fixed costs are always the same, whilst the variable costs depend on the driving distance, the drivers etc.. The fix costs consist of the annual investment, insurance and the vehicle tax, which is country- and vehicle- specific. The annual investment consists of the gross investment and the annuity factor.

The variable costs consist of the same initial factors, as the fixed costs do, namely annual investment, insurances and vehicle tax. The only difference is that in this case, these factors are calculated dependent on aspects, such as the vehicle type, the driver, the annual milage etc. The annual investment consists of the fuel consumption and the energy price, whilst the vehicle tax consists of the maintenance work and the repair costs in case of damages. (Castillo Campo and Álvarez Fernández, 2023: 6)

5.1.1 TCO analysis

(Scorrano et al., 2021: 1-12) developed such a TCO analysis which shows the cost differences between ICE vehicles and EVs in exceptional detail, based on Italy as a geographical location. The model includes 46 vehicles, available in Europe, of which 14 are fully electric, 7 are petrol powered and 25 vehicles are diesel powered. To conduct a meaningful analysis, the vehicles are grouped into 3 segments, depending on size and payload. These segments are: city, panel and box. The vehicle segment used by the business depends on the industry sector. The vehicles relevant for this thesis are rather the panel and the box segment. The panel segment vehicles used in the analysis are: Mercedes Vito, Peugeot Expert and Nissan NV300, which are all priced between 21 450€ and 43 983€. The box segment vehicles which are used in the analysis are: Renault traffic, Peugeot Boxer and Fiat Ducato, with prices between 23 070€ and 95 780€. The purpose of (Scorrano et al., 2021: 1-12) research was a detailed sensitivity and scenario analysis. The goal was to evaluate the impact on electric vehicle cost competitiveness of annual distance travelled.

In the analysis, the factors like holding period and resale value, driving profile and financial and regulatory incentivizing policies are considered. The Initial costs, which are taken from the EVs include upfront expenses, manufacturer retail price, retailer discounts, governmental subsidies, registration costs and costs for charging infrastructure. Concerning electricity price, the authors decided to use the average price of different locations, e.g. home/depot charging and public charging etc.. The outcome of the analysis should be the threshold price for the electric vehicle that would make the vehicle equivalent or competitive from an economical point of view (TCO) versus a diesel or petrol vehicle.(Scorrano et al., 2021: 1-12)

The base line scenario of the analysis assumed an annual distance travelled of 10,000km per year (40km per day), 80% urban driving, 100% charging at the depot and no subsidies or governmental regulations, favouring EVs (e.g. purchase price subsidy etc.). The analysis was conducted with 253 working days a year (104 weekends and 8 festivities). The result of the base line scenario shows that the panel segment is currently not cost competitive. That is because the lower annual operating costs can't offset the higher initial costs. For the panel segment to be cost competitive in the base line scenario, the price should be less than 25,506€, while the average market price of those vehicles is 32,947€. Furthermore, the box segment is even less cost competitive than the panel segment. The costs for the box EVs are twice as high as with a comparable diesel vehicle. To be cost competitive, the box EVs should costs less than 25,506€, while the average market price amounts to 64,643€.(Scorrano et al., 2021: 1-12)

For further clarification of the cost competitiveness of EVs, the role of the annual distance travelled in the base line scenario is varied. The threshold eLCV purchase price describes the break-even purchase price of the vehicles, with which they become cost competitive to the ICE counterparts. The assumption of this variation is the fact, that with an increasing annual distance travelled, the savings in operating costs are rising and therefore, the cost competitiveness of EVs increases. (Scorrano et al., 2021: 1-12)

The results of this analysis are displayed in the following figures 14 and 15.

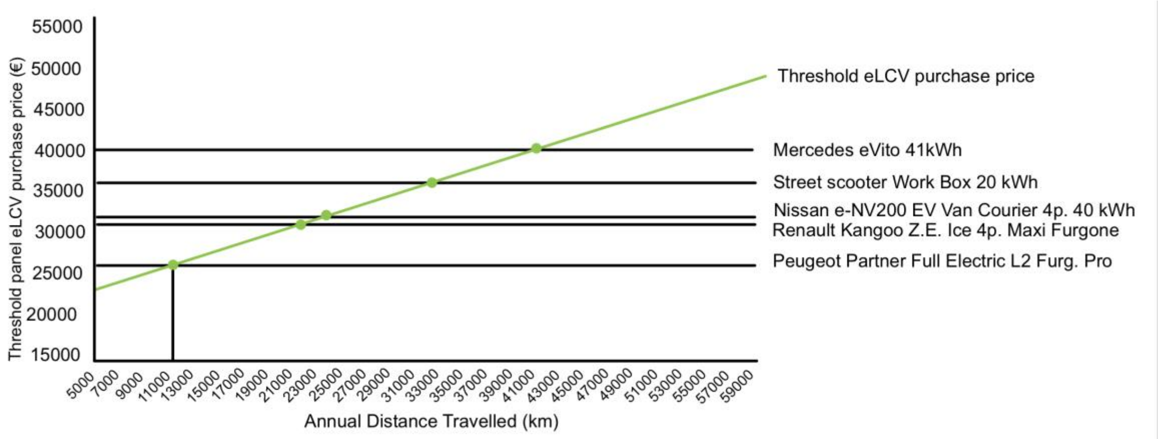

Figure 14: Threshold price of panel EV purchase price compared to panel diesel ICE vehicles (Scorrano et al., 2021: 8)

The panel segment EVs become cost competitive compared to their ICE counterparts when starting at an annual distance travelled of approx. 12,000km. All things considered, 3 panel EVs are cost competitive in comparison to the diesel counterparts. (Scorrano et al., 2021: 8)

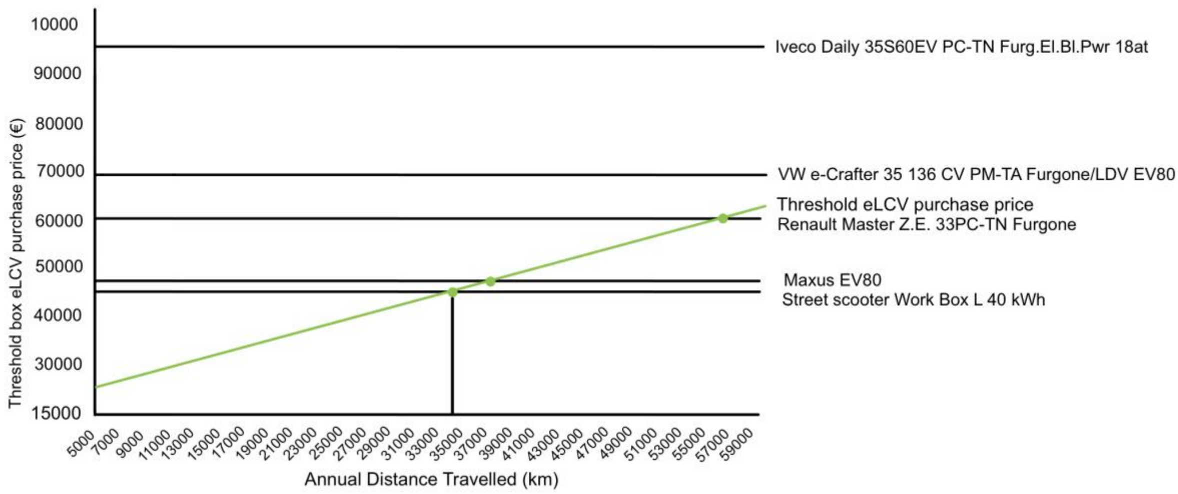

Figure 15: Threshold price of box EV purchase price compared to panel diesel ICE vehicles (Scorrano et al., 2021: 8)

The box segment EVs are becoming cost competitive at an annual distance travelled of just approx. 35,000km, which means in a real-life business case, that none of the box EVs is cost-competitive to the conventional counterparts. (Scorrano et al., 2021: 8)

The conclusion of the base-line scenario is, that the EVs have a higher average TCO/km than their combustion engine counterparts.

However, governmental subsidies and incentives can change the cost-competitiveness of EVs. Those subsidies can include purchase price reductions, as the purchase price for EVs is often considerably higher than the price for an comparable ICE vehicle counterpart. Furthermore, governmental incentives can include accessing fees for ICE vehicles in low emission zones and privileges for EVs, such as free parking etc. To elaborate the impact of subsidies on the cost-competitiveness of EVs two scenarios were developed. In the first scenario, there is a purchase price subsidy of 6000€. In the second scenario there is additionally also a fee of 550€ to enter low emission zones. (Scorrano et al., 2021: 8-12)

The results of the first scenario were, that almost all panel EVs become cost competitive, even with low annual distances travelled. Some vehicles, e.g., Peugeot Partner even incurred negative values, which mean cost savings in comparison to an ICE vehicle counterpart. In the box segment, only 2 vehicles become cost competitive at a reasonable annual distance travelled. In the second scenario, the cost advantage in the panel segment was even extended with 4 panel EVs, incurring lower costs than their ICE vehicle counterparts. In the box segment, the results from the first scenario didn't change. (Scorrano et al., 2021: 8-12)

The overall conclusions of this detailed analysis are that EVs are not cost-competitive, unless specific circumstances, e.g. governmental subsidies and incentives exist. The main reason for the bad cost performance of EVs is the high purchase price and the price for e.g. charging infrastructure, which often can't be offset by the lower operating costs. Panel EVs can be cost competitive, depending on the use case, if certain governmental actions are in place. Box

EVs are never cost competitive, regardless of the circumstances. Therefore, it is only cost beneficial for a part of companies to implement EVs. (Scorrano et al., 2021: 9-12)

(Klumpp, 2014: 7-9) explains the cost competitiveness problem of EVs as a matter of not only purchase price but also payload. The payload of EVs imposes a significant problem for fleet operators, as it is often just 55% of the payload, that an ICE vehicle can handle (Melander et al., 2022: 7).

(Klumpp, 2014: 7-10) conducted a detailed TCO analysis, to show the impact of the lower payload on the cost competitiveness of EVs. The vehicles compared were a diesel powered vehicle, which has an initial price of 35 170€ and an comparable electric vehicle, having an initial price of 100 000€. The payload of the diesel vehicle is 1,310kg, whilst the payload of the EV is just about 800kg. Two scenarios were established, in which the vehicles could be used. The first scenario includes deliveries with a maximum of 800kg payload, whilst the other scenario exceeds the 800kg of payload (=1,310kg payload). The impact on the costs are displayed in table 3.

Table 3. Comparison of costs between EV and diesel engine vehicle (Klumpp, 2014: 9)

	EV	Diesel engine vehicle	
	Transport weights per tour		
	800kg	1,310kg	800kg
Kilometre-based costs per tour	3.23€	2.21€	3.62€
Time-based costs per tour	25.00€	13.13€	21.50€
Total costs per tour	28.23€	15.34€	25.12€
Utilization	100%	100%	59%

It becomes evident, that in both scenarios, the diesel vehicle incurs lower costs. Although the kilometre-based costs per tour are lower for the EV in the first scenario with a lower load to be delivered, the diesel vehicle incurs lower costs in all other categories. Additionally, it must be mentioned, that the diesel vehicle just has a utilization of 59% of the payload, it could carry. Especially in the scenario in which a heavier load must be transported, the diesel vehicle incurs significantly lower cost than the EV. This is due to the utilization of the vehicle, as with the heavier load, the diesel vehicle is 100% utilized, while the load is too heavy for the EV. The result of the analysis is that for higher payloads and longer delivery tours, EVs are up to 90% more cost-intensive than combustion engine vehicles. The general statement of the author is that on average EVs are not feasible for tours that are above 100km.(Klumpp, 2014: 11) To display this, a comprehensive evaluation scheme for last mile distribution was developed, which is displayed in figure 16.

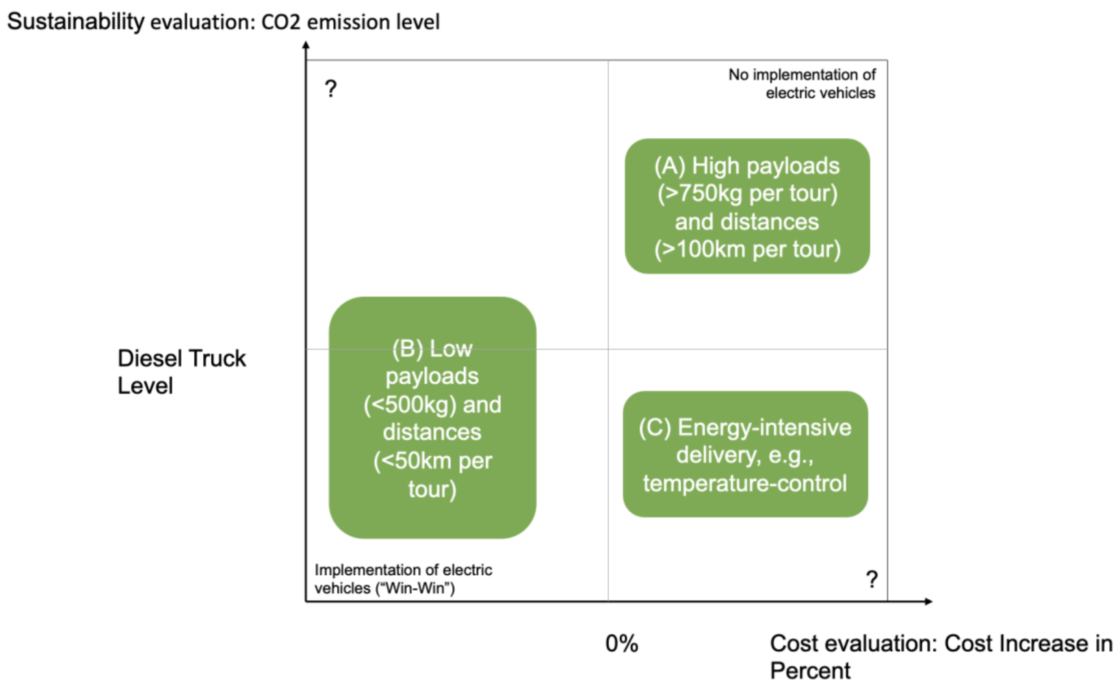

Figure 16: Comprehensive evaluation scheme for last mile distribution (Klumpp, 2014: 11)

Three use-case scenarios for vehicles of commercial fleets can be categorized. The first scenario is low payloads below 500 kg and short distances of 50 km or below. For this scenario, EVs are cost competitive, compared to their diesel-powered counterparts. For the second scenario, with high payloads over 800 kg and long tours over 100 km EVs are neither cost- nor sustainably competitive to their diesel counterparts. In the third scenario, where the company must consider energy intensive deliveries, EVs are sustainably competitive but not cots competitive to their diesel-powered counterparts. It can be concluded, that EVs are just feasible for a small fraction of businesses with very particular business requirements. (Klumpp, 2014: 3-12)

(Quak et al., 2016b: 1507-1515) explained the issue on a more general basis. The authors took the European FREVUE project as a reference, in which the use of EVs was tested in various different cities, e.g. Amsterdam, Lisbon, London, Madrid etc. The focus of the paper was the presentation of real-case experiences of the companies, which participated in the project. The authors listed the findings into two categories: possible extra costs with EVs and possible savings with EVs. The possible extra costs were incurred in various business cases because of the high initial price, high replacement costs, investment costs for charging infrastructure, grid update costs, landlord permission costs and employee training costs. Especially important are the grid upgrade costs and the bureaucratical effort, associated with them. As an example, a fleet operator in London was mentioned, who had to update the energy grid for the charging stations. Therefore, he had to pay the cost to the energy provider, although not owning the energy grid. Furthermore, the landlord permission costs were high. Another important aspect is the missing dealer network for EVs. Thereby, EV repairs took exceptionally long and incurred business losses, because of outage of vehicles.

