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Utilizing a transport management system to reduce the carbon footprint of transportation in a global marine and energy technology organization

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TIIVISTELMÄ:

Kestävän kehityksen merkitys on jatkuvassa kasvussa ja kestävyydestä on tullut tavoiteltava ominaisuus yritysten keskuudessa. Tämä korostuu nykypäivänä erilaisilla kestävillä tavoitteilla, joihin yritykset sitoutuvat vastatakseen ilmastolakien vaatimuksiin ja kuluttajien ekologisempiin valintoihin, ja aiheesta on tehty myös useita tutkimuksia. Saavuttaakseen päämääränsä päästöjen vähentämiseksi, yritysten on kiinnitettävä huomiota toimintansa hiilijalanjälkeen. Kuljetussektori on yksi suurimmista hiilidioksidipäästöjen aiheuttajista maailmassa ja siksi siihen keskittymällä on mahdollista saavuttaa merkittäviäkin päästövähennyksiä toimitusketjuissa.

Tämä pro gradu -tutkielma on toteutettu tapaustutkimuksena yritykselle. Tutkielman tavoitteena on selvittää tehokkaimmat tavat hyödyntää tapausyrityksen käyttämää kuljetustenhallintajärjestelmää niin, että on mahdollista pienentää saapuvan materiaalin kuljetuksista syntyvää hiilijalanjälkeä. Lisäksi tavoitteena on tutkia, mistä kuljetusten hiilijalanjälki tapausyrityksessä muodostuu, miten päästöjä on mahdollista mitata kuljetustenhallintajärjestelmän avulla ja millaisia vaikutuksia sen hyödyntämisellä on aikaan, kustannuksiin ja luotettavuuteen, kun valitaan ympäristöystävällisempiä kuljetusmuotoja. Näiden tavoitteiden saavuttamiseksi on suoritettu tapausyrityksen sisäisiä haastatteluja sekä perehdytty käytössä olevan kuljetustenhallintajärjestelmän tarjoamiin ominaisuuksiin.

Tutkimus on kvalitatiivinen tapaustutkimus. Tutkimuksen teoreettinen osuus käsittelee rahtikuljetusten eri muotoja ja niihin liittyviä päästöjä sekä kuljetustenhallintajärjestelmien toimintaa ja roolia kuljetuksista syntyvien päästöjen mittaamisessa ja hallitsemisessa. Tutkielman empiirisessä osuudessa on tarkoitus kuvata tapausyrityksen nykyisiä kuljetusprosesseja ja kuljetusten hiilijalanjäljen muodostumista sekä tarkastella, miten kuljetustenhallintajärjestelmää tutkimushetkellä hyödynnetään tapausyrityksessä. Tutkielman tiedonkeruumenetelmiä ovat kirjallisuuskatsaus, haastattelut ja kuljetustenhallintajärjestelmään liittyvät esitelmät ja esitysmateriaalit.

Tuloksena saatiin näkemys siitä, mistä kuljetusten hiilijalanjälki tapausyrityksessä muodostuu ja tunnistettiin mahdollisuuksia kuljetustenhallintajärjestelmän tehokkaammalle hyödyntämiselle päästöjen mittaamisessa ja vähentämisessä. Tapausyrityksen suurimmiksi päästöjen aiheuttajiksi kuljetusmuodoista todettiin lentorahti ja maantiekuljetukset. Kuljetustenhallintajärjestelmää on hyödynnetty tapausyrityksessä kuljetusprosessin taustalla ja järjestelmässä on useita ominaisuuksia, joita ei vielä ole hyödynnetty ja jotka mahdollistavat päästöjen mittaamisen ja vähentämisen, kun niitä hyödynnetään tehokkaasti. Dataa keräämällä ja yhdistämällä sen kuljetustenhallintajärjestelmään on mahdollista saada vertailukelpoisia raportteja, joiden perusteella tapausyritys voi jatkossa tehdä strategisia päätöksiä kuljetuksiin ja kuljetusyrityksiin liittyen.

AVAINSANAT: Kuljetus, kestävä kuljetus, rahtikuljetus, kuljetustenhallintajärjestelmä, päästöt, hiilijalanjälki

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ABSTRACT:
The importance of sustainable development is constantly growing, and sustainability has become a desired characteristic among companies. Today, this is highlighted by various sustainability goals that companies commit to meet the requirements of climate laws and consumers' more ecological choices along with the volume of research conducted on the matter. Companies must consider the carbon footprint of their operations to achieve their aim of lowering emissions. Because the transportation industry is one of the largest producers of carbon dioxide emissions worldwide, focusing on it enables huge emission reductions across supply chains.

This master's thesis is conducted as a case study for a company. The objective of the thesis is to find out the most effective ways to utilize a transport management system used by the case company to reduce the carbon footprint caused by the transportation of the incoming material flow. The thesis aims to investigate what factors contribute to the carbon footprint of transportation in the case company, how emissions can be measured using a transport management system, and how its utilization affects time, cost, and reliability when choosing more environmentally friendly modes of transportation. To achieve these objectives, internal interviews were performed at the case company, and the features of the transport management system were familiarized.

The research is a qualitative case study. The theoretical part of the research focuses on the various modes of freight transportation and the related emissions, as well as the functions and role of transport management systems in measuring and controlling emissions from transportation. The objective of the empirical part of the research is to describe the current transportation processes of the case company and the generation of the carbon footprint of transportation and to examine how the transport management system is currently utilized in the case company. The research methods include a literature review, interviews, and presentations related to the transport management system.

The research provided insight into the elements of the carbon footprint of transportation in the case company and the potential for more effective utilization of the transport management system in measuring and reducing emissions. The main sources of emissions in the case company were discovered to be air freight and road freight transportation. The transport management system has been used to support the transportation process in the background, and the system offers several features that have not yet been fully used, that allow emissions to be measured and decreased when effectively utilized. Data collection and integration with the transport management system make it possible to obtain comparable reports that can be used to guide future strategic choices regarding transportation and transportation providers.

KEYWORDS: Transportation, sustainable transportation, freight transportation, transport management system, emissions, carbon footprint

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Abbreviations

3PL	Third-Party Logistics
AI	Artificial Intelligence
ATM	Adaptive Traffic Management
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CSF	Critical Success Factors
EDI	Electronic Data Interchange
ERP	Enterprise Resource Planning
ETA	Estimated Time of Arrival
EU	European Union
GDP	Gross Domestic Product
IT	Information Technology
ITS	Intelligent Transport System
KPI	Key Performance Indicator
NOx	Nitrogen Oxide
PTMS	Public Transport Management Subsystem
RFTM	Road Freight Transport Management
SO_2	Sulfur Dioxide
TMS	Transport Management System
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
UNGA	United Nations General Assembly
WMS	Warehouse Management System

1 Introduction

This chapter provides an overview of the thesis. It explains the background of the research, its methods, the objective of the research, and the research questions. Additionally, it introduces the case company, clarifies the limitations of the research, and finally presents the structure of the paper.

1.1 Background of the research

The issue of sustainability has been significant for quite some time and will continue to be so in the future in both the individual and corporate worlds. Sustainability research and its implementation in various fields are critical because fighting climate change impacts the future of the entire planet. The increasing efforts of companies and organizations to reduce their carbon footprint and move towards more sustainable and environmentally conscious strategies and operations demonstrate the significance of sustainable development in the industrial field. Reducing emissions and switching to cleaner fuels are just two examples of how large organizations can make a significant contribution to minimizing global warming and conserving non-renewable energy sources. According to Chen et al. (2022), 198 countries worldwide have made the commitment to pursue carbon neutrality, and a total of 4.5% of these have achieved the goal. Over half of those countries work to meet the targets by 2050–2070 (Chen et al., 2022).

The use of fossil fuels and the generation of greenhouse gases have both increased, which has resulted in an increase in environmental issues and an increase in the temperature of the atmosphere over time (Chen et al., 2022). The significance of sustainability in freight transportation is emphasized as industrial development and freight transport volume increase (Dadsena et al., 2019). According to Larson (2021), transportation is responsible for the majority of emissions connected to logistics. Since fossil fuels are used to power a variety of vehicles, including trains, trucks, planes, and ships, they are the primary source of transportation emissions (Larson, 2021). Therefore, increasingly more environmentally conscious decisions are being made when selecting a mode of transportation (Pajić et al., 2022). In addition to the environmental impact, the decision must examine the costs, transportation time, and infrastructure (Pajić et al., 2022). The process of selecting a mode of transportation needs to be developed and given more attention because it can impact the long-term sustainability of an entire company's business as well as the competitiveness of a company from a cost and time standpoint (Pajić et al., 2022).

1.2 Research methods and research objectives

The research is conducted as a case study, with a literature review as the theory of the research and a qualitative analysis of the case company as the empirical research part. The main objective of the research is to determine the most effective ways to use a transport management system to reduce carbon emissions generated by the transportation of the incoming material flow. Therefore, the research aims to form an understanding of the transportation process in the case company, how the carbon footprint in transportation is created, and how it can be affected by utilizing a transport management system. Consequently, it becomes also necessary to explore how a transport management system can be used to measure the carbon footprint. Finally, the research examines the costs associated with reducing carbon footprint and how utilizing a transport management system affects the time and reliability of transportation.

The research questions have been defined as follows to achieve the objectives of the research:

1. What does the carbon footprint of freight transportation consist of?
2. How does utilizing a transport management system affect and measure the carbon footprint of freight transportation?
3. What effects does utilizing a transport management system have on time, cost, and reliability when choosing more sustainable transportation methods?

1.3 Introduction of the case company

This research is conducted as a case study in cooperation with a multinational marine technology company headquartered in Finland. The case company is a listed company that produces a range of power sources and technology for the marine and energy sectors (Case Company, Website 2023). The case company aims to invest in sustainable technology and service innovations as a leading provider of life cycle solutions and technology, with the goal of considering environmental issues while simultaneously improving the financial success of customers (Case Company, Website 2023). The main incoming material flow for the case company includes the shipment of parts, components, and products connected to marine and energy markets. The most common modes of transportation are air, road, sea, and rail transportation, and goods are shipped worldwide but primarily from Europe and Asia.

The sustainability strategy of the case company relies on the economic, environmental, and social pillars of sustainable development, and it attempts to pursue financial profitability, environmentally friendly products and services, and responsible business (Case Company, Website 2023). One of the case company's sustainability objectives is to achieve carbon neutrality in its own operations by 2030 (Case Company, Website 2023), and the topic of this research is related to this goal.

1.4 Limitations

This research focuses on the case company's situation, goals, transportation processes, and methods to use the transport management system. The research and its results cannot be generalized to other contexts due to the nature of a case study, as this research is limited to a specific company and a specific transport management system. The results would be likely to differ for different companies since transportation processes are not identical and alternative transport management system options may provide different solutions for measuring emissions and decreasing the carbon footprint. Furthermore, the research concentrates on the emissions caused by the incoming material flow and excludes the emissions generated by the transportation of the outgoing material flow of the case company. The objective of the research is also not to compare other transport management systems on the market with one another, but rather to focus on the transport management system utilized in the case company and its key features and methods of usage.

1.5 Structure of the thesis

The thesis consists of five main chapters, which proceed in a systematic order. The structure and the main chapters are shown in Figure 1 below. The introduction provides the background of the study, defines the methods and objectives of the study as well as research questions, describes the case company and its sustainability-related goals, and explains the limitations of the research.