The possible savings with EVs were on the one hand the lower maintenance costs, and on the other hand the lower operating costs. The maintenance costs were reported to be approx. 20-30 % lower as with ICE vehicles. The operating costs nevertheless depend on the geographical location and the energy prices for the fleet operator. As a conclusion the current cost disadvantages outweigh the cost advantages. Therefore, the usage of EVs doesn’t provide a positive business case as of today. (Quak et al., 2016b: 1507-1515)

To sum up, it must be stated, that EVs are only limited cost competitive to comparable ICE powered counterparts. This cost competitiveness depends on a broad variety of factors. Therefore, each business must conduct an analysis for its individual use case to find out, whether there is economic feasibility to use EVs or not.

5.2 Sustainability

Regardless of the costs, EVs often seem to have one major advantage over conventional ICE vehicles. The reputation of EVs is to be much more economically friendly than their ICE vehicle counterparts. This reputation is mainly due to their zero-tailpipe emissions. Nevertheless, aspects, such as the source of energy and the production process of EVs are often criticized.

Especially in the freight transportation industry, the sustainability of EVs represents an important issue. This is because fleet operators want to reduce their environmental impact. Therefore, the question arises, which technology is more environmentally friendly in the end, conventional ICE vehicles or EVs.

(Marmiroli et al., 2020: 11-17) have created a detailed sustainability analysis comparing 3 different powertrain versions of one vehicle in Italy. The three versions are diesel powered, CNG powered, and electricity powered. Except the powertrain, the vehicles don't differ to one another. The focus of the sustainability analysis of EVs is both on the production stage and the use stage. The production stage considers all emissions from the component production to the distribution on the market. The environmental impacts of the production stage of the vehicles are displayed in the figure 17. To conclude the analysis, a detailed life cycle analysis was established. This analysis included the environmental impacts of the production phase and the use phase of the respective vehicles. As the energy mix of the respective country significantly influences the sustainability of the use phase of EVs, the life cycle analysis was conducted for Italy and Norway and results from both countries were compared. (Marmiroli et al., 2020: 11-17)

Important for interpreting the results of the analysis is to know, how the energy mix of Italy and Norway is structured. In 2021, fossil fuels accounted for 79 % of the total primary energy supply in Italy. Only 18 % of energy produced was incurred through renewable energies. (Statista Research Department, 2022) As this energy mix isn't sustainable, it is not a good example and therefore it was compared to Norway. Norway's electricity mix is a showcase example for sustainable energy production with 100 % energy coming from renewable energy sources, including 91.5 % coming from hydro power. (Statista Research Department, 2023c)

Using renewable energy sources to produce energy is not only important because of the higher emissions, which are incurred while burning fossil fuels. Additionally, to their high emissions, fossil fuels have a rather low energy density. In practice this means, that the energy needed to produce 1 kWh of electricity is 1.07 kWh for a hydropower plant, while its 3 kWh for a coal plant. (Marmiroli et al., 2020: 14)

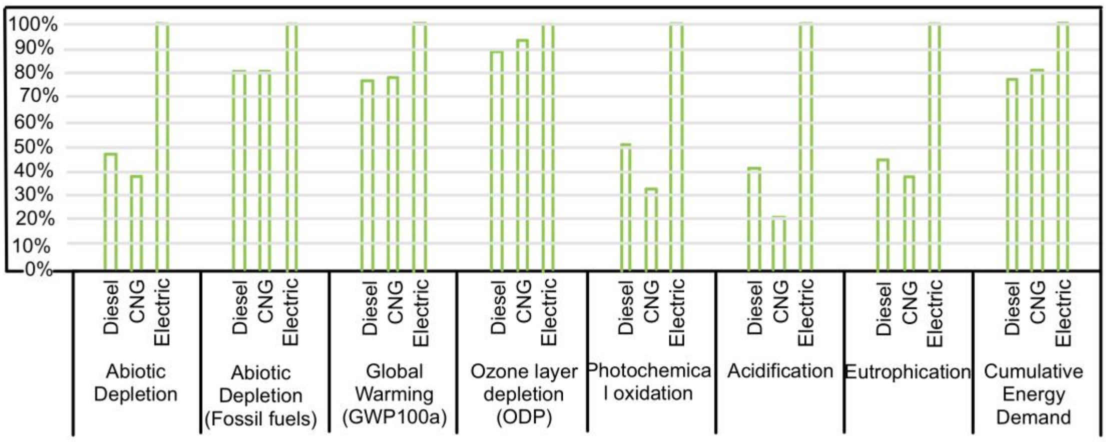

Figure 17: Comparison of the impacts of vehicle production - Process contribution (Marmiroli et al., 2020: 12)

The different emission categories are important to understand, in which aspect, emissions are incurred. The explanations for the environmental impact criteria can be seen in the glossary of this paper. (Marmiroli et al., 2020: 12)

As the illustration presents, the EV incurs the highest emissions for all different environmental impact categories. This is mainly because of the weight of the vehicle and the vehicle’s batteries, whose production can be considered as being environmental harming. When comparing the “big picture” of all production stages, it becomes evident, that more than 70 % of the differences in emissions in each category are due to the powertrain solution of the vehicle. (Marmiroli et al., 2020: 12-14)

In the use stage, the consumption is tested by comparing the environmental impact of a typical delivery mission of both the EV and ICE vehicles. For this comparison all consumptions are converted into kWh/100km. The CNG powered vehicle incurs the highest consumption with 1.73 kWh/100 km on average, while the diesel vehicle incurs 1.25 kWh/100 km. In difference to these conventional vehicles, the EV only incurs 0.53 kWh/100 km on average. This higher energy efficiency of EVs means a direct environmental benefit. However, when comparing the cumulative energy demand of the vehicles (including the production stage) this efficiency gap is offset by 50 %, due to the energy intensive and environmental harming EV production stage. (Marmiroli et al., 2020: 12)

In the life cycle analysis made for Italy, it is evident, that the use phases of the vehicles are dominant stages. Especially the environmental impact of the conventional vehicles (diesel & CNG) is due to the use phase. It is apparent, that the EV is more environmentally friendly than the conventional vehicles in 4 out of 8 categories concerning the combustion of fossil fuels. This means in practice, that the emissions, concerned with the initial electricity production (in Italy based on fossil fuels) is emitting less than the conventional vehicles, which burn the fossil fuels themselves to produce energy. The 4 categories in which EVs are more environmentally friendly than conventional vehicles are: abiotic depletion (fossil fuels), global warming, ozone layer depletion and cumulative energy demand. However, it must be stated, that on the contrary the EV is more environmentally harming in the other 4 out of 8 categories. These categories are abiotic depletion, photochemical oxidation, eutrophication, and acidification.

This can be explained, as these categories are mainly dominated by the environmental impact of the production stage. It becomes evident, that EVs are more environmentally friendly than conventional vehicles in the use phase. Even if the electricity mix is focused on fossil fuels as source for energy production. (Marmiroli et al., 2020: 14) The results of the life cycle analysis with the Italian electricity mix can be seen in figure 18.

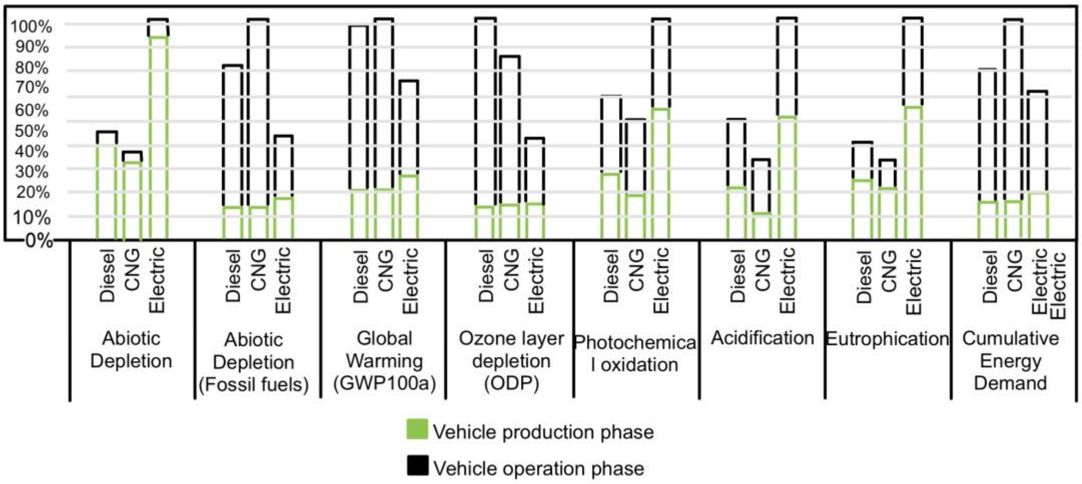

Figure 18: Complete life cycle impacts per travelled km using the Italian electricity mix (Marmiroli et al., 2020: 16)

If the electricity mix is based on renewable energy sources, the use phase of EVs becomes even more sustainable. The same life cycle analysis, based on the electricity mix of Norway is presented in figure 19. (Marmiroli et al., 2020: 15-16)

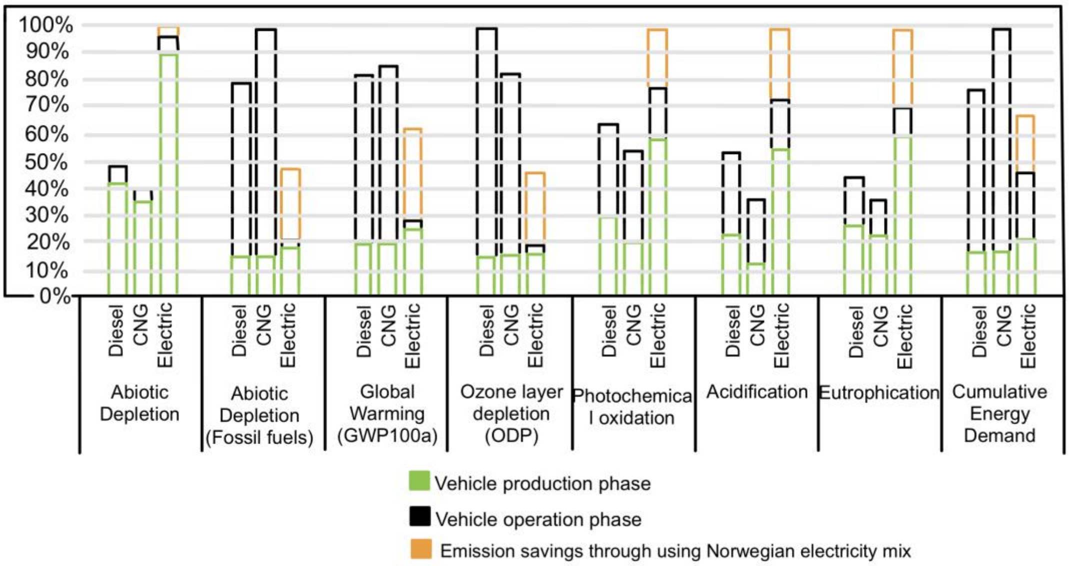

Figure 19: Complete life cycle impacts per travelled km using the Norwegian electricity mix (Marmiroli et al., 2020: 15-16)

The advantage of EVs over conventional vehicles in terms of environmental friendliness in the 4 categories, who concern the combustion of fossil fuels is further increased with the Norwegian electricity mix. This is because the sources of energy in the Norwegian electricity mix emit far less, than the sources of energy in the Italian electricity mix do. The impact of using the Norwegian energy mix, rather than the Italian energy mix is displayed on hand of the dotted areas. However, it is important to note, that the energy mix doesn't change the impact of the production phase of EVs. Therefore, EVs still perform worse than conventional vehicles in 4 out of 8 categories (the same as with the Italian energy mix). (Marmiroli et al., 2020: 15-16)

(Yang et al., 2023: 1; 3; 11; 15-19) have shown a possible environmental impact when implementing a certain number of EVs. Their specific study is based on the UK market. In the study different adoption scenarios are formulated depending on which the environmental impact is shown. The base line scenario is the starting point. This scenario assumes a slow increase in the amount of EVs and an decrease of fuel cell vehicles. In this scenario, the number of zero-emission vans just reaches 89.9 % in the year 2040. Another of those 4 transition scenarios is the so-called "rapid transition scenario", which assumes a sharp increase in EV van registrations in the early 2020s. Furthermore, it is assumed that 48 % of new vans are electric in the year 2025 and already 97 % in 2030. The UK market should reach 100 % implementation of EV vans from 2032. The possible reduction in annual emissions according to these 4 scenarios is presented in figure 20.

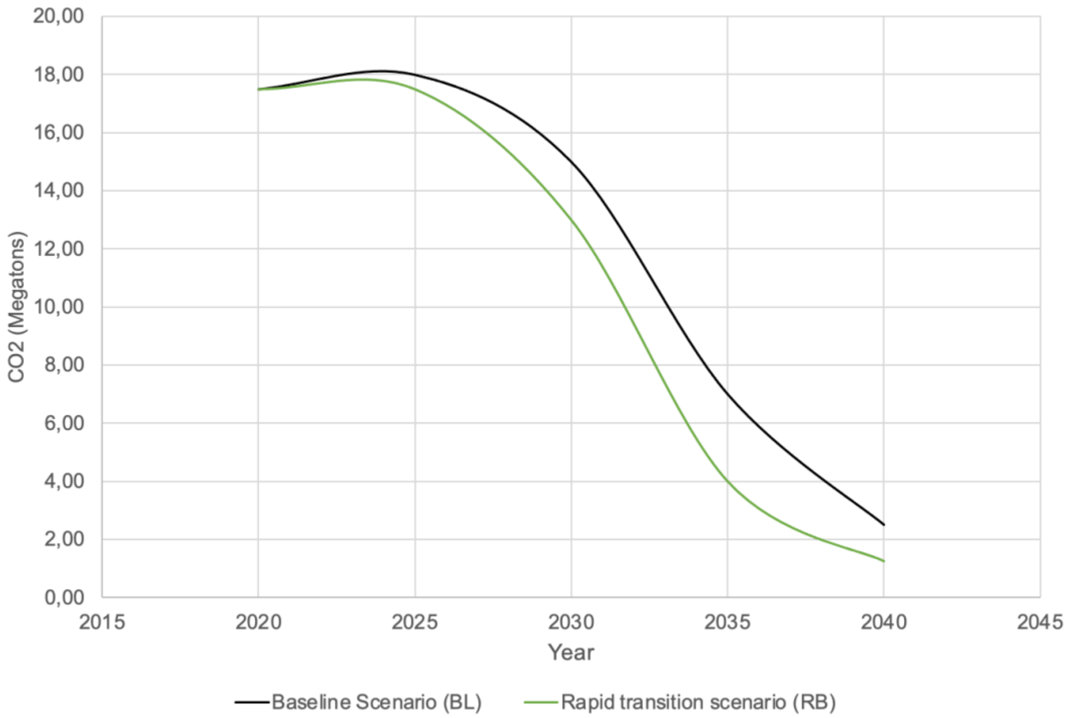

Figure 20: Annual Co2 emissions from the transportation sector in the UK under 4 different scenarios (Yang et al., 2023: 11)

The green line, numerated with “RB” marks the rapid transitioning scenario. It becomes evident, that with a rapid transitioning to EVs, a 69.7% reduction in Co2 emissions (compared to a base line scenario) becomes possible. (Yang et al., 2023: 4-5)

6 Results of the Case Studies

In addition to research based on literature review also primary data was collected by interviewing experts from two Finnish logistics companies, which are doing business in urban delivery and road transportation. In this chapter the case companies are introduced and their use of electric vehicles, as an alternative powertrain solution, described. The aim of the primary research was to apply the theoretical knowledge of literature review into practice. The analysis of the case study data is structured in form of a comparison between the two companies.