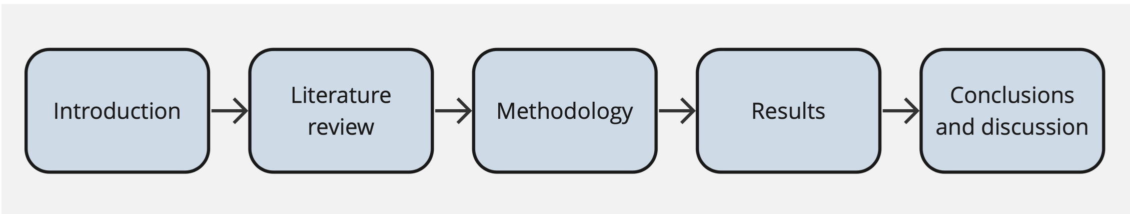

Figure 1. The structure of the thesis.

After the introduction, the second chapter of the paper is the theoretical part, which as a literature review addresses the freight transportation industry and how it relates to sustainability, as well as how emissions are produced in the freight transportation sector and how emissions can be reduced. The research on transport management systems, including how they are utilized, what features they have, and the various types of transport management systems, is further discussed in the second part of the literature review. Furthermore, it addresses how the systems are connected to emissions reduction and how they can be utilized to enhance transportation, as well as future development potential.

The third chapter provides an overview of the research methodology. The chapter discusses the research design, the methods employed to collect the data for the study, and the procedure for analyzing the data. Furthermore, the reliability and validity of the study are assessed in the chapter.

The results of the empirical part of the research are discussed in the fourth chapter. The results explain the current transportation processes employed by the case company as well as the present method of operating the transport management system. Furthermore, the chapter presents an overview of the transport management system's potentially utilized features. Finally, answers are provided to the research questions with a discussion of the most effective ways to utilize the transport management system to reduce the carbon footprint of transportation in the case company.

Lastly, the fifth chapter includes conclusions of the results of the empirical part. Additionally, it offers a discussion between the theory and the results of the study. Furthermore, it examines potential future research prospects.

2 Literature review

A literature review is conducted to examine scientific research and literature on transportation, carbon footprint, and transport management systems. The chapter is divided into two main subheadings, which are further divided into smaller subheadings, which discuss the topics and their definitions.

2.1 Sustainable transportation and emission reduction

The first section of this chapter covers the idea of freight transportation and presents some of the most commonly used modes of transportation. Furthermore, the chapter discusses in the second section how research on freight transport sustainability has changed and what is meant by sustainability concerning freight transportation in general. In addition, the chapter briefly explains the concept of carbon footprint. The following section of the chapter discusses the factors that influence the carbon footprint of freight transportation. After that, it is investigated how sustainability can be measured and what kind of emission reduction approaches are offered in the scientific literature. Finally, the drivers and barriers to implementing sustainability are discussed, followed by a look at the policies and regulations that have an impact on reducing carbon footprint in the transportation industry.

2.1.1 Definitions

2.1.1.1 Freight transportation

Freight transportation is an important part of supply chains (Ranaiefar & Regan, 2011, p. 333; Fulzele & Shankar, 2021), and Pathak et al. (2019) define it as a linking connection between various supply chain participants. Simultaneously, Santos and Piva (2021) consider transportation as the most significant part of logistics and describe it as the transfer of products between locations. Ben-Akiva et al. (2013, p. 3) further argue that transportation provides the connection between production and consumption, which do not typically occur in the same location. From an economic perspective, Fulzele and Shankar (2021) claim that transportation performs a vital part in the economy since it generates profits, while Ben-Akiva et al. (2013, p. 3) see effective transportation as a requirement for long-term economic growth. Further, Pramanik (2013) states that the aim of the modern transportation sector should optimize benefits in terms of economic growth, safety, and a clean environment while utilizing the least number of resources necessary to do so.

As the population grows, so does the demand to consume, which in turn increases the volume of freight transportation (Yazdani et al., 2020). As more people move into urban centers, freight transportation increases due to greater industrial activity, trade, and on-going economic growth (Yazdani et al., 2020; Fulzele & Shankar, 2022; Zhu & Xiong, 2023). Truck traffic grows as the number of online purchases increases constantly and remarkably rapidly, as almost all shipments from online stores are transported by truck at some point during their route (Ellram & Murfield, 2017). However, transporting the final product to the consumer is not the only stage that necessitates transportation. Khooban (2011) explains that transportation occurs at many stages of the supply chain, such as when raw materials are transported to the supplier, semi-finished products are transported from supplier to manufacturer, and final products are transported to retailers or directly to consumers. This is shown in Figure 2, where arrows illustrate the transportation of materials and products between different parties of the supply chain.

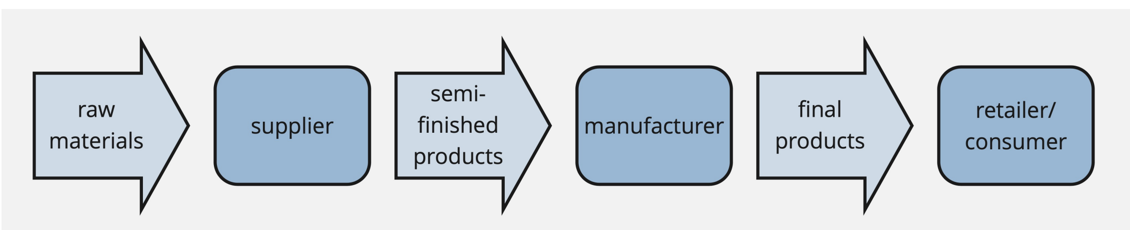

Figure 2. Transportation in the supply chain.

As modes of freight transportation, Fulzele and Shankar (2022) and Lv and Shang (2023) mention road, water, railway, and air. According to Santala (2011), vans, trucks, and heavy trucks are the most widely used modes of transportation on the roadways. Dadsena et al. (2019) agree and continue that trucks are the most dominant mode of road freight transportation since they are readily available and can cross geographic barriers. Long-distance passenger vehicles can also be used for transportation in certain instances (Santala, 2011). According to Balueva et al. (2022), maritime transportation is the most common mode of international transportation, because it increases the efficiency of the supply chain and is flexible for transporting various products, and ships can transport both big quantities and individual shipments of goods. Transporting goods by sea is also cost-effective (Balueva et al., 2022).

As modes of maritime transportation, Santala (2011) mentions line shipping and tramp shipping. In line shipping, ships have predetermined schedules, routes, and ports (Santala, 2011). Consignors need to book cargo space on the ship for their cargo and ships travel the route whether or not they are fully booked (Santala, 2011). In tramp shipping, precise timetables and routes are not observed, and costs and the quantity of freight can be negotiated through charter agreements (Santala, 2011). The ports used by maritime transport can either be public, in which case a price is charged for port traffic, or they can be private, in which case they are administered, for instance, by a specific company, and the owner company uses them for loading and offloading its own cargo (Santala, 2011).

Freight trains are typically used to move goods on the tracks and are not meant for passengers (Santala, 2011). Zhang et al. (2019) list the advantages of rail freight transportation as high capacity, long transportation distance, reliability, and safety. Zhang et al. (2019) separate rail freight transportation into scheduled and unscheduled freight trains. Scheduled trains operate faster and have the option of adding or removing cars at intermediate stations (Zhang et al., 2019). Without a schedule, trains operate based on demand (Zhang et al., 2019). However, occasionally cargo can also be carried alongside passenger railways (Santala, 2011). Train equipment is mostly powered by diesel or electricity (Santala, 2011).

Transportation of air freight is possible using either special air cargo planes or the holding area of passenger airplanes (Santala, 2011). Sales and Scholte (2023) claim that around half of all flights worldwide are for passengers and the other half are for cargo. Typically, a forwarder is used to arrange for the transportation of air freight (Sales & Scholte, 2023). The forwarder books a spot on the aircraft for the cargo and negotiates the price (Sales & Scholte, 2023). Santala (2011) mentions air freight, express freight, and courier services for air transportation. Because airplanes typically spend more time being loaded and unloaded on the ground than they spend in the air, loading efficiency is important (Sales & Scholte, 2023). Reasons for selecting air freight transport are often urgency, the potential of product spoiling, and costs (Sales & Scholte, 2023). Even though air freight is often more expensive than other modes of transportation, occasionally a company can make more money by flying goods to their destination (Sales & Scholte, 2023).

When the transport journey is long, such as when moving across countries, the transport route often consists of several transport parts (Santala, 2011). Transports that combine at least two distinct modes of transportation are known as multimodal transports, such as truck-ship or truck-train combinations (Santala, 2011; He et al., 2017). Especially transports by plane and ship necessitate the use of a truck also because the cargo cannot typically reach the destination instantly by plane or ship (Santala, 2011). Intermodal transports also use at least two modes of transportation, but the goods are only carried in one transport unit, such as a container (Santala, 2011). Poorly arranged or organized transportation modes make transportation less efficient (He et al., 2017). For instance, China frequently lacks the infrastructure necessary to support multimodal transportation when compared to developed nations (He et al., 2017). Ports, railways, and airports should be created to facilitate seamless and effective freight connections between different transportation modes (He et al., 2017).

Various characters in the transportation sector have been detailed in the literature. The three groups involved in transportation, according to Khooban (2011), are the shipper, the carrier, and the government. Shippers transport goods from one location to another in a specific manner and offer several transportation services (Khooban, 2011). Further, Khooban (2011) categorizes carriers as common carriers, private carriers, and contract carriers. Companies that provide transportation services to the general public for routes and prices published in advance, such as railways, bus lines, cruise ships, and commercial airlines, can be considered common carriers (Khooban, 2011). Private carriers are in a better position to provide a more dependable and customizable service (Khooban, 2011). Contract carriers, on the other hand, give a specific service at a specific price to a limited number of shippers based on the contracts (Khooban, 2011). Lastly of the groups, governments are in charge of public transportation networks such as ports, roads, and railways (Khooban, 2011). Government responsibilities additionally include taxation of the transportation industry and controlling the transportation of hazardous materials (Khooban, 2011).

Khooban (2011, p. 112) outlines three methods for deciding on a transport frequency, which are customized transport, consolidated transport, and frequent operation. In the customized transport method, the customer requests the truck and the driver to the departure location, where the truck is loaded, and then it proceeds to the customer's destination for unloading. The process is therefore simple for the customer, but from the perspective of the carrier, this is unpredictable in terms of timetable and requires proper planning in order to make optimal use of all resources available (Khooban, 2011, p. 112). The second method is consolidated transport, which allows for the use of economies of scale because it assumes that trucks are loaded with orders from various locations (Khooban, 2011, p. 112). Transport carriers profit from this mode of transportation because it has lower costs and higher capacity fill rates, but it also necessitates a detailed plan, particularly in terms of scheduling when deliveries are picked up from multiple locations (Khooban, 2011, p. 112). From the perspective of the customer, consolidating transport is not the most time-efficient (Khooban, 2011, p. 112). The third option is frequent operation, in which transportation schedules are predetermined (Khooban, 2011, p. 113). This method requires more investment in capacity from the carrier to prepare for large numbers of customers, but the customer gets a specific timetable in advance.