6.1 Data collection methods

The goal of the primary research conducted was to receive information on the use of electric vehicles in urban freight transportation companies in Finland. As it might have been difficult to receive responses to a survey, conducting interviews with three experts was chosen as a method of data collection. The companies, which were requested for an interview were: DHL Express Finland, UPS, Posti and one company, which wished to stay anonymous. From those companies, Posti and the anonymous company agreed to an interview for the purposes of the research. The interviews were conducted in February-March 2023. The interview with the Vice President in Sourcing in Posti Oy, Mr. Lehmuskallio, was conducted face-to-face. The other two interviews with the representatives of the company wishing not to be mentioned, were conducted online via videocalls. The interviews were semi-structured interviews including several topics with open answers. The interview information was tracked down in word documents by the interviewer. The cover letter and topics of the interview are described in appendix 1.

6.2 Posti Oy

Posti is the national postal service company in Finland, owned 100 % by the Finnish government. It was founded in 1638 just as Finland was still a part of

Sweden and acts until today.(Posti Group Oyj, 2023d) Posti operates both with domestic shipments in Finland and with import to Finland. This is possible due to the multiple international partnerships Posti has with other postal service businesses, such as DHL and Bring.(Posti Group Oyj, 2016)

The product solutions, which are offered by Posti can be divided into customer service solutions and business service solutions. The customer service solutions concentrate on the shipments of all different types of goods, reaching from small letters to large parcels and including domestic- as well as international- shipments. The business service solutions are more diversified, including all different types of logistics value chain services, e.g. warehousing, transport, handling of the flow of goods and tailor-made in-house-logistics systems. (Posti Group Oyj, 2023e)

Posti has ambitious environmental goals. Overall, the aim is to achieve net-zero greenhouse gas emissions in all business areas in the year 2030, which is 20 years earlier than the goal, set by the European Union. The European Union goals for achieving net-zero greenhouse gas emissions in 2050 are rather seen as a threat, as there is a high uncertainty concerning the actions, which will follow, if those goals can’t be met. (Lehmuskallio, 2023; Posti Group Oyj, 2023f)

To achieve those ambitious environmental targets, Posti has developed a roadmap for the adoption of alternative powertrain solutions in all their business areas. Therein, all business areas have been divided into different vehicle groups, e.g. <3.5t, 3.5t-16t, 16-26t, 26t>, and they are aligned with the respective powertrain technology. Additionally, the feasibility of implementing different alternative powertrain solutions has been tested. For vehicles <3.5t, the electric powertrain solution is feasible for business use since 2020. The roadmap showed, that until the year 2030, the percentage of electric vehicles in the fleet (vehicles <3.5t) is going to increase step by step. (Lehmuskallio, 2023)

Currently, the vehicle fleet of Posti in Finland, including all vehicles of its approx. 600 subcontractors contain approx. 2700-3000 vehicles (<3.5t) in total.

Amongst those vehicles, there are approx. 200 electric vehicles. The electric vehicles are mainly operating in the Helsinki area, which allows Posti to deliver fully emission-free in Helsinki. Additionally, it must be stated, that in 2023, the area for fully electric deliveries is planned to be extended to the cities of Espoo, Vantaa, Turku and Tampere. (Lehmuskallio, 2023; Posti Group Oyj, 2023b, 2023g)

6.3 Company X

The other case company of the primary research wished to stay anonymous. Therefore, information is presented in such a way that it does not reveal the identity of the company. The company is also a freight transport company, operating in multiple countries, such as Sweden, Finland, Denmark, Norway and parts of Germany. This logistics service provider started in the early 17th century in Sweden and expanded over the years until reaching its status to be one of the most important actors in freight transportation in the Nordics. (Company x, 2023)

The product solutions, which are offered by the company are similar to those offered by Posti. The service offering can be divided into customer and business service solutions as well. The customer service solutions include shipping parcels inside the Nordics and internationally with the help of multiple international cooperation’s. The diverse business solutions, which are offered include all services, reaching from warehousing products to marketing. (Company x, 2023)

As Posti, this other company has ambitious targets to reduce the environmental impacts of logistics. Their plan aims at greening last mile business operations until the year 2027. Furthermore, the overall goal is to provide complete fossil-free logistics until 2030. Therefore, the goals of Posti and the other case company are similar. Both want to reach net-zero greenhouse gas emissions in 2030, which is 20 years earlier than the goal set by the European Union. (Interviewee 1 of company x, 2023; Interviewee 2 of company x, 2023)

To achieve the electrification of last mile logistics services, the company has developed a roadmap for this sector. This states, that there are 18 electric vehicles operating in Finland until now. Following these 18 vehicles, 42 vehicles are planned to be added at the end of year, 2023, increasing the number of total electric vans to 60. In 2024, the number of electric vans should increase by 80 new vehicles and in 2025 by 120 new vehicles. It can be figured that the investment gradually increases from year to year. (Interviewee 2 of company x, 2023)

An important factor to consider, when deciding on the vehicle mix of the vehicle fleet is, that the majority of the vehicle fleet is outsourced to subcontractors. This means, that the company doesn’t own most of the vehicles, operating in the business operations. This makes the adoption of electric vehicles complicated, as the company itself doesn’t have any influence on the vehicle fleet of its subcontractors. The only way of influencing this aspect is creating new contractual obligations for the subcontractors or creating incentives for the adoption of electric vehicles. The vehicle fleet of the companies’ branches in Sweden and Denmark have implemented electric vehicles already for a long time, but as various market differences suggest, the implementation in Finland just started in 2023. Currently, the vehicle fleet of vans (<3.5t) of the company included approx. 300 vehicles. Until now, the company ordered 20 electric vehicles for the Finnish vehicle fleet, of which 7 have already arrived. Additionally, there are 10 electric vans, which are owned by subcontractors. (Interviewee 1 of company x, 2023; Interviewee 2 of company x, 2023)

6.4 Vehicle selection of case companies

There are certain vehicle characteristics, which are of decisive importance for vehicle fleet operators. These are e.g. purchase price, operating costs, driving distance, payload and the time needed for recharging/refuelling. Company x uses the Ford e-Transit. (Interviewee 1 of company x, 2023) Posti is using different electric models, including the Citroen e-Berlingo and e-Jumpy and the Mercedes e-Sprinter. (Lehmuskallio, 2023) In the following analysis, the vehicles are compared concerning their technical specifications. Additionally, the vehicle choice behaviour of the case study companies is explained and analysed.

The vehicles, which are used by the case study companies are listed in table 4 in a price ascending order from the cheapest model, the Citroen e-Berlingo, to the most expensive model, the Ford e-Transit.

Table 4. Comparison of vehicle models used by case study companies (Allgemeiner Deutscher Automobil-Club e.V., 2023d, 2023e, 2023f, 2023g)

Specifications	 Citroen e-Berlingo	 Citroen e-Jumpy	 Mercedes e-Sprinter	 Ford e-Transit
Price (excl. VAT)	27,943.38€	33,437.61€	52,127.27€	57,727.29€
PS	136	136	116	184
Trunk capacity	3300l	4600l	11000l	9300l
Dead weight	1665kg	1901kg	2455kg	2559kg
Max. Payload	725kg	929kg	1045kg	941kg
Consumption combined (WLTP)	19,7 kwh/100km	24,9 kwh/100km	33,9 kwh/100km	29,7 kwh/100km
Range combined (WLTP)	280km	212km	120km	263km
Gross Battery capacity	50kwh	50kwh	41kwh	77kwh
Fast charging (DC) possible?	Yes	Yes	Yes	Yes
Fastest charging time possible (AC or DC)	AC: 100% -> 305 min DC: 80% -> 30 min	AC: 100% -> 285 min DC: 80% -> 32 min	AC: 100% -> 360 min DC: 80% -> 20 min	AC: 100% -> 480 min DC: 80% -> 34 min

The Ford e-Transit is used by company X, although it's the most expensive of all vehicles selected. The reason for this decision lies in the geography and operational range of company X. The company does not constitute as the national postal office of Finland, which means that they don't own multiple locations around Finland, but rather just one terminal in Vantaa. Nevertheless, their business area does not only include Vantaa, but rather the entire Helsinki Metropolitan area and Espoo. Therefore, all routes currently start at the terminal in Vantaa. The delivery structure of the company x constitutes more as a point-to-point structure as presented in chapter 4.4.2. The terminal in Vantaa thereby constitutes as a starting point, while the respective next delivery point is always a customer. (Interviewee 1 of company x, 2023; Interviewee 2 of company x, 2023)This means, that when a delivery is to a location in e.g., Espoo, the initial driving distance from the terminal in Vantaa to the delivery area in Espoo constitutes already to approx. 32km. (Google LLC, 2023a)

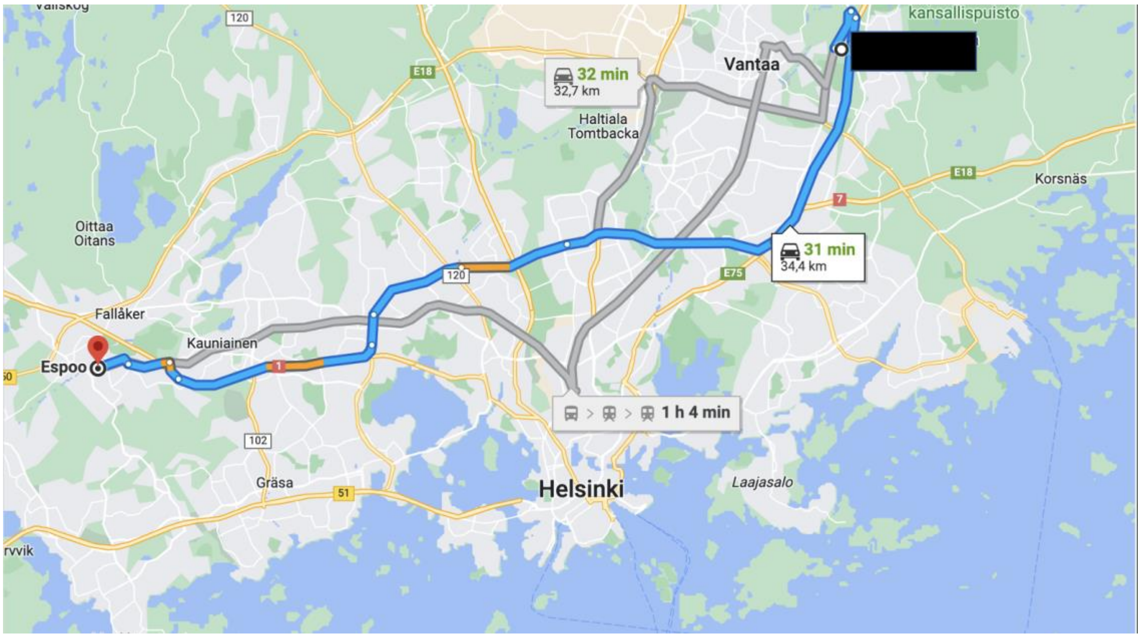

Figure 21: Distance between terminal and delivery area in Espoo (Google LLC, 2023a)

Therefore, the company requires the vehicle to have a big range, as the initial driving distance forth and back from the depot to the delivery area can already constitute 34.4km x 2= 68.8km, without any deliveries having been made. Also important to state is the fact, that the WLTP range, mentioned in the listing of the technical features of the vehicles is just an estimation and does not constitute to the real driving range, especially in winter times (see chapter 4.2.3).

This geographical orientation does not only create the need for a high driving range but also for a high trunk capacity, as there is no hub in e.g. Espoo to load or unload further deliveries during the day. This means, that to be as efficient as possible, the company should load all deliveries for Espoo onto the vehicle in the morning, so that all deliveries can be made in one shift without having to drive back and forth between the delivery area and the terminal. Therefore, vehicle specifications like the range and the size of the van (by means of loading capacity) are of special importance for profitability due to the company´s specific transportation needs.(Interviewee 1 of company x, 2023; Interviewee 2 of company x, 2023)

Due to the need for trunk capacity, only the Mercedes e-Sprinter and the Ford e-Transit can be considered, as the two Citroen models constitute more to small sized vehicles, trunk capacity of which is too small. When comparing the e-Sprinter and the e-Transit range-wise, the big difference between these two vehicles becomes clear. The e-Sprinter has less than half of the range of what the e-Transit supports (120 km <-> 263 km).(Allgemeiner Deutscher Automobil-Club e.V., 2023e, 2023d) This explains, why company X had picked the Ford e-Transit although it has a high initial price.

Posti uses 3 different models of electric vehicles in its deliveries: Citroen e-Berlingo, e-Jumpy and the Mercedes e-Sprinter. To understand, why these vehicles are feasible for Posti, but not for company X, it is important to know about the geographical location of Posti as well. Some example terminal locations of Posti in the Helsinki Metropolitan area are displayed in figure 22. (Google LLC, 2023b; Lehmuskallio, 2023)

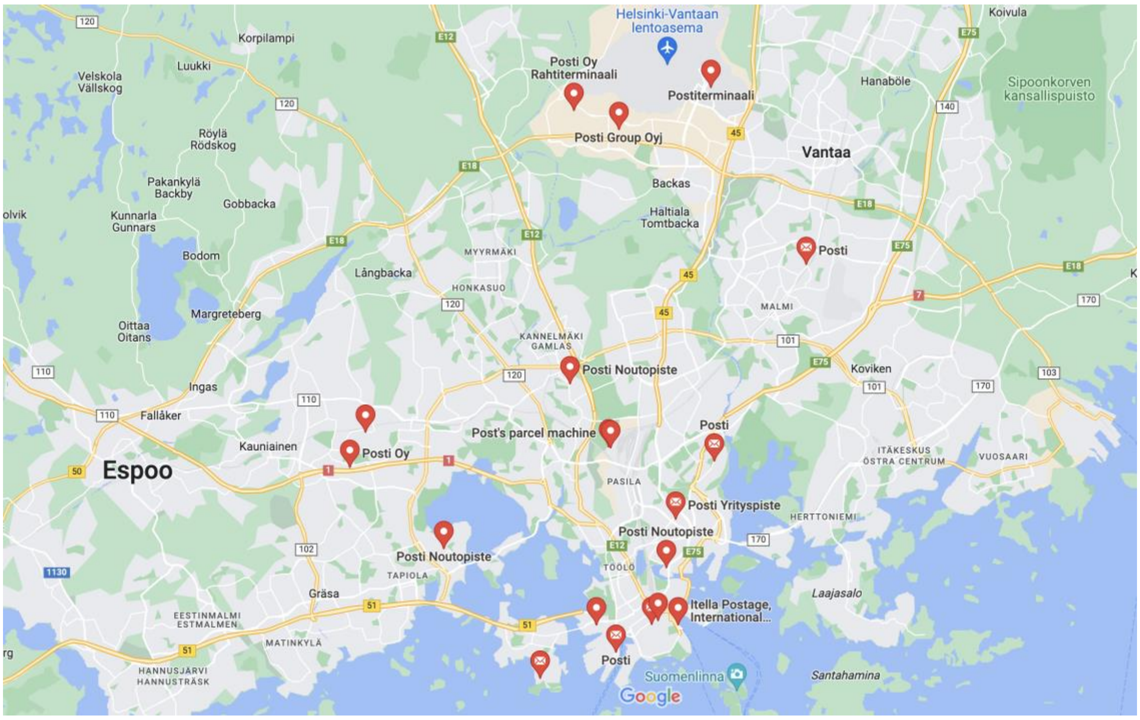

Figure 22: Posti terminal locations in the Helsinki Metropolitan Area (Google LLC, 2023b)

As the location network suggests, Posti does own multiple terminals, who are spread all around the Helsinki Metropolitan area. Therefore, their route network rather constitutes as a hub-and-spoke structure, as stated in chapter 4.2.3. The different hubs are the terminals, from which the vehicles address the various customers. This structure provides multiple benefits, especially when it comes to the use of electric vehicles. The drivers have the possibility of loading freight during operating hours, as there is always a hub nearby. Additionally, charging during operating hours becomes possible. Therefore, Posti has the possibility to diversify the selection of electric vehicles, as the needs in payload and driving range are significantly lower. The requirements for the vehicles rather shift to the charging aspects. As Posti can charge during the operating hours, the use of fast charging becomes more important. This becomes evident to a certain degree, as the selected vehicles have rather small batteries, but are charged quickly. The range of the Mercedes e-Sprinter is really small, but the recharging is within 20 minutes from 0 to 80 % is the fastest among all vehicles compared in this thesis.(Allgemeiner Deutscher Automobil-Club e.V., 2023e; Google LLC, 2023b; Lehmuskallio, 2023)

7 Analysis of drivers and barriers of implementing electric vehicles

7.1 SWOT and TOWS analysis based on literature review

In this chapter the advantages and disadvantages of electric vehicles for commercial transport, as well as the drivers and barriers for their implementation into commercial fleets are analysed based on literature review with the help of a SWOT & TOWS analysis. The driver and barriers are analysed also based on the primary data collected via interviews in the case companies Posti Oy and another Finnish logistics company.

SWOT analysis is a tool for companies to measure their strengths and weaknesses, which are factors relating to the company’s internal environment. Those are set into relation with the opportunities and threats, which are factors, relating to the company’s external environment. After stating all strengths, weaknesses, opportunities and threats and numbering them descending in terms of their importance, there is a possibility to conduct also a TOWS analysis. This analysis tool means formulating strategies through linking the different aspects of the SWOT analysis.

A 2D TOWS analysis model is introduced first. Strategies of this 2D model include e.g., strengths-opportunity strategies, which aim to resolve, how the company could use its internal strengths to maximize the external opportunities identified. Furthermore, there is the possibility to formulate so called strengths-threat strategies, which show, how the company could use its internal strengths to minimize the threats from the external environment. Moreover, there are weakness-opportunity strategies, which show how the company could minimize its weaknesses to maximize the identified the opportunities. At last, there are weakness-threat strategies, that state, how the company could minimize its weaknesses to minimize the threats from the external environment.

Additionally, there is the possibility of establishing a 3D TOWS analysis, which adds further aspects to the already mentioned strategies. The strength-threat strategies are extended by the factor of opportunities. This creates a strategy, showing how you could use your strengths by using the opportunities you identified to minimize the threats. The weakness-opportunity strategies can be expanded by the factor of strengths. This generates a strategy, establishing how to minimize a weakness by using the strengths combined with the opportunities you identified. At last, the weakness-threat strategies can be enlarged by the opportunities you identified. This creates a strategy, which shows how to minimize the weaknesses you identified by using the opportunities to avoid the threats.

In this thesis the object of the SWOT and TOWS analyses are companies, which potentially could use electric vehicles in their daily business. Therefore, the strengths/advantages, weaknesses/disadvantages, opportunities/drivers, and threats/barriers of electric vehicles are listed in a SWOT analysis. Then, the TOWS analysis is presented in a way, that the listed components are combined, resulting in a 3D modelling of strategies, which could help potential companies to evaluate the feasibility of the use of electric vehicles in their urban freight forwarding business.

A detailed SWOT analysis was conducted based on secondary data to elaborate further the usability of electric vehicles in urban freight. The SWOT analysis is presented in detail and by literature source as follows.

Strengths/Advantages of electric vehicles:

(Melander et al., 2022: 6-9)

- Local zero emissions/environmental benefits in general
- Entering of environmental zones possible
- Low operating costs

- Technical operating benefits (e.g. direct heating/cooling etc.)
- High energy efficiency
- TCO is in most cases lower than conventional vehicles (depending on subsidies, taxes, fuel etc.)

(Klumpp, 2014: 8)

- Less maintenance needed

(Besbes et al., 2020: 44;51)

- Implementation of regenerative breaking technology which conserves the brakes and regenerates energy when breaking
- Higher efficiency than conventional ICE vehicles especially in urban areas

(Iwan et al., 2019: 113-114)

- Cost & sustainability efficiency
- Reduced noise & exhaust emissions

(Lebeau et al., 2016: 253)

- Improved working conditions due to more comfortable driving (acceleration, smoothness, quietness)

(Quak and Nesterova, 2014: 277)

- Good marketing for the company, due to establishment of a green image

Weaknesses/Disadvantages of electric vehicles:

(Melander et al., 2022: 9-10)

- Need for charging infrastructure
- Long charging time can disrupt daily business activities
- High initial/purchasing costs
- Limited range
- Limited payload
- Increase in delivery time for daily operations due to charging in between
- Low range can lead to a total failure of daily business activities (when vehicle is empty and it has to get towed)
- Employee education needed
- Vehicle routing needs rearrangement depending on business model

(Iwan et al., 2019: 115)

- Missing infrastructure for repair facilities

(Quak and Nesterova, 2014: 268-273)

- Often range is not more than 100-150km
- This leads to an increased need for vehicles as well as employees to cover the same amount of freight as before with ICE vehicles
- Long downtimes possible due to malfunctions and limited availability of spare parts
- Lack of after-sale support in many cases

(Anosike et al., 2021: 6-8)

- Factors which have been not important before, like driving behavior, temperature, geographical topography, weather conditions, weight of transport become important factors as these heavily influence vehicle range
- Ineffective use of paid labor for driver due to vehicle charging time, if vehicle charging time is during daily operations
- Battery lifespan is estimated to be approx. only 6 years (depending on various factors)

(Besbes et al., 2020: 40)

- Especially temperature is important, as battery degradation starts when the vehicle is operated in temperatures below 15 or above 35 degrees Celsius

(Interviewee 1 of company X, 2023)

- Need for investment into new real estate

(Klumpp, 2014: 12)

- Unfeasible for energy-intensive last mile transport task (e.g. grocery, pharmaceutics etc.) due to need for additional energy -> further limitation in range

Opportunities/Drivers:

Opportunities/Drivers from a governmental perspective:

(Melander et al., 2022: 6-9)

- Establishment of environmental zones
- Purchasing incentives (e.g., free parking, tax deduction, purchase price subsidies)
- Extending of delivery time windows for EV's

- Governmental regulations

(Quak et al., 2016a: 166)

- Strengthening of EURO standard requirements

(European Comission, 2011)

- On a European level: European commission's ambition to make urban freight transport emission free by 2030

(Anosike et al., 2021: 14)

- For example, UK government restricting the sale of new ICE vehicles by 2035

Opportunities/Drivers from an <u>environmental</u> perspective:

(Melander et al., 2022: 6-9)

- Environmental concerns & Lifestyle changes
- Establishment of a green image possible (Melander et al., 2022: 6-9) such as Coca-Cola did, as they marked the costs for switching to EV's as marketing expenses (Quak and Nesterova, 2014: 282)

(Iwan et al., 2019: 114)

- Long term resource shortages

Opportunities/Drivers from an <u>economic</u> perspective:

(Lebeau et al., 2016: 246-250)

- Studies show that vehicle fleet operators become less sensitive to purchasing cost the higher the purchasing costs are
- When companies with high willingness to pay buy EV's now, this will lead to a reduction in price in the long term
- Environmentally friendly transport vehicles can be used as a marketing tool

(Klumpp, 2014: 9)

- Long term reduction in initial price due to mass production/economies of scale

(Melander et al., 2022: 6-9)

- Business model development makes EV's more suitable for commercial use

(Iwan et al., 2019: 114-118)

- Although of limited range and limited payload, sufficient for most urban freight deliveries

(Russo and Comi, 2002)

- It is estimated that 80% of freight trips in European cities are shorter than 80km

Threats/Barriers:

Threats/Barriers from a <u>company´s internal</u> perspective:

(Melander et al., 2022: 9-10)

- Mental barriers
- Uncertainty about the future
- Lack of information and knowledge
- Practicability concerns
- Customers are not willing to pay higher cost for environmentally friendly delivery

(Quak and Nesterova, 2014: 272)

- Many companies don’t buy EV’s now, because they are anxious about the next generation being much better than the current

(Anosike et al., 2021: 8-10)

- Uncertainty about battery lifespan and battery swapping costs
- Doubts about whether lower operating costs will offset higher purchasing price
- Doubts in residual value due to missing of a second-hand market

(Klumpp, 2014: 10-11)

- Limited payload can lead to a negative business case for EV’s due to need for more cars, more employees, more time
- Unfeasible for energy-intensive last mile transport task (e.g. grocery, pharmaceutics etc.) due to need for additional energy -> further limitation in range

Threats/Barriers from an <u>external environmental</u> perspective:

(Melander et al., 2022: 9-10)

- Limited supply of electricity and raw materials
- Lack of charging infrastructure
- Limited energy grid capacity
- High bureaucratical effort for fast charging due to lack of grid capacity
- Geographical variance in efficiency and usability of EV’s

- Low selection of feasible EV's for urban freight forwarding companies

(Anosike et al., 2021: 2)

- EV's are rather seen as a niche product, not establishing a new market but rather trying to disrupt the current market for conventional vehicles
- Vehicle choice behaviour analysis gets more important and complicated

(Quak and Nesterova, 2014: 277)

- Positive business case using EV's is difficult without any support from governmental authorities
- Without governmental encouragement logistics market is often not willing to implement EV's

TOWS matrix in presented in table 5 and in full size in appendix 2. In the TOWS analysis, the prior aspects of the SWOT analysis are combined to create 3D-modelled strategies, which further elaborate the feasibility of electric vehicles for commercial fleet operators.

Table 5. SWOT and TOWS Analysis of EVs

Internal / External	**Strengths (S)** • **Low operating costs & maintenance S1** • **Environmental benefits S2** • **High efficiency S3**	**Weaknesses (W)** • **Low range W1** • **High initial cost W2** • **Long charging time W3** • **Need for high investments (real estate, vehicle routing etc.) W4** • **Need for/missing of charging infrastructure W5**
Opportunities (O) • **Governmental regulations, restrictions & subsidies O1** • **Sufficient range for 80% of European urban deliveries O2** • **Lifestyle & Mindset changes in society O3** • **Resource shortages (e.g. fuel) O4**	S/0 Strategy-Attack Strategy • S2+O1: Use the strength of having environmental benefits (such as low emissions etc.) in order to maximize the opportunity of governmental regulations imposed against vehicles with bad environmental performance • S2+O3: Use the strength of having environmental benefits (such as low emissions etc.) in order to maximize the opportunity of changes in lifestyle and the society to gain a good image • S3+O4: Use the strength of having a high energy efficiency to maximize the opportunity of resource shortages (-> be a more attractive alternative to ICE vehicles needing fuel)	W/O Strategy + S • W1/O2+S3:Minimize the weakness of having a low range by maximizing the opportunity of urban freight transportation having short distances and the strength of having a high energy efficiency • W2/O1+S1:Minimize the weakness of having high initial costs by using the opportunity of governmental support/subsidies and the strength of having low follow-up costs • W3/O2+S3: Minimize the weakness of having long charging times by using the opportunity of having a sufficient range for most urban deliveries and the strength of having a high energy efficiency • W4/O1+S1: Minimize the weakness of having a high need for investment by using the opportunity of having governmental subsidies and the strength of having low follow-up costs
Threats (T) • **Limited & unsecure energy supply T1** • **Positive business case not existing without gov. support T2** • **Customers are not willing to pay more for environmentally friendly transport T3**	S/T Strategy + O • S3/T1+O4: Minimize the treat of having a limited energy supply by using the strength of having a high energy efficiency to maximize the opportunity of future resource shortages • S1/T2+O1: Minimize the threat of having no positive business case without governmental support by using the strength of having low operating and maintenance cost and maximizing the opportunity of governmental subsidies • S1/T3+O1: Minimize the threat of customers not being willing to pay more for environmentally friendly transport by using the strength of having low follow up costs and maximizing the opportunity of governmental subsidies	W+O+S/T Strategy-Defense Strategy + T • W1+O2/T1: Minimize the weakness of having a low range by using the opportunity of having a sufficient range for most urban city deliveries to avoid the threat of having an impact through the limited & unsecure energy supply • W2+W4+O1/T2: Minimize the weaknesses of having high initial costs & investment needs by using the opportunity of having governmental support to avoid the threat of having no positive business case without governmental support • W5+O1/T1: Minimize the weakness of the missing charging infrastructure by using the opportunity of governmental subsidies to avoid the threat of having an impact because of the limited & unsecure energy supply

7.2 SWOT and TOWS analysis based on case companies

In the company X there were different reasons behind the decision to implement electric vehicles. The company acts in the Nordic countries and therefore the business operations are impacted by governmental regulations (e.g. low-emission zones), imposed in countries, such as Sweden and Denmark. As the company must comply to the strong regulations in these countries, it was decided to follow the same strategy also in Finland. Another driver is the social trend, which goes into the direction of saving the environment and especially favouring and developing environmental-friendly modes of transportation. As customers value environmental aspects more, the company X decided to implement electric vehicles to and improve their company image. (Interviewee 1 of company x, 2023; Interviewee 2 of company x, 2023)

Barriers for the implementation of EVs into the vehicle fleet in company X are arising from the technical specifications of EVs, which impose limitations in the daily business operations. The major barriers are the limited range and the limited payload. (Interviewee 1 of company x, 2023; Interviewee 2 of company x, 2023)

In the interview with Mr. Lehmuskallio from Posti Oy, it became evident, that governmental regulations are not the major driver for Posti to implement more EVs. This is so because Posti mainly operates in Finland and the Finnish regulations are not as restricting as in other Nordic countries. For Posti, the major motivation is to contribute to the change in society to save the environment. Additionally, it must be stated, that EVs can mean a major economic advantage over conventional vehicles in the long term due to the low electricity prices in Finland. The high initial price of the vehicles and the fact, that the customers are not willing to pay more for environmentally friendly transportation was seen as the barriers to implement EVs in Posti. (Lehmuskallio, 2023)

Based on the interview results in the case companies it can be concluded that the drivers and barriers found out based on theory in chapter 7.2 apply also in practice. TOWS analysis is used to help company X and Posti to justify the implementation of EVs into their commercial fleets even more than currently.