2.1.1.2 Sustainable freight transportation

Bai et al. (2017) claim that there has not been much research on transportation fleets from a sustainability point of view, although the topic of transportation is rather substantial in terms of environmental sustainability and the amount of emissions from transportation can be significant. They continue that the topic presents a challenge because it is influenced by numerous factors, some of which may be challenging to assess. Bai et al. (2017) continue claiming that also sustainable vehicle selection and evaluation have been studied relatively little. However, according to Ellram and Murfield (2017), the amount of research on environmentally sustainable freight transportation has grown significantly since 2010.

In their research, Ellram and Murfield (2017) examine the studies carried out between 1990 and 2015 on environmental sustainability in freight transportation and the findings in them. According to their paper, the last three years of their study timeframe saw a noticeable increase in the publication of papers on the subject. Ellram and Murfield (2017) observe from the evolution of the investigated studies that they initially treated transportation as a minor component within logistics sustainability, and towards the end of their investigation period, the studies have mainly concentrated on the perspective of environmentally sustainable freight transportation.

Ellram and Murfield (2017) continue to investigate the evolution of the studies from the geographical scope perspective. At the beginning of their research period from 1990 to 2015, studies on the subject are only conducted in North America, but after 2010, the majority of studies are from the EU area. Ellram and Murfield (2017) attribute this growth to the fact that environmental regulations in the EU are stricter than elsewhere, which has resulted in closer research on the subject there.

As the number of freight transports increases, so do the external costs associated with them (Ranaiefar & Regan, 2011, p. 333), making it more challenging to meet pollution reduction goals (Chen et al., 2023). These external costs include not only air and water pollution but also traffic accidents and noise pollution, as well as indirect impacts on plants and animal groups (Ranaiefar & Regan, 2011, p.333). The main environmental issues in the long term are global warming and increasing carbon dioxide emissions in the atmosphere (Ranaiefar & Regan, 2011, p. 333). Following this, Santala (2011) considers both noise pollution and emissions as environmental challenges in his paper. Additionally, Bai et al. (2017) agree that the transportation of goods, materials, and people has the greatest environmental impacts along supply chains for organizations. Lv and Shang (2023) continue, that the transportation industry contributes significantly to greenhouse gas pollution.

Bai et al. (2017) analyze transportation sustainability from Triple Bottom Line viewpoints. Triple Bottom Line (TBL) is a framework introduced by John Elkington in 1994 (Elkington, 2018). The framework examines the economic, environmental, and social impacts of the company's investments (Elkington, 2018). According to the theory, a company is considered to account for all real business costs when it implements a business based on TBL (Elkington, 2018). From the perspective of economic sustainability, it is feasible to assess how well a transport vehicle meets the fundamental requirements of transportation in terms of time, quality, and cost (Bai et al., 2017). When considering social sustainability, it is reasonable to evaluate the level of transportation safety a vehicle offers and whether this level of safety is compatible with concerns about human health (Bai et al., 2017) The dimension of social sustainability can also include employee training, health, and safety (Bai et al., 2017). From the environmental sustainability dimension, it is possible to evaluate the compliance of a transport vehicle with local, national, and international environmental laws, as well as its use of non-renewable resources, pollution, and waste generation (Bai et al., 2017).

According to Ellram and Murfield (2017), research published before the turn of the century concentrates on reducing consumption as well as the use and disposal of materials. Today, the emphasis is more on creating methods and technologies as well as organizing cooperation with stakeholders in the supply chain (Ellram & Murfield, 2017). He et al. (2018) highlight the fact that when several existing pieces of literature are combined, it is clear that they focus on evaluating sustainability from the standpoint of logistical operations and supply chain.

2.1.1.3 Carbon footprint

Fossil fuel combustion produces greenhouse gas emissions, which are frequently referred to as carbon footprint (Franchetti & Apul, 2012). Although other sources contribute to greenhouse gas emissions, human activity creates the majority of carbon dioxide, which is where the term carbon originates (Franchetti & Apul, 2012). Therefore, the carbon footprint can be used to represent the overall quantity of carbon dioxide emissions produced by an operation, whether directly or indirectly, or produced throughout each stage of a product's life cycle (Wiedmann & Minx, 2007). When minimizing the carbon footprint, the primary focus should be on reducing emissions and energy usage, developing the processes and technologies of the company, and reallocating resources (Franchetti & Apul, 2012).

2.1.2 Factors affecting the carbon footprint in freight transportation

Today, the majority of air pollutants in urban areas are caused by industry and motor vehicles (Barros et al., 2018). A significant amount of these emissions come from stationary sources as well as industry and other similar sources (Barros et al., 2018). Pollutant emissions into the atmosphere are thought to originate from the transportation sector (Barros et al., 2018) and pollution grows along with an increase in freight transportation (Fulzele & Shankar, 2021). According to Barros et al. (2018) carbon monoxide (CO) and carbon dioxide (CO_2) are the two most damaging transportation-related gas emissions that are categorized as greenhouse gases and are responsible for global warming. In addition to CO_2, Heinold (2020) defines freight transportation emissions as sulfur dioxide (SO_2) and nitrogen oxides (NO_x), both of which are generated when gasoline and energy are combusted to power vehicles.

Understanding the factors that affect carbon dioxide emissions is essential for low-carbon development (Chen et al., 2023). Borén et al. (2017) further highlight in their study that the transportation industry contributes significantly to greenhouse gas emissions because it is currently heavily reliant on fossil fuels. For instance, in China oil accounts for almost 60% of the use of fossil fuels in transportation, which results in significant carbon dioxide emissions (Chen et al., 2023). The level of carbon dioxide in the atmosphere increases as a result of transportation emissions, which has an impact on climate change (Borén et al., 2017). According to Zhu and Xiong (2023), the transportation sector accounts for at least 25% of total greenhouse gas emissions in developed countries. Road transportation has been identified as a major contributor to greenhouse gas emissions in various studies (Wassan et al., 2020; Lv & Shang, 2023; Zhu & Xiong, 2023). According to the paper written by Pajić et al. (2022), trucks made up 23% of European road transportation emissions in 2019, despite accounting for only 2% of all vehicles in Europe at the time. In their paper, Fulzele and Shankar (2021) state that road freight transportation accounts for 40% of greenhouse gas emissions in metropolitan areas.