For company X, the low range/low payload, missing charging infrastructure, governmental regulations and lifestyle changes in society were of special importance.(Interviewee 1 of company x, 2023; Interviewee 2 of company x, 2023) As a first strategy, the company x could use the strength of having environmental benefits provided by the use of EVs (such as low emissions etc.) in order to maximize the opportunity of governmental regulations imposed against the usage of vehicles not performing environmentally-friendly enough (such regulation as setting low emission zones etc.). Furthermore, the company X could use the strength of having environmental benefits with EVs (such as low emissions etc.) in order to maximize the opportunity of changes in lifestyle and in the society. This way they could gain good corporate image.

For Posti, the environmental benefits, low operating and maintenance costs, high efficiency, lifestyle changes in society, high initial costs and the fact that customers are not willing to pay more for environmentally friendly transportation were of special importance.(Lehmuskallio, 2023) As a first strategy, Posti could use the strength of having environmental benefits with EVs (such as low emissions etc.) in order to maximize the opportunity of changes in lifestyle and the society to gain a good corporate image. Furthermore, Posti could minimize the threat of customers not being willing to pay more for environmentally friendly transport by using the strength of having low follow-up costs with EVs. At last, Posti could minimize the weakness of having high initial costs for EVs by using the strength of having low follow-up costs with EVs.

7.3 Analysis of the impact of the implementation

In the following sub-chapters, the impact of the implementation of electric vehicles into the vehicle fleets of the companies is analysed based on the theoretical framework presented in chapter 4. The impact is based on vehicle fleet management, vehicle routing and charging and these topics are analysed from the case companies´ point of view.

7.3.1 Vehicle fleet management

The first important aspect in vehicle fleet management, when implementing EVs, is the vehicle fleet mix. Company X has implemented so far 18 vehicles equipped with an electric powertrain solution out of 300 operating in Finland. As the EVs constitute only a small fraction of the total vehicle fleet, limited payload and limited range of EVs are not impacting negatively on company x´s business operations. (Interviewee 1 of company x, 2023; Interviewee 2 of company x, 2023) However, it is important to note, that the problems aligned with the low payload and low range of EVs are going to increase over time unless company X does not change the geographical location of its terminals.

It would be feasible for company X to use conventional vehicles side-by-side with EVs for a longer time. This way the business need could be satisfied and ensured. Over time, it will be necessary to change some aspects related to the vehicle routing (see 4.2). Regardless of the vehicle routing, EVs are going to advance in technology, which means that the current problems, such as range and payload will be minimized in the long term.

The vehicle fleet mix of Posti is similar to the mix of company X, as it includes in total approx. 2700 - 3000 vehicles (<3.5 t in total), of which approx. 200 are electric. (Lehmuskallio, 2023) Due to the geographical orientation of Posti, the problems of limited range and payload are not a major concern to Posti in the urban areas. Therefore, no major change in the business structure is needed to implement more EVs over time.

7.3.2 Vehicle routing

Another important aspect is the vehicle routing. The geographical setting, used by the companies were presented in 4.2.2. The company X is currently using a point-to-point structure, while Posti relies on a hub and spoke structure. As expected, this imposes different issues for the companies.

Range

As company X has only one terminal in Vantaa but has deliveries in the complete Helsinki Metropolitan area, most of the range is already for driving from the terminal to the delivery area e.g., from Vantaa to Espoo. Therefore, the limited range of EVs is one of the major impacts on the business. Tests of company x show, that already during the loading time of the vehicles in the morning, approx. 18 km of the vehicle range are used. This is due to the fact, that the vehicles drive around in the loading area. To solve the range issue and efficient business operations with EVs, important changes must be made in the vehicle routing. (Interviewee 1 of company x, 2023; Interviewee 2 of company x, 2023)

For Posti, the situation is different. Posti used a hub and spoke system already before implementing EVs into the vehicle fleets. Therefore, there is no need to change the vehicle routing, as this system already minimizes the payload and range issues. To optimize the vehicle routing system even further, Posti has understood the importance of cloud-based vehicle fleet management with real time vehicle data. With this cloud-based system, which is connected to the charging concepts of Posti, optimum efficiency concerning electricity costs and route assignment to the vehicles can be reached. (Lehmuskallio, 2023)

Temperature

The effects of ambient temperature on the range of EVs were presented in chapter 4.2.3. Impact of temperature is especially important in Finland, as it can be really cold in winter time. The average temperature in Finland is below 0 degree Celsius in 4 of 12 months. This means that during 1/3 of the year, the energy consumption of electric vehicles can increase to 40%. (“National Centers for Environmental Information (NCEI),” 2023)

Therefore, the ambient temperature is one of the factors, which reduces the already limited range of the vehicles of the company x even more. During the interviews, it became evident, that the cold temperatures in the winter times create a major problem. The range of the Ford e-Transit is reduced to approx. 140 km in real life. This capacity loss restricts the feasible use of EVs in daily business operations even further. (Interviewee 1 of company x, 2023; Interviewee 2 of company x, 2023)

Even though the ambient temperature has a major impact on the driving range of EVs, the impact of the limited range in winter times doesn't impose a big challenge for Posti. This is due to the hub- and spoke- network again, which allows reducing driving distances and convenient charging between business operations. (Lehmuskallio, 2023)

Payload

The payload is another major issue for the company x. The general aim of the company is not to change the delivery time window and not to increase the total number of vehicles and drivers. The major issue of the payload constraint is the business model of the company, which relies on variable shipment weights not known well in advance. Therefore, payload restrictions impose a bottleneck for daily business operations. Another problem, accompanied with the limited payload of the vehicles is the high battery weight. Due to this, EVs are heavier than the comparable conventional vehicles. In Finland, the regulations state, that drivers with a B-license are only allowed to drive vehicles, the weight of which is up to 3.5 t. This imposes a major issue, as the EVs with relatively high payload have a high weight and this restricts the driver selection. (Interviewee 1 of company x, 2023; Interviewee 2 of company x, 2023)

For Posti, the limited payload of EVs doesn't impose a major issue, due to the existing hub and spoke structure. Furthermore, an optimal efficiency in the distribution of payload is achieved by using diverse vehicle models.

Suggestions for vehicle routing

Some of the presented general approaches for route optimization in chapter 7.4.2 could be feasible for company x. The best solution would be a hub-and spoke- system. This would enable the drivers to reload freight during the operating hours. Furthermore, opportunity for charging during the loading of the cargo would become possible. This would all in all reduce the problems of limited range and payload and enable the advanced application of EVs into daily business operations.

Concerning the impact of ambient temperature, there are multiple options. The establishment of a hub- and spoke- system would reduce the problem related to temperature for the company x as well.

7.3.3 Charging

The last major impact on companies, when implementing electric vehicles into their vehicle fleets, is the charging. Next, the current charging situation of the case companies is presented.

Currently, the charging infrastructure of the company X is in the development phase. Tests of the company show, that charging only overnight is often not sufficient to satisfy business needs. This is due to various factors, one of them being the loading phase of the vehicles. During the loading of the freight in the morning, the vehicles drive around in the loading area. Therefore, they often already use approx. 18 km of their range. Due to the fact, that the public charging infrastructure in Finland is not sufficient for business operations, the company wants to rely solely on private charging infrastructure. The goal for developing this private charging infrastructure is to have a 22 kw charger at every loading spot. Additionally, fast chargers are needed, as the business needs require that the company can recharge the vehicles to 80 % in less than 30 minutes. By implementing fast chargers, charging during the loading times of the vehicles would be possible. That would mean, that the vehicles leave the depot in the morning, come back at the afternoon to load new freight, and charge during this time and then leave again for a final shift. (Interviewee 1 of company x, 2023; Interviewee 2 of company x, 2023)

Posti owns already sufficient charging infrastructure. This charging infrastructure is spread across all hubs of Posti. Posti has implemented modern software, which increases the efficiency in the vehicle fleet management process. Such software includes e.g. cloud-based vehicle fleet management, which shares real-time data of vehicles. Furthermore, the vehicle routing software is closely connected to the charging infrastructure, which provides optimum efficiency, e.g., lower electricity costs, fast vehicle assignment etc. (Lehmuskallio, 2023)

To implement fast chargers, company x should make a detailed analysis, which results in the number of fast chargers needed. This would ensure, that no more chargers are implemented, that are not actually needed, as the price for fast charging infrastructure is high. Furthermore, the chargers should be optimally spread across all hubs, which have been established lately to ensure optimum flexibility and short driving distances. Additionally, company x should consider implementing a charging strategy for charging conducted during the daily operations. Such a strategy, would provide the maximum charging efficiency with the least time-effort. In addition to the downtime charging strategy, which means charging at night, the company x could implement an opportunity charging strategy. This strategy would mean recharging during breaks, in which the vehicles aren’t used. An example for such a break could be OC during loading or unloading or when break or shift changes. This strategy would not only reduce the range problem but also reduce the initial price for EVs, as a smaller battery capacity for the vehicles can be chosen, while still ensuring feasible business operations. Use of opportunity charging can, depending on the individual company, lead to significant cost savings. (Interviewee 1 of company x, 2023; Interviewee 2 of company x, 2023; Teoh et al., 2018: 1-18)

Posti has already developed its charging infrastructure to the right direction. Charging infrastructure is already spread into various hubs. Additionally, various software, which increases the efficiency of the charging and vehicle fleet management process, has been implemented. However, Posti could also implement different charging strategies. Especially the opportunity charging strategy would be interesting as this could provide significant cost savings for Posti as well. (Lehmuskallio, 2023)

7.3.4 Analysis of costs

Costs are one of the most important criteria in vehicle selection that commercial fleet operators are considering. Data related to costs was collected with help of interviews from the two case companies to make a comparison to situation, in which no EVs would have been bought. The two major cost factors to consider are initial costs and operational costs.

Initial costs

Company x tries to keep the initial costs as low as possible trough using sufficient planning. The planning is conducted through a consultant company, which is doing research for the diverse planning needed, such as vehicle routing etc. However, this planning can also be considered a big cost factor. As the investment costs for charging infrastructure are high, the company wants to use a leasing option for the charging systems required. When leasing the equipment needed, they are able to find out about the usability and reliability of the infrastructure without owning the infrastructure themselves and tying their equity in it. Additionally, to the costs of charging infrastructure, the higher initial costs for the vehicles must be considered. When studying the vehicle used by company x, Ford e-Transit, its conventional version starts at 48 698 €, while the electric version is 74 214 €. (Allgemeiner Deutscher Automobil-Club e.V., 2023d; Ford-Werke GmbH Kundenzentrum, 2023) This constitutes a price increase of approx. 52 % just due to the different powertrain. The governmental subsidises in Finland are also not helping the company, as they are 6000 € per electric van but can be applied to 5 vehicles per year only. Therefore, a huge fond for the investment costs is needed. Additionally, special driver education was needed from outsourced companies. (Interviewee 1 of company x, 2023; Interviewee 2 of company x, 2023)

For Posti, all cost factors are similar. High investment costs for charging infrastructure, higher initial purchase price of the vehicles and employee education. Nevertheless, Posti stated, that the business case has been already positive from the beginning of the implementation in 2020. In the future, they want to benefit from decreasing purchase prices of EVs, while battery capacities are increasing. Therefore, EVs will get even more attractive for business use in the future for Posti.(Lehmuskallio, 2023)

Operational costs

Due to a lack of experience, a comparison of which technology is cheaper concerning operating costs can’t be made for company X. This lack of experience includes e.g., the battery durability. Interviewee 1 estimated, that after 4 years of usage, the higher initial price of EVs will be offset by the lower operating costs of EVs. Additionally, interviewee 2 stated, that the TCO is lower when using EVs than with a comparable conventional vehicle. However, there is an overall doubt about the longevity of the vehicles, concerning the battery. (Interviewee 1 of company x, 2023; Interviewee 2 of company x, 2023)

Posti has conducted a detailed analysis, comparing the operating costs of conventional ICE vehicles and EVs. The result of this analysis was, that the break-even-point of EVs is 30 000 km per year on 250 working days/year. This would constitute to 120 km a day. The increasing electricity prices have also been included in the analysis. The result was that until 30 cents/kWh, EVs are cost-competitive compared to conventional ICE vehicles. In Posti, there is no uncertainty about the longevity of e.g., the batteries, as there is a high conviction towards the suitability and longevity of electric powertrain solutions. (Lehmuskallio, 2023)

Company X should first change their geographical structure and spread charging infrastructure in all different locations. This would reduce the needs for range and payload. Following this step, the company could diversify the vehicle selection to reduce the spendings in initial vehicle purchase price. Additionally, they could search for EVs, whose battery is not included in the initial price. Therefore, a monthly battery fee for renting the battery applies. This would solve the issue with the high purchase price on the one hand, while reducing uncertainty with battery longevity on the other hand, because the battery is ensured over the time of renting.

7.3.5 Analysis on stakeholder satisfaction

As the customer- as well as employee- satisfaction constitutes as an important factor for the business image and reputation, another interview point, which was discussed with the representatives of the case companies was the satisfaction of the stakeholders.

As company X has not implemented many EVs into their vehicle fleet yet, no representative analysis about the employee satisfaction can be made. However, it can be stated, that the employees, who had been in touch with the new vehicles have been very satisfied so far. Especially features like the good acceleration, the silence, when driving, and the elimination for the need to refill gasoline are seen as an improvement by the employees. (Interviewee 1 of company x, 2023; Interviewee 2 of company x, 2023)

For Posti the result is more representative, as more vehicles have been implemented until now. Posti reports a high employee efficiency in general. This is based on various advantages in comfort compared to conventional vehicles. Advantages include the fast heating and cooling, the fast acceleration and not needing to stop to refill the gasoline. (Lehmuskallio, 2023)

Eventually, the case companies could make different employee surveys about the satisfaction with the vehicles. Depending on the different employee responses, there would be the possibility to adapt the vehicle choice characteristics based on employee feedback.

The customers are another important part of the stakeholder group of urban freight transportation companies. Their satisfaction ultimately determines the number of jobs available for the company. Therefore, their satisfaction should be of highest priority for the companies.

As company X has not implemented many EVs yet, the problem of representative data and results occurs again. However, based on the answers received in the interviews, the customers are happy about the new vehicles and always like to start a conversation about them. (Interviewee 1 of company x, 2023; Interviewee 2 of company x, 2023)The customers of Posti are satisfied, if there is no increase in cost for them caused by use of EVs but a gain of the transportation being sustainable, which is the case in the current business scenario. (Lehmuskallio, 2023)

In general, the companies should pay attention to the fact, that no costs are added for the customer. Different research shows, that customers are not willing to pay more for sustainable transportation. (Melander et al., 2022: 10) Additionally, the daily business operations should continue, as the customers know them. That’s because customers don’t like a change in the already known business model. Changes, such as extending the delivery time window etc. could therefore lead to a serious decrease in customer satisfaction levels.

8 Conclusions

Electric engines as an alternative powertrain solution are one of the most polarising issues in the transport industry as of today. The previous research conducted in this thesis presents the possibilities and limitations of this technology.

The current vehicle market for commercial electric vehicles is very competitive. New players are entering the market every day, providing vehicles, that are more advanced than the competitors vehicles. Traditional vehicle manufacturers struggle with the competitors entering the market, as they themselves are not able to produce EVs with the same technical specifications to offer a competitive price. Even though both the already well-established companies and new market entrants are trying to produce the best vehicle, the current vehicle market is not yet providing many feasible vehicles for commercial transport. This is due to various specifications of the vehicles, such as initial price, range, payload and time needed for recharging. The most vehicles, which are available on the market, as of 2023, are not feasible for commercial transportation.

Nevertheless, it must be stated, that the future is going to improve the situation. New technologies will arise and new market entries will increase competition even further. In combination with economies of scale and increasing business knowledge, this will lead to the development of new vehicles, which will have a lower pricing, a higher range and payload and a shorter recharging time.

Regardless of the limited selection of feasible vehicles on the current vehicle market, there are various drivers and barriers, respectively rooting for or against the implementation of electric vehicles into the urban freight logistics industry. Based on the research of this thesis, it was found out, that the most important drivers, ruling for the implementation of electric vehicles relate to 3 sub-groups, being either economic, environmental, or governmental. The main economic drivers are low operating costs of the vehicles, a high energy efficiency and resource shortages (e.g. fuel). Furthermore, from an environmental perspective, the most important aspects are environmental benefits and lifestyle changes in society. The main drivers from a governmental side concern different regulations, restrictions and subsidies related to the commercial usage of the vehicles.

Additionally, the barriers for the implementation were also covered in this thesis. Barriers are mainly relating to an economic perspective. The main barriers are therefore vehicle characteristics, such as a low range, high initial costs, long recharging times, missing infrastructure, no positive business case without governmental support and customers, who are not willing to pay for environmentally friendly transportation. It must be stated that the drivers and barriers for the implementation of electric vehicles depend on the geographical location and the individual business and operational situation of the company. In general, it is however sufficient to state, that as of 2023, the barriers for the implementation prevail the drivers for the implementation. Often, companies struggle with the bad vehicle characteristics, which are not sufficient to support the daily business operations. Therefore, the status of implementing electric vehicles into commercial fleets remains low. To change this situation in the future, both technical development in the electric vehicle market and also governmental efforts are needed. Governments should increase subsidies for electric vehicles and restrict the usage of conventional ICE vehicles. Additionally, measures should be taken, which help the EV manufacturers to develop new technologies easier and faster.

Regardless of the insufficient current vehicle market and the many barriers for the implementation of EVs into commercial fleets, it can be feasible for some companies to implement EVs. Therefore, the possible impact of implementing EVs into commercial fleets becomes important. In the research conducted, it was found out, that the main impacts relate to the topics of vehicle fleet management, vehicle routing and charging. In the vehicle fleet management, companies struggle with replacing conventional ICE vehicles with EVs, as these are not capable of providing the same vehicle characteristics. Therefore, commercial fleets increase to cover the same amount of business needs. Vehicle routing has never been as important as before. This is due to the reduced range and payload of EVs. Companies must change not only their routes but also the entire route network to be able to implement EVs. Implementing EVs does not only lead to huge investments into charging infrastructure, but also the planning of charging and the development of charging strategies becomes important. Depending on the business needs, the charging strategies can impact daily business operations.

In conclusion, it must be stated, that implementing EVs creates the need for many different structural changes in the business. Vehicle fleet management and vehicle routing existed also before EVs but their implementation into vehicle fleet makes these topics more important than ever before. Vehicle charging is a new aspect, which has arisen along with EVs. It has not been important before, as vehicle refuelling has been uncomplicated and has not required big investments from the business. Businesses should plan well in advance to minimize the bad impacts of implementing EVs into their commercial fleet. This planning incurs high additional costs. Therefore, it can be stated, that the impacts of implementing EVs into commercial fleets mainly focus on additional investment costs and additional planning.

The total cost of ownership is the most important vehicle characteristic for commercial fleet operators. Therefore, a detailed cost analysis was established in this thesis. It compared conventional ICE vehicles and EVs. EVs generally incur lower operating costs, whilst ICE vehicles incur lower initial costs. However, based on the TCO analysis the result is that EVs are not cost-competitive unless specific governmental subsidies and regulations are set to promote EVs. The main reasons for the bad cost performance are due to the high initial purchase price, the high investment costs for EV charging infrastructure and the low payload of the vehicles. Therefore, only small- and mid- sized transport EVs can be cost competitive, if certain governmental regulations and subsidies are in place. Box EVs (e.g., Mercedes eSprinter) are never cost-competitive compared to conventional ICE vehicles as of 2023.

Concerning the cost aspect, it must be concluded, that EVs are only feasible from the cost perspective for a small fraction of companies. The vehicles, that the companies use should thereby be small- or medium- sized and the payload needs should not exceed approx. 800 kg. Additionally, there should be certain governmental regulations and subsidies in place, which encourage the implementation of EVs. If one of those factors can’t be met by the companies, EVs are not cost-competitive as they incur higher costs in daily business operations than ICE vehicles.

The main driver for implementing EVs is their sustainable image. Companies want to decrease GHG emissions, emitted by their daily business operations. The sustainable image of EVs is mainly created through their zero tailpipe emissions. Nevertheless, the production process of EVs is often said to be environmentally harming, as well as the source of electricity used for charging EVs. Therefore, a detailed sustainability analysis was also conducted focusing on the aspects of vehicle production and vehicle use stage. The analysis made of the sustainability of the production phase of EVs suggests that the production of the batteries used in EVs is environmentally harming. When comparing EVs to conventional ICE vehicles in the production phase, EVs have an environmental performance, which is much worse than the one of conventional ICE vehicles. Additionally, the environmental performance of EVs in the use phase was compared to conventional ICE vehicles. Based on this comparison the conclusion is that the environmental performance of the use phase depends on the electricity mix of the country. Nevertheless, it must be stated, that regardless of the electricity mix of the country, EVs are always more environmentally friendly than conventional ICE vehicles in the use phase. Therefore, the issue of environmental performance of EVs depends on the longevity of the systems. For commercial transport purposes, where a maximum lifetime of 10 years for vehicles can be assumed, EVs are currently not more environmentally friendly than ICE vehicles, as the bad impact of the production phase can’t be offset by the use phase of just 10 years.

Based on the research of this thesis, the writer s concludes, that as of 2023, EVs are not feasible for commercial implementation to a large degree. EVs are only feasible for a very small fraction of businesses, as certain requirements must be met. Currently, there are still many aspects slowing down the implementation of EVs, such as the limited vehicle selection, bad vehicle performance, needs for high investments, necessary change in business practices or business model, bad cost performance and bad sustainable performance (in short term). The current market of EVs is not as developed as it should be to satisfy business requirements. Furthermore, it is not feasible for companies to be forced to change their business models according to EV specifications. A vehicle should be seen more as a tool satisfying business needs than creating new needs. The writer additionally concludes that the political efforts of various governments are in a too early phase of implementation and not arranged on the right front.

8.1 Future outlook

As a suggestion, it becomes evident, that freight transportation businesses should wait with the implementation of EVs, until the various limitations mentioned have been eliminated or diminished. Further research on this topic would be feasible in approx. 5 - 7 years. It can be assumed that with increasing economies of scale and experiences in production, companies are able to produce vehicles, that have a lower initial price, higher range, and a higher payload within this timeframe. Additionally, the production phase can be developed in a much more sustainable way.

This research focused on the usage of electric engines as an alternative powertrain solution, as this is the most widespread powertrain solution besides conventional ICE's. Nevertheless, there are also other powertrain solutions available, such as hydrogen-fuel cell. The hydrogen-fuel cell vehicle does power its electric engines by the electricity generated in the fuel cell. Although this technology is available as of 2023, it isn't implemented nearly as far as the electric powertrain solution. However, this technology imposes another major possibility to replace conventional ICE vehicles. Therefore, further research on comparing also the opportunities of hydrogen-fuel-cell engines is interesting and recommended.

References

Abivin, 2019. *Hub & Spoke vs Point-To-Point* [online]. Available at: <https://www.abivin.com/post/hub-spoke-vs-point-to-point-which-is-better-for-roadways-delivery> [accessed 4.3.23].

Al-dal'ain, R., Celebi, D., 2021. Planning a mixed fleet of electric and conventional vehicles for urban freight with routing and replacement considerations. *Sustainable Cities and Society*, 73: p. 4-7. DOI: https://doi.org/10.1016/j.scs.2021.103105

Allgemeiner Deutscher Automobil-Club e.V., 2023a. *Renault Master Kastenwagen L2H2 3,5t E-TECH Electric (52 kWh) (ab 09/22): Technische Daten, Bilder, Preise | ADAC* [online]. Available at: <https://www.adac.de/rund-ums-fahrzeug/autokatalog/marken-modelle/renault/master/iii-facelift-2/326367/> [accessed 3.10.23a].

Allgemeiner Deutscher Automobil-Club e.V., 2023b. *Renault Kangoo Rapid Z.E. (33 kWh) (2-Sitzer) (inkl. Batterie) (06/17 - 06/22): Technische Daten, Bilder, Preise | ADAC* [online]. Available at: <https://www.adac.de/rund-ums-fahrzeug/autokatalog/marken-modelle/renault/kangoo/ii-facelift/279972/> [accessed 3.9.23b].

Allgemeiner Deutscher Automobil-Club e.V., 2023c. *Mercedes-Benz eVito 111 Kastenwagen lang (35 kWh) (07/19 - 12/21): Technische Daten, Bilder, Preise | ADAC* [online]. Available at: <https://www.adac.de/rund-ums-fahrzeug/autokatalog/marken-modelle/mercedes-benz/vito/447-facelift/306686/> [accessed 3.11.23c].

Allgemeiner Deutscher Automobil-Club e.V., 2023d. *Ford E-Transit Kastenwagen 350 L2 (ab 05/22): Technische Daten, Bilder, Preise | ADAC* [online]. Available at: <https://www.adac.de/rund-ums-fahrzeug/autokatalog/marken-modelle/ford/transit/7generation-facelift/324154/> [accessed 3.29.23d].

Allgemeiner Deutscher Automobil-Club e.V., 2023e. *Mercedes-Benz eSprinter 312 Kastenwagen Hochdach A2 (35 kWh) (ab 03/20): Technische Daten, Bilder, Preise | ADAC* [online]. Available at: <https://www.adac.de/rund-ums-fahrzeug/autokatalog/marken-modelle/mercedes-benz/sprinter/907-910/311720/> [accessed 3.29.23e].

Allgemeiner Deutscher Automobil-Club e.V., 2023f. *Citroen e-Jumpy Kastenwagen XS (50 kWh) Control (05/21 - 07/21): Technische Daten, Bilder, Preise | ADAC* [online]. Available at: <https://www.adac.de/rund-ums-fahrzeug/autokatalog/marken-modelle/citroen/jumpy/3generation/321930/> [accessed 3.29.23f].

Allgemeiner Deutscher Automobil-Club e.V., 2023g. *Citroen e-Berlingo Kastenwagen L1 Control (11/21 - 08/22): Technische Daten, Bilder, Preise | ADAC* [online]. Available at: <https://www.adac.de/rund-ums-fahrzeug/autokatalog/marken-modelle/citroen/berlingo/3generation/322507/> [accessed 3.29.23g].

Anosike, A., Loomes, H., Udokporo, C.K., Garza-Reyes, J.A., 2021. Exploring the challenges of electric vehicle adoption in final mile parcel delivery. *International Journal of Logistics Research and Applications,* 1–25: p. 2-14. DOI: https://doi.org/10.1080/13675567.2021.1978409

ARRIVAL UK LTD., 2023. *Arrival | Why Arrival* [online]. Available at: <https://arrival.com/topic/why-arrival> [accessed 3.10.23].

BDEW, 2023. *Strompreis Entwicklung in Deutschland für Haushalte und Industrie | BDEW* [online]. Available at: <https://www.bdew.de/service/daten-und-grafiken/bdew-strompreisanalyse/> [accessed 5.26.23].

Besbes, W., Dhouib, D., Wassan, N., Marrekchi, E., 2020. *2. Role of Green Technology Vehicles in Road Transportation Emissions – Case of the UK, in: Solving Transport Problems : Towards Green Logistics*. John Wiley & Sons, Incorporated. p.40,44,51

Beyrouthy, L., 2022. *E-commerce revenue in Europe 2025 | Statista* [online]. Statista. Available at: <https://www-statista-com.ezproxy.metropolia.fi/forecasts/715663/e-commerce-revenue-forecast-in-europe> [accessed 1.28.23].

B-ON GmbH, 2023. *Die Produkte | B-ON* [online]. Available at: <https://www.b-on.com/the-products> [accessed 3.10.23].

Browne, Micheal, Allen, J., 2011. *Enhancing the sustainability of urban freight transport and logistics* [online]. Available at: <https://www.unescap.org/sites/default/files/bulletin80_Article-1.pdf> [accessed 6.3.23].

Carlier, M., 2022. *Europe: eLCV sales by model market share | Statista* [online]. Statista. Available at: <https://www.statista.com/statistics/1232047/europe-elcv-sales-model-market-share/?locale=en> [accessed 3.9.23].

Castillo Campo, O., Álvarez Fernández, R., 2023. Economic optimization analysis of different electric powertrain technologies for vans applied to last mile delivery fleets. *Journal of Cleaner Production,* 385, p.2-6. DOI: https://doi.org/10.1016/j.jclepro.2022.135677

Chevalier, S., 2022. *Europe: e-commerce delivery preferences 2020 | Statista* [online]. Statista. Available at: <https://www-statista-com.ezproxy.metropolia.fi/statistics/980543/e-commerce-delivery-preferences-in-selected-countries-in-europe/?locale=en> [accessed 4.10.23].

Clausnitzer J., 2022. *Preferred methods of delivery Finland 2020 | Statista* [online]. Statista. Available at: <https://www-statista-

com.ezproxy.metropolia.fi/statistics/1259464/preferred-methods-of-delivery-finland/?locale=en> [accessed 4.10.23].

Company x, 2023. *Company x webpages* [online]. Company x. [accessed 4.20.23].