According to Ranaiefar and Regan (2011, p. 334), truck freight transportation is relatively more costly and consumes more fuel than maritime and rail freight transportation, resulting in higher emissions. Despite this, they continue that truck freight transportation is the most common mode of inland transportation. Lv and Shang (2023) note that ports consume a lot of fossil fuels, resulting in a considerable amount of carbon dioxide emissions, and that developing strategies to minimize these emissions has been perceived to be challenging. Nonetheless, among all modes of transportation, air transport generates the most greenhouse gases worldwide and is responsible for more than one-third of all transport-related CO_2 emissions (Hu et al., 2019).

In their study, Hu et al. (2019) evaluate the contribution of transportation emissions to the carbon footprint of Swedish final consumption in 2011. They consider emissions from all modes of transportation in Sweden, except for emissions from households and the government's private transportation. As a result, 14% of the Swedish carbon footprint is transportation emissions by industry (Hu et al., 2019). According to Hu et al. (2019), a single major category is maritime and coastal transportation, and maritime transportation emissions are caused mainly by the transport of manufactured goods, as industrial product freight is primarily handled by sea. Hu et al. (2019) continue, that air transport is another significant category of transportation emissions in Sweden. However, the main sources of air transportation emissions are vacation packages and passenger flights (Hu et al., 2019).

Lo-Iacono-Ferreira et al. (2020) analyze the carbon footprint resulting from the storage, packaging, transport, and waste treatment of fruit and vegetables. In their study, fruits and vegetables are transported from Spain to Germany and France. The findings of the study reveal that transportation generates the biggest carbon footprint, and the size of the created carbon footprint in the research is affected by the length of the journey and the waste to be disposed of, such as shipping boxes (Lo-Iacono-Ferreira et al., 2020). Waste treatment processes vary between countries in the research, implying that the destination market has another effect on the carbon footprint in addition to the location (Lo-Iacono-Ferreira et al., 2020). The result of the study is supported by Marchi and Zanoni (2023), who write that transportation-related emissions are influenced by the length of the travel, the vehicle's speed, the size of the freight, and the number of journeys taken. This conclusion is also supported by Zhu and Xiong (2023), whose research based in China shows that the number of freight vehicles, as well as the transport time, have an increasing impact on emissions from the road freight transportation of goods. In their paper, Bell and Horvath (2020) investigate how the shipment of fresh produce affects the environment. They employ oranges in their study and observe the transportation of oranges both locally and abroad. Because oranges transported further are more likely to be delivered by effective and thus significantly less emitting ways, such as container ships, Bell and Horvath (2020) discover that it can be less emitting to transport oranges farther than to utilize local products. Oranges produced locally are frequently transported by truck, resulting in higher emissions and less efficient transportation (Bell & Horvath, 2020).

According to Taniguchi et al. (2014), due to their huge capacity, large freight transport vehicles can carry a greater quantity than smaller transport vehicles, which reduces the number of vehicles in traffic and therefore reduces traffic jams. Zhu and Xiong (2023) agree that the number of freight vehicles affects the variation in carbon dioxide emissions. However, due to the demand for punctuality, just-in-time deliveries may frequently utilize smaller freight transport vehicles (Taniguchi et al., 2014). According to Taniguchi et al. (2014), large freight transport vehicles consume more fossil fuels, are noisier, and produce more air pollution per unit than passenger cars. Older freight transport trucks in particular may pollute more (Taniguchi et al., 2014). However, when the high capacity of the vehicles is taken into consideration, the overall energy consumption and environmental effect of transportation using large vehicles are reduced (Taniguchi et al., 2014).

The relationship between the economy and emissions is frequently investigated in research on emissions. In their paper, Liimatainen et el. (2014) experiment with and compare theoretically various economic developments and discover that the quantity of carbon dioxide emissions is remarkably similar across all of them. However, Liimatainen et al. (2014) discover a relationship between GDP and carbon dioxide emissions. Furthermore, Zhu and Xiong (2023) utilize carbon dioxide emissions from transportation in

China as data in their research and conclude that population growth is a major contributor to the increase in emissions. Chen et al. (2023) continue by stating that in China investments are particularly increasing carbon dioxide pollution in the transportation sector.

Many studies discover a connection between fuel costs and carbon emissions. According to Wassan et al. (2020), the price of fuel can have an indirect impact on the emissions produced by transportation because low fuel prices may cause consumers to use private vehicles more frequently. When fuel prices are higher, people might choose to use other modes of transportation, like public transportation (Wassan et al., 2020). Zhu and Xiong (2023) continue that emission reductions should begin with increasing the price of fuel. Additionally, they assert that changes in carbon dioxide emissions are influenced by the cost of fuel. Conversely, Buslaev et al. (2021) investigate lowering the carbon footprint of field transporting and producing hydrocarbons in the Arctic area. In terms of lowering the carbon footprint of transportation, Buslaev et al. (2021), contend that reducing the cost of the energy needed for heating and pumping the fluid and increasing the number of transported products are the best solutions. Therefore, different transport sectors may be affected differently by a change in the price of fuel and energy.