Dadzie, K.Q., Chelariu, C., Winston, E., 2005. Customer service in the internet-enabled logistics supply chain: website design antecedents and loyalty effects. *Journal of Business Logistics,* 26 (1), p.53. DOI: https://doi.org/10.1002/j.2158-1592.2005.tb00194.x

Denchak, M., 2021. *Paris Climate Agreement: Everything You Need to Know | NRDC* [online]. Natural Resources Defense Council. Available at: <https://www.nrdc.org/stories/paris-climate-agreement-everything-you-need-know> [accessed 1.28.23].

Deutsche Bundesregierung, 2022. *Klimaschutzgesetz: Klimaneutralität bis 2045 | Bundesregierung* [online]. Available at: <https://www.bundesregierung.de/breg-de/themen/klimaschutz/klimaschutzgesetz-2021-1913672> [accessed 1.31.23].

DHL, 2022. *The Reasons DHL Embraces Electric Vehicles - DHL Express SG* [online]. DHL. Available at: <https://www.dhl.com/discover/en-sg/logistics-advice/sustainability-and-green-logistics/reasons-dhl-embraces-electric-vehicles> [accessed 3.2.23].

European Commission, 2011. *Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system* [online]. Available at: < https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2011:0144:FIN:en:PDF> [accessed 6.3.23].

The European Plastic Pipes & Fittings Association, 2023. *Environmental Impact Criteria* [online]. Available at: <https://www.teppfa.eu/wp-content/uploads/EPD-LCA-Environmental-Impact-Explanation-1.pdf> [accessed 6.3.23].

Ewert, R., Martins-Turner, K., Thaller, C., Nagel, K., 2021. Using a Route-based and Vehicle Type specific Range Constraint for Improving Vehicle Routing Problems with Electric Vehicles. *Transportation Research Procedia,* 52: 518–519. DOI: https://doi.org/10.1016/j.trpro.2021.01.061

FedEx, 2022. *Charged Up About Electric Vehicles | FedEx* [online]. Available at: <https://www.fedex.com/en-us/sustainability/electric-vehicles.html> [accessed 3.2.23].

Forbes Media, 2023. *Forbes about Arrival* [online]. Available at: <https://www.forbes.com/profile/denis-sverdlov/?sh=12a62ec8ae7c> [accessed 3.10.23].

Ford-Werke GmbH Kundenzentrum, 2023. *Ford Nutzfahrzeuge & Transporter – alle Neuwagen | Ford DE* [online]. Available at: <https://www.ford.de/nutzfahrzeuge-modelle> [accessed 3.13.23].

Geodis GmbH, 2017. *PRESS KIT PRESS RELEASE Geodis launches Distripolis, a new take on city logistics* [online]. Available at: <https://silo.tips/download/distripolis-geodis-invents-the-urban-logistics-of-the-future> [accessed 6.3.23].

Geodis GmbH, 2012. *Corporate Social Responsibility Report* [online]. Available at: <https://geodis.com/mx//sites/default/files/2018-07/Geodis-SD-Report-2012.pdfY> [accessed 6.3.23].

Global Petrol Prices, 2023a. *Finnland Energiepreise | GlobalPetrolPrices.com* [online]. Global Petrol Prices. Available at: <https://de.globalpetrolprices.com/Finland/> [accessed 5.26.23].

Global Petrol Prices, 2023b. *Deutschland Energiepreise | GlobalPetrolPrices.com* [online]. Global Petrol Prices. Available at: <https://de.globalpetrolprices.com/Germany/> [accessed 5.26.23].

Google LLC, 2023a. *Directions for driving from Vantaa, Helsinki to Espoo, Helsinki.* [online]. Google Maps. Available at: <https://www.google.com/maps> [accessed 4.24.23].

Google LLC, 2023b. *Posti terminal locations in the Helsinki Metropolitan Area* [online]. Google Maps. Available at: <maps.google.com> [accessed 4.24.23].

Huijbregts, M.A.J., Rombouts, L.J.A., Hellweg, S., Frischknecht, R., Hendriks, A.J., van de Meent, D., Ragas, A.M.J., Reijnders, L., Struijs, J., 2006. Is Cumulative Fossil Energy Demand a Useful Indicator for the Environmental Performance of Products? *Environmental Science & Technology,* 40: 641. DOI: https://doi.org/10.1021/es051689g

Huskie, K., 2012. *Distripolis: a case study in urban deliveries* [online]. Available at: <https://evessio.s3.amazonaws.com/customer/3c4f8c0e-2afe-45cf-b275-2896667156c4/event/6ba0c7c5-d4ca-4d6f-bb1e-ccaa0b5ddb53/General_Content/10._KEVIN_HUSKIE_Geodis_Distripolis_v2.pdf> [accessed 6.4.23].

Iwan, S., Allesch, J., Celebi, D., Kijewska, K., Hoé, M., Klauenberg, J., Zajicek, J., 2019. Electric mobility in European urban freight and logistics – status and attempts of improvement. *Transportation Research Procedia,* 39: 114–118. DOI: https://doi.org/10.1016/j.trpro.2019.06.013

John, A., Growcom, E., 2008. *Vegetable Industry Carbon Footprint Scoping Study What is a Carbon Footprint? An overview of definitions and methodologies* [online]. Available at: <https://www.daf.qld.gov.au/__data/assets/pdf_file/0003/59025/Hort-Fruit-Drought-Carbon-Report1.pdf> [accessed 6.4.23].

Kleiner, F., Doruk Özdemir, E., Schmid, S.A., Beermann, M., Çatay, B., Moran, B., Taeck Lim, O., Friedrich, H.E., 2015b. *Electrification of transport logistic vehicles: A techno-economic assessment of battery and fuel cell electric transporter* [online]. Available at: <https://www.researchgate.net/publication/278675536_Electrification_of_transport_logistic_vehicles_A_techno-economic_assessment_of_battery_and_fuel_cell_electric_transporter> [accessed 6.4.23].

Klumpp, M., 2014. *Electric Mobility in Last Mile Distribution, Efficiency and Innovation in Logistics*. Springer International Publishing, Cham. p. 3-12

Lebeau, P., Macharis, C., Van Mierlo, J., 2016. Exploring the choice of battery electric vehicles in city logistics: A conjoint-based choice analysis. *Transportation Research Part E: Logistics and Transportation Review*, 91: 246–253. DOI: https://doi.org/10.1016/j.tre.2016.04.004

Lockwood, M., 2013. The political sustainability of climate policy: The case of the UK Climate Change Act. *Global Environmental Change*, 23: 1–2. DOI: https://doi.org/10.1016/j.gloenvcha.2013.07.001

Marmiroli, B., Venditti, M., Dotelli, G., Spessa, E., 2020. The transport of goods in the urban environment: A comparative life cycle assessment of electric, compressed natural gas and diesel light-duty vehicles. *Applied Energy*, 260: 11-17. DOI: https://doi.org/10.1016/j.apenergy.2019.114236

Maxomotive Deutschland GmbH, 2023a. *Über MAXUS | Maxus* [online]. Available at: <https://maxusmotors.de/ueber-maxus> [accessed 3.10.23a).

Maxomotive Deutschland GmbH, 2023b. *Maxus – elektrische Nutzfahrzeuge, funktional und zuverlässig* [online]. Available at: <https://maxusmotors.de/> [accessed 3.10.23b).

Melander, L., Nyquist-Magnusson, C., Wallström, H., 2022. Drivers for and barriers to electric freight vehicle adoption in Stockholm. *Transportation Research Part D: Transport and Environment,* 108: 3-10. DOI: https://doi.org/10.1016/j.trd.2022.103317

Mercedes-Benz AG, 2023a. *Van Online Configurator | Mercedes-Benz* [online]. Mercedes-Benz AG. Available at: <https://voc.mercedes-benz.com/voc/de_de?_gl=1*a0c3gj*_gcl_aw*R0NMLjE2Nzk0MTYwOTQuQ2p3S0NBandxLVdnQmhCTUVpd0F6S1NINk9lNFU2OWdJNHY4QU5seXdIT1Rfa29WaWQ4ck1pZ3I4czBkd3pEMnRpd181MEl3WnZYZ3ZSb0MzR3NRQXZEX0J3RQ..&_ga=2.179104548.1264966755.1679416081-654909957.1678453145&_gac=1.190441305.1679416101.CjwKCAjwq-WgBhBMEiwAzKSH6Oe4U69gI4v8ANlywHOT_koVid8rMigr8s0dwzD2tiw_50IwZvXgvRoC3GsQAvD_BwE> [accessed 3.21.23a].

Mercedes-Benz AG, 2023b. *Vito Kastenwagen BASE 114 CDI lang kaufen | Mercedes-Benz Store* [online]. Mercedes-Benz AG. Available at: <https://www.mercedes-benz.de/passengercars/buy/new-car/product.html/Vito-Kastenwagen-BASE-114-CDI-lang_5-20061505_DE_354ae2f5> [accessed 3.21.23b).

Mercedes-Benz AG, 2023c. *Vito finden | Mercedes-Benz Store* [online]. Available at: <https://www.mercedes-benz.de/passengercars/buy/new-car/search-results.html/?emhmodel=Vito&emhbodyType=PANEL_VAN&emhvehicleAssortment=new-commercial-vans&emhsort=monthly-asc&gclid=Cj0KCQiAx6ugBhCcARIsAGNmMbgPoeLgAoGEI7v05qKSjZJg6zpO6ZVEfGCsPstKs1UADStNRLUimB0aAlzlEALw_wcB#vehicles&kpid=go_cmp-225583481_adg-44701993095_ad-396911510544_kwd-314018040645_dev-c_ext-> [accessed 3.10.23c).

Mercedes-Benz AG, 2023d. *EQV finden | Mercedes-Benz Store* [online]. Available at: <https://www.mercedes-benz.de/passengercars/buy/new-

car/search-results.html/?emhmodel=EQV&emhvehicleAssortment=new-passenger-cars&emhsort=monthly-asc&gclid=Cj0KCQiAx6ugBhCcARIsAGNmMbh3QkPEuiB6jiboZbEIQdsj4nM_N9d56NjfrEws_dGMj3hQ8-eVkOYaArzzEALw_wcB&emhfuel_type=ELECTRIC#vehicles&kpid=go_cmp-8619295423_adg-87161355579_ad-406548034920_kwd-757893994971_dev-c_ext-> [accessed 3.10.23d).

Mercedes-Benz AG, 2023e. *Sprinter Kastenwagen | Mercedes-Benz Transporter* [online]. Mercedes-Benz AG. Available at: <https://www.mercedes-benz.de/vans/de/sprinter/panel-van?kpid=go_cmp-225583481_adg-44701993095_ad-396911510544_kwd-314018040645_dev-c_ext-&gclid=Cj0KCQiAx6ugBhCcARIsAGNmMbj5DfTjs0dPHo3Br1hNYoUeoeyXUZVmx-VGyqguQd47TARnGdFA_iIaAqJtEALw_wcB> [accessed 3.10.23e).

Millner, A., 2010. Modeling Lithium Ion battery degradation in electric vehicles. *Conference on Innovative Technologies for an Efficient and Reliable Electricity Supply:* 349–356. DOI: https://doi.org/10.1109/CITRES.2010.5619782

Nathan Dale, 2021. *What is WLTP and what does it mean? WLTP Explained* [online]. Evans Halshaw. Available at: <https://www.evanshalshaw.com/blog/what-is-wltp/> [accessed 4.3.23].

National Centers for Environmental Information (NCEI) [online], 2023. *National Centers for Environmental Information.* Available at: <https://www.ncei.noaa.gov/> [accessed 4.25.23].

Nick Zamanov, 2022. *Cost of Commercial EV Charging Station - News - Cyberswitching* [online]. Cyber Switching. Available at: <https://cyberswitching.com/commercial-ev-charging-station-cost/> [accessed 4.4.23].

Nissan Center Europe GmbH, 2023a. *E-Transporter – Der neue Nissan Townstar l Nissan* [online]. Available at:

<https://www.nissan.de/fahrzeuge/neuwagen/townstar.html> [accessed 3.10.23a).

Nissan Center Europe GmbH, 2023b. *Der NISSAN e-NV200 EVALIA – Elektro familienauto 7-Sitzer | Nissan* [online]. Available at: <https://www.nissan.de/fahrzeuge/neuwagen/e-nv200-evalia.html?&cid=psm_cmid=14561512030_grid=144756808028_adid=595889163320&gclid=Cj0KCQiAx6ugBhCcARIsAGNmMbhqDLIGPzgwI2DABpEns8yhN6J7jxXxcsRPU47UdDVt6ZlHulJbYscaArkaEALw_wcB&gclsrc=aw.ds> [accessed 3.10.23b).

Nissan Center Europe GmbH, 2023c. *Technische Daten – der NISSAN e-NV200 | NISSAN* [online]. Available at: <https://www.nissan.de/fahrzeuge/neuwagen/e-nv200/technische-Daten.html> [accessed 3.10.23c).

Nissan Center Europe GmbH, 2023d. *Technische Daten – neuer Nissan Townstar I Nissan* [online]. Available at: <https://www.nissan.de/fahrzeuge/neuwagen/townstar/abmessungen.html> [accessed 3.10.23d).

Placek, M., 2022a. *Leading freight transportation firms worldwide 2021 | Statista* [online]. Available at: <https://www.statista.com/statistics/503884/leading-freight-transportation-firms-worldwide/?locale=en> [accessed 2.28.23].

Placek, M., 2022b. UPS - ground fleet 2016 | Statista [online]. Statista. Available at: <https://www.statista.com/statistics/806077/ups-ground-fleet-business-segment/> [accessed 2.28.23].

Posti Group Oyj, 2023. *More electric vehicles in use – In addition to Helsinki, electric cars will now also be used in Turku, Tampere, Espoo, and Vantaa to deliver Posti's parcels home - Posti* [online]. Posti Group Oyj. Available at: <https://www.posti.com/en/media/media-news/2023/more-electric-vehicles-in-

use--in-addition-to-helsinki-electric-cars-will-now-also-be-used-in-turku-tampere-espoo-and-vantaa-to-deliver-postis-parcels-home/> [accessed 3.2.23].

Posti Group Oyj, 2016. *Posti strengthens its cooperation with DHL and Bring - News Releases - Customer support - Posti* [online]. Posti Group Oyj. Available at: <https://www.posti.fi/en/customer-support/news-releases/20160311_posti-strengthens-its-cooperation-with-dhl-and-bring> [accessed 4.21.23].

Posti Group Oyj, 2023a. *Consumers chose Posti as Finland's most sustainable parcel and logistics brand - Posti* [online]. Posti Group Oyj. Available at: <https://www.posti.com/en/sustainability/news/Consumers-chose-Posti-as-Finlands-most-sustainable-parcel-and-logistics-brand/> [accessed 3.2.23a).

Posti Group Oyj, 2023b. *Home parcel - For businesses - Posti* [online]. Posti Group Oyj. Available at: <https://www.posti.fi/en/for-businesses/parcels-and-logistics/all-services/home-parcel> [accessed 4.10.23b).

Posti Group Oyj, 2023c. *History - Posti* [online]. Posti Group Oyj. Available at: <https://www.posti.com/en/group-information/history/> [accessed 4.21.23c).

Posti Group Oyj, 2023d. *For businesses - Posti* [online]. Posti Group Oyj. Available at: <https://www.posti.fi/en/for-businesses> [accessed 4.21.23d).

Posti Group Oyj, 2023e. *Sustainability at Posti - Posti* [*online*]. Posti Group Oyj. Available at: <https://www.posti.com/en/sustainability/sustainability-at-posti/> [accessed 4.21.23e).

Posti Group Oyj, 2023f. *Case: Fully electric home deliveries in Helsinki - Posti* [online]. Posti Group Oyj. Available at: <https://www.posti.com/en/sustainability/practical-examples/case-fully-electric-home-deliveries-in-helsinki/> [accessed 4.21.23f).

Postnord Oy, 2023. *Home delivery* | *PostNord* [online]. Available at: <https://www.postnord.fi/en/receive/home-delivery> [accessed 4.10.23].

Powertrain definition and meaning | Collins English Dictionary [online], 2023. Available at: <https://www.collinsdictionary.com/dictionary/english/powertrain> [accessed 2.14.23].

Proctor, C., 2023. *Internal-combustion engine | Definition & Facts | Britannica* [online]. Britannica. Available at: <https://www.britannica.com/technology/internal-combustion-engine> [accessed 2.17.23].

Quak, H., Nesterova, N., 2014. *Towards zero emission urban logistics: Challenges and issues for implementation of electric freight vehicles in city logistics*. Emerald Group Publishing Ltd. DOI: https://doi.org/10.1108/S2044-994120140000006011 p. 268-282

Quak, H., Nesterova, N., van Rooijen, T., 2016a. Possibilities and Barriers for Using Electric-powered Vehicles in City Logistics Practice. *Transportation Research Procedia*, 12: 166. DOI: https://doi.org/10.1016/j.trpro.2016.02.055

Quak, H., Nesterova, N., van Rooijen, T., Dong, Y., 2016b. Zero Emission City Logistics: Current Practices in Freight Electromobility and Feasibility in the Near Future. *Transportation Research Procedia,* 14: 1507–1515. DOI: https://doi.org/10.1016/j.trpro.2016.05.115

Rastani, S., Yüksel, T., Çatay, B., 2019. Effects of ambient temperature on the route planning of electric freight vehicles. *Transportation Research Part D Transport and Environment,* 74: 125–135. DOI: https://doi.org/10.1016/j.trd.2019.07.025

Renault Deutschland AG, 2017. *Ab 20.820 Euro: KANGOO Z.E. mit 270 km Reichweite - Renault Welt* [online]. Renault Deutschland AG. Available at: <https://blog.renault.de/neues-von-renault-renault-kangoo-ze-mehr-reichweite/> [accessed 3.9.23].

Rizet, C., Cruz, C., Vromant, M., 2016. The Constraints of Vehicle Range and Congestion for the Use of Electric Vehicles for Urban Freight in France. *Transportation Research Procedia*, 12: 506. DOI: https://doi.org/10.1016/j.trpro.2016.02.005

Russo, F., Comi, A., 2002. *A general multistep model for urban freight movements* [online]. Available at: <https://aetransport.org/public/downloads/cR1sx/526-514ec4ed9ba34.pdf> [accessed 6.4.23].

Scorrano, M., Danielis, R., Giansoldati, M., 2021. Electric light commercial vehicles for a cleaner urban goods distribution. Are they cost competitive? *Research in Transportation Economics*, 85: 1-12. DOI: https://doi.org/10.1016/j.retrec.2020.101022

Shmailan, A.S. Bin, 2016. The relationship between job satisfaction, job performance and employee engagement: An explorative study. *Issues in Business Management and Economics*, 4: 2–4. DOI: https://doi.org/10.15739/IBME.16.001

Statista, 2022. *Greenhouse gas emissions worldwide | Statista* [online]. Available at: <https://www-statista-com.ezproxy.metropolia.fi/study/69601/greenhouse-gas-emissions-worldwide/> [accessed 6.4.23].

Statista Research Department, 2023a. *Nordics: average weekly working hours by country 2021 | Statista* [online]. Statista. Available at: <https://www-statista-com.ezproxy.metropolia.fi/statistics/1275643/nordics-average-weekly-working-hours/?locale=en> [accessed 4.10.23].

Statista Research Department, 2023b. *Norway: electricity production by source 2021 | Statista* [online]. Available at: <https://www.statista.com/statistics/1025497/distribution-of-electricity-production-in-norway-by-source/> [accessed 4.17.23].

Statista Research Department, 2022. *Italy: energy mix 2021 | Statista* [online]. Statista. Available at: <https://www.statista.com/statistics/873552/energy-mix-in-italy/> [accessed 4.17.23].

Statista Research Department, 2023. *Finland: monthly electricity prices 2023 | Statista* [online]. Statista. Available at: <https://www.statista.com/statistics/1271437/finland-monthly-wholesale-electricity-price/> [accessed 3.21.23].

Storch, H., Scharrenberg, B., 2023. *Sustainable Fuels for Logistics* [online]. Available at: <https://www.dhl.com/content/dam/dhl/global/dhl-global-forwarding/documents/pdf/glo-dgf-sustainable-fuels-for-logistics.pdf> [accessed 6.4.23].

Streetscooter GmbH, 2023. *Home | Streetscooter GmbH Elektro Nutzfahrzeuge | Streetscooter GmbH Elektro Nutzfahrzeuge* [online]. Available at: <https://www.streetscooter.com/de/> [accessed 3.10.23].

Tario, J., 2014. *New York City Green Loading Zones Study Final Report* [online]. Bureau of transport statistics. Available at: <https://rosap.ntl.bts.gov/view/dot/28092/dot_28092_DS1.pdf?> [accessed 6.20.23].

Teoh, T., 2022. Electric vehicle charging strategies for Urban freight transport: concept and typology. *Transport Reviews*, 42: 157–174. DOI: https://doi.org/10.1080/01441647.2021.1950233

Teoh, T., Kunze, O., Teo, C.-C., Wong, Y., 2018. Decarbonisation of Urban Freight Transport Using Electric Vehicles and Opportunity Charging. *Sustainability*, 10: 1-18. DOI: https://doi.org/10.3390/su10093258

Tiseo, I., 2023. *EU: carbon dioxide emission sources 2020 | Statista* [online]. Statista. Available at: <https://www.statista.com/statistics/999398/carbon-dioxide-emissions-sources-european-union-eu/> [accessed 5.23.23].

Tomlinson, V., 2020. *UPS invests in Arrival and orders 10,000 Generation 2 Electric Vehicles* [online]. Arrival Press Releases. Available at: <https://arrival.com/news/ups-invests-in-arrival-and-orders-10000-generation-2-electric-vehicles> [accessed 3.10.23].

United States Parcel Service, 2022. *Electric vehicles | About UPS* [online]. United States Parcel Service. Available at: <https://about.ups.com/us/en/social-impact/environment/sustainable-services/electric-vehicles---about-ups.html> [accessed 2.28.23].

Verlinde, S., Macharis, C., 2016. Innovation in Urban Freight Transport: The Triple Helix Model. *Transportation Research Procedia*, 14: 1251–1257. https://doi.org/10.1016/j.trpro.2016.05.196

Virta Global, 2022. *AC, DC Chargers: Their EV Charging Capacities | Virta* [online]. Virta Global. Available at: <https://www.virta.global/blog/ev-charging-and-basics-of-electricity> [accessed 4.3.23].

Wolf, S., Teitge, J., Mielke, J., Schütze, F., Jaeger, C., 2021. The European Green Deal — More Than Climate Neutrality. *Intereconomics*, 56: 99. DOI: https://doi.org/10.1007/S10272-021-0963-Z

Woollaston, V., 2015. *Sleeping habits of the world revealed through Sleep Cycle app | Daily Mail Online* [online]. Available at: <https://www.dailymail.co.uk/sciencetech/article-3042230/Sleeping-habits-world-revealed-wakes-grumpy-China-best-quality-shut-eye-South-Africa-wakes-earliest.html> [accessed 4.10.23].

Yang, Z., Tate, J., Morganti, E., Philips, I., Shepherd, S., 2023. How accelerating the electrification of the van sector in Great Britain can deliver faster CO2 and NOx reductions. *Sustainable Cities and Society*, 88: 104300. DOI: https://doi.org/10.1016/j.scs.2022.104300

Yuksel, T., Michalek, J.J., 2015. Effects of Regional Temperature on Electric Vehicle Efficiency, Range, and Emissions in the United States. *Environmental Science & Technology,* 49: 1-2. DOI: https://doi.org/10.1021/es505621s

Appendices

Generalized cover letter

Dear Mr./Ms. XY,

my name is Marco Sesterhenn and I'm an exchange student from Germany, currently studying at Metropolia UAS in Helsinki. I have received your contact information from Mr./Ms. XY.

Currently, I'm working on my Bachelors Thesis, in which I present the possibilities and limitations of the application of electric engines as an alternative powertrain solution in the urban freight logistics industry. In my research, I want to present a logistics provider, which is aiming at implementing new technologies, like electric powertrain solutions for urban freight logistics operations. XY would fit as a good example due to the broad vehicle fleet and the amount of business operations, conducted in urban freight transport.

Herewith, I want to ask, if it would be possible to have a short interview with you about the XY vehicle fleet and the implementation of electric vehicles in the fleet. I would be grateful for your time to have an interview, as it would help me to bring forward my research on the topic.

Thank you in advance for your time and your consideration

Yours sincerely

Marco Sesterhenn

Information about interviewees

In the thesis, the primary research was conducted through 3 interviews with 2 companies, operating in the urban freight transport industry in Finland.

One interview was conducted with the vice president in sourcing of Posti Oyj, Mr. Lehmuskallio. All direct and indirect quotations of the interview with Mr. Lehmuskallio are marked with (Lehmuskallio, 2023). The interview was conducted face to face in the headquarter of Posti Oyj in Helsinki on the 27.02.2023.

The other two interviews were conducted with Interviewee 1 and Interviewee 2, both being employees of a company, who requested anonymity. Both interviews were conducted via video conferences. The interview with Interviewee 1 took place on the 24.02.2023. All direct and indirect quotations of the interview with Interviewee 1 are marked with (Interviewee 1 of company x, 2023). The interview with Interviewee 2 took place on the 24.03.2023. All direct and indirect quotations of the interview with Interviewee 2 are marked with (Interviewee 2 of company x, 2023).

Generalized Interview document

Dear Mr./Ms. XY, in the following, I summarized the main topics and aspects, I want to discuss with you in the interview.

Interview topics:

- 1. Size of the vehicle fleet in terms of number of small and medium sized vans (<3.5t).

- 2. Reasons for the implementation of electric vehicles into the vehicle fleet

- 3. Which van model was chosen and why ? (which criteria where especially important, was the selection of models sufficient ?).

- 4. Impacts on the day-to-day operations of the company, due to the usage of electric vehicles (e.g. vehicle fleet management, vehicle routing, charging concepts).

- 5. Investment costs, compared to a situation, in which the company would have continued the use of combustion engines.

- 6. Operating costs of the electric vehicles, compared to combustion engine vehicles.

- 7. Employee efficiency and satisfaction with the electric vehicles.

- 8. Customer satisfaction with deliveries being made by electric vehicles.

- 9. Future plan of the company for the vehicle fleet.

- 10. Commitment to the EU net-zero greenhouse gas emission goals by 2050.

- 11. Personal opinion about electric engines in the urban freight logistics industry?

Statistics and Figures

Table 6: SWOT & TOWS Matrix of electric vehicles

Internal / External	**Strengths (S)** • **Low operating costs & maintenance S1** • **Environmental benefits S2** • **High efficiency S3**	**Weaknesses (W)** • **Low range W1** • **High initial cost W2** • **Long charging time W3** • **Need for high investments (real estate, vehicle routing etc.) W4** • **Need for/missing of charging infrastructure W5**
Opportunities (O) • **Governmental regulations, restrictions & subsidies O1** • **Sufficient range for 80% of European urban deliveries O2** • **Lifestyle & Mindset changes in society O3** • **Resource shortages (e.g. fuel) O4**	S/0 Strategy-Attack Strategy • S2+O1: Use the strength of having environmental benefits (such as low emissions etc.) in order to maximize the opportunity of governmental regulations imposed against vehicles with bad environmental performance • S2+O3: Use the strength of having environmental benefits (such as low emissions etc.) in order to maximize the opportunity of changes in lifestyle and the society to gain a good image • S3+O4: Use the strength of having a high energy efficiency to maximize the opportunity of resource shortages (-> be a more attractive alternative to ICE vehicles needing fuel)	W/O Strategy + S • W1/O2+S3:Minimize the weakness of having a low range by maximizing the opportunity of urban freight transportation having short distances and the strength of having a high energy efficiency • W2/O1+S1:Minimize the weakness of having high initial costs by using the opportunity of governmental support/subsidies and the strength of having low follow-up costs • W3/O2+S3: Minimize the weakness of having long charging times by using the opportunity of having a sufficient range for most urban deliveries and the strength of having a high energy efficiency • W4/O1+S1: Minimize the weakness of having a high need for investment by using the opportunity of having governmental subsidies and the strength of having low follow-up costs
Threats (T) • **Limited & unsecure energy supply T1** • **Positive business case not existing without gov. support T2** • **Customers are not willing to pay more for environmentally friendly transport T3**	S/T Strategy + O • S3/T1+O4: Minimize the treat of having a limited energy supply by using the strength of having a high energy efficiency to maximize the opportunity of future resource shortages • S1/T2+O1: Minimize the threat of having no positive business case without governmental support by using the strength of having low operating and maintenance cost and maximizing the opportunity of governmental subsidies • S1/T3+O1: Minimize the threat of customers not being willing to pay more for environmentally friendly transport by using the strength of having low follow up costs and maximizing the opportunity of governmental subsidies	W+O+S/T Strategy-Defense Strategy + T • W1+O2/T1: Minimize the weakness of having a low range by using the opportunity of having a sufficient range for most urban city deliveries to avoid the threat of having an impact through the limited & unsecure energy supply • W2+W4+O1/T2: Minimize the weaknesses of having high initial costs & investment needs by using the opportunity of having governmental support to avoid the threat of having no positive business case without governmental support • W5+O1/T1: Minimize the weakness of the missing charging infrastructure by using the opportunity of governmental subsidies to avoid the threat of having an impact because of the limited & unsecure energy supply

Sources related to Table 6:

Sources for Strenghts:

(Besbes et al., 2020: 44;51; Iwan et al., 2019: 113-118; Klumpp, 2014: 8; Melander et al., 2022: 6-9)

Sources for Weaknesses:

(Anosike et al., 2021: 6-8; Interviewee 1 of company x, 2023; Iwan et al., 2019: 115; Melander et al., 2022: 9-10; Quak and Nesterova, 2014: 268-273)

Sources for Opportunities:

(Anosike et al., 2021: 14 ; European Comission, 2011; Iwan et al., 2019: 114-118; Lebeau et al., 2016: 246-250; Melander et al., 2022: 6-9; Quak et al., 2016a: 166; Quak and Nesterova, 2014: 282; Russo and Comi, 2002)

Sources for Threats:

(Klumpp, 2014: 3-12; Melander et al., 2022: 9-10; Quak and Nesterova, 2014: 272-277)