Several studies indicate that the transportation industry is a major source of emissions and that emissions increase in correlation with a growing number of transportation activities. The most emissions are produced by air transportation and road freight transportation. Many studies have been conducted on the factors that influence emissions, and they frequently examine the duration of the journey, speed of the vehicle, capacity of the mode of transportation, and the number of journeys taken as contributing factors. Furthermore, several studies discover a connection between decreasing emissions and increasing fuel prices. In addition to carbon dioxide emissions, studies often consider additional negative transportation externalities such as noise pollution and traffic congestion.

2.1.3 Sustainability measurement and emission reduction methods

As the volume of freight transportation increases, the goal is to control harmful environmental costs (Yazdani et al., 2020). According to Naderipour et al. (2021), the overall amount of greenhouse gases constitutes the carbon footprint. The mass of carbon equivalency can be used to express greenhouse gas emissions (Franchetti & Apul, 2012). However, Zhu and Xiong (2023) claim that because the causes of carbon dioxide emissions are so closely linked with one another, it can be challenging to identify and separate them at times. As a result, it can be difficult to create strategies to decrease emissions when the causes are uncertain (Zhu & Xiong, 2023).

Achieving sustainability necessitates not just defining objectives, but also establishing significant parameters and monitoring and assessing progress and performance within an organization (Fulzele & Shankar, 2021). Utilizing all three TBL perspectives provides advantages while monitoring and determining areas where performance has to be improved (Fulzele & Shankar, 2021). In their research, Fulzele and Shankar (2021) gather Key Performance Indicators (KPIs), which they organize into three categories according to the TBL perspectives. From a financial perspective, KPIs measure variables like geographical reach, punctuality of deliveries, and damages that happen during delivery (Fulzele & Shankar, 2021). The social perspective measurement includes the number of accidents (Fulzele & Shankar, 2021). From an environmental point of view, the amount of emission produced can be estimated in proportion to factors like route or quantity of transports, or the metrics can be route optimization or the volume of usage of different modes of transportation (Fulzele & Shankar, 2021). However, it is important to remain in consideration that different KPIs often have varying weights (Fulzele & Shankar, 2021).

According to Wong et al. (2018), the literature related to emission reduction generally focuses on the usage of truck loads and the routing of trucks. In their study, which specifically focuses on three third-party logistics (3PL) companies in Hong Kong, Wong et al. (2018) discuss how 3PL companies might enhance their operations while lowering carbon dioxide emissions in the supply chain in daily operations. In order to assess carbon emissions from logistics activities, Wong et al. (2018) create an organization-based metric. By relating truck capacity, truck size, loading volume, fuel consumption, traveling distance, and the number of destinations, Wong et al. (2018) analyze how well trucks operate on their routes and what the utilization rate is. To achieve carbon-reducing activities, reduce the number of trucks and enhance their utilization, and reduce time and distance costs, they design a multi-criteria carbon-driven model (Wong et al., 2018). The final simulation system's goal is to decrease the amount of time needed to create a loading plan that considers the size of the cargo, the capacity of the truck, and the destinations (Wong et al., 2018). Zhu and Xiong (2023) complement these findings, arguing that emission reductions should begin by lowering the number of transport vehicles in use, as well as the market share of road freight transportation. Along with these, it should be examined whether it is feasible to reduce transportation lengths while increasing transportation intensity (Zhu & Xiong, 2023).

The same theme is continued by Evangelista et al. (2017), who discover practical steps to adopt green initiatives. These efforts include improving vehicle loading, reducing empty running, choosing low-energy modes of transportation, and providing employees with training that includes knowledge of the environment and carbon footprint. Additionally, using transport planning systems and loading planning are seen to be essential parts (Evangelista et al., 2017). Furthermore, in their research on KPIs used to measure the performance of sustainable freight transportation, Fulzele and Shankar (2021) highlight the metrics they find to be the most important in terms of reducing emissions in the transportation industry. Route optimization stands out among these measures since it affects several other factors. Route optimization shortens the distance traveled, reduces driving time, and minimizes vehicle idle time (Fulzele & Shankar, 2021). The optimal route eliminates unnecessary turns along the way, and all these factors mentioned reduce the amount of fuel consumed (Fulzele & Shankar, 2021). Other significant KPIs Fulzele and Shankar (2021) highlight include the number of empty or half-empty vehicles, which increases the number of unnecessary routes, and the formulation of environmental policies in companies.

Heinold (2020) remains researching a relevant topic. He analyzes the emissions of rail transportation using five distinct emission estimation techniques. Heinold (2020) uses a variety of factors in his study, including the distance traveled, the number of carriages on the train, the average speed, the number of stops, the volume of the freight in each carriage, and the altitude differences on the route. Heinold (2020) discovers that the emission level decreased in certain models when the weight and number of carriages were increased along with the distance traveled. When there is more speed or stops on the way, or if there are a lot of altitude differences along the way, emissions from rail transportation increase (Heinold, 2020). However, the findings are also affected by the technical characteristics of the trains (Heinold, 2020).

Considering that each mode of transportation has a distinct carbon footprint, choosing one over another may be able to reduce the amount of carbon dioxide emissions produced. In their study on the selection of a mode of transportation, Pajić et al. (2022) used nine criteria for transportation in Western EU countries. According to them, costs and time should be considered in the decision, including the time spent on transportation and customs clearance, as well as the lead times. In addition, the energy consumption of transportation and the resulting greenhouse emissions measured in CO_2 should be considered (Pajić et al., 2022). The final three significant criteria stated in the research are flexibility, which is necessary regarding adapting transportation, traffic congestion that contributes to time, and the capacity provided by the mode of transportation (Pajić et al., 2022). Furthermore, Pajić et al. (2022) weigh all nine criteria in their study, and the two most significant criteria are cost and transportation time. The two least important criteria are capacity and traffic congestion (Pajić et al., 2022).

Pizzol (2019) studies the carbon footprint of intermodal ferry and truck freight transportation operating on Scandinavian routes. As previously stated, intermodal transport refers to two or more different transport methods with the same transport unit, such as transporting a container by both a ferry and a truck (Pizzol, 2019). In his study, Pizzol (2019) compares intermodal truck-ferry routes and road-only routes in Scandinavia with each other. Based on previous studies it is assumed in his research that intermodal transport can generate fewer emissions when higher-emission vehicles are replaced by lower-emission vehicles. As a result, Pizzol (2019) finds that a route that includes both a ferry and a truck can have lower greenhouse gas emissions than a road-only route. The fuel used, the type of ferry, and the route taken all have an impact on the emissions produced by ferries (Pizzol, 2019). Using ferry routes can also reduce emissions when it significantly shortens the alternative land route (Pizzol, 2019). Similarly, Craig et al. (2013) claim that intermodal transport must be long enough for the reductions in carbon dioxide emissions it generates to balance its slower speed compared to truck-only transportation of the same freight.

Heinold and Meisel (2018) research intermodal large freight transportation as well, but instead of sea-land connections, they analyze railways and roads. According to the findings of their research, 90% of the freight transports generated less carbon emissions on routes using intermodal transportation than on routes using only roads. But depending on the country, the outcome might differ, for instance, because of the varying altitude differences of the route (Heinold & Meisel, 2018). Additionally, they discover in their study that transporting heavy goods produces fewer greenhouse gases than transporting voluminous goods. Finally, Heinold and Meisel (2018) caution that using only one average emission level in a broad area can lead to errors in emission evaluation.

When choosing the mode of transportation, attention should be paid to whether the delivered goods necessarily always require the fastest possible mode. According to Froese (2013), companies regularly choose road freight transport since it is faster than rail or water transport. However, although delivering freight by rail and water is slower, it is less harmful to the environment than transporting cargo by road. Froese (2013) utilizes 5,000 freight transport orders and their time constraints provided by the customers as input in his research to examine if all transports are so urgent that they require road freight transportation. He so notices that slightly more than half of the road freight transports investigated in the study were not time-critical, which indicates that it would have also been possible to transport them more slowly and sustainably.

Emissions and their reduction in the private transportation sector have also been studied. In their study, Barros et al. (2018) estimate the carbon footprint produced by the modes of transportation by students and professors in a university in Brasilia, as they travel between home and the university. Barros et al. (2018) discover that in the research private driving is the largest source of CO_2 emissions. An alternative to reduce emissions could be commuting, in which a group of people who live close to each other drive in the same car (Barros et al., 2018). Continuing from here, Te and Lianghua (2019) study what effects carsharing has on the environment in China. They notice that as the market changes, there is a rise in energy savings and greenhouse gas emission reductions. According to the findings, there will be higher environmental advantages if the carsharing market is long-lasting (Te & Lianghua, 2019). Additionally, they note that research on the impacts of carsharing in Europe has shown that it has enhanced local environmental quality and decreased carbon emissions (Te & Lianghua, 2019).

Companies can impact transportation emissions through their technology decisions (Ellram & Murfield, 2017) and in order to decrease emissions, new low-carbon technologies should be developed (Chen et al., 2022). Bai et al. (2017) argue that the discovery, choice, and adoption of more environmentally friendly vehicles should be developed as a part of the establishment and improvement of more sustainable supply chains. According to Masmoudi et al. (2020), modern diesel vehicles are already designed to operate on both regular and biodiesel without the need for any special modifications. Wassan et al. (2020) continue that utilizing vehicles powered by alternative fuels could decrease the emissions generated in the transportation sector. Electric and electric hybrid cars are examples of such vehicles (Wassan et al., 2020). Chen et al. (2022) suggest electricity, biofuels, hydrogen, and electric fuels as alternatives to fossil fuels, with electricity being the most beneficial for reducing emissions. Borén et al. (2017) support increasing awareness of the potential of electric vehicles in business and the transition to electric vehicle systems at both the individual and organizational levels. It would be important to pay particular attention to those stakeholders whose transition from fossil fuels to electric vehicles would have a significant impact (Borén et al., 2017).

In his study, Ghosh (2020) investigates different kinds of electric vehicles and their charging capabilities, such as solar panels, as well as the challenges of implementing electric vehicles. Because electric vehicles release no greenhouse gases, Ghosh (2020) claims that replacing traditional diesel and petrol-powered vehicles with electric vehicles could reduce emissions in the transport sector. However, Wassan et al. (2020) note that because there are no exhaust gas emissions, it is frequently believed that electronic vehicles emit zero pollution. In theory, nevertheless, the electricity needed by vehicles also causes emissions (Wassan et al., 2020). It should also be emphasized that the usage of electric vehicles demands the development of battery charging infrastructure (Fulzele & Shankar, 2022). Despite this, Moro and Lonza (2018) estimate that adopting electric vehicles instead of gasoline-powered vehicles can decrease greenhouse gas emissions by up to 60% and substitute diesel vehicles by up to 50% in EU member states.

Figure 3 illustrates how various factors may be employed to improve the sustainability of freight transportation (Fulzele & Shankar, 2022). Sustainable freight transportation is shown in the center of the figure, from which sustainable performance is gradually enhanced (Fulzele & Shankar, 2022). Strategic planning is the start phase, which includes a commitment from senior management to developing sustainability along with planning. The following phase is transportation mode selection, which optimizes the utilization of various modes of transportation while also including intermodal and multimodal modes of transportation. The third is education and training, which requires competent employees and continuous learning. Next are environmental policies, which, for instance, are regulated by governments (Fulzele & Shankar, 2022). The final phase is technologies, which refers to the development and implementation of greener technology in the organization (Fulzele & Shankar, 2022).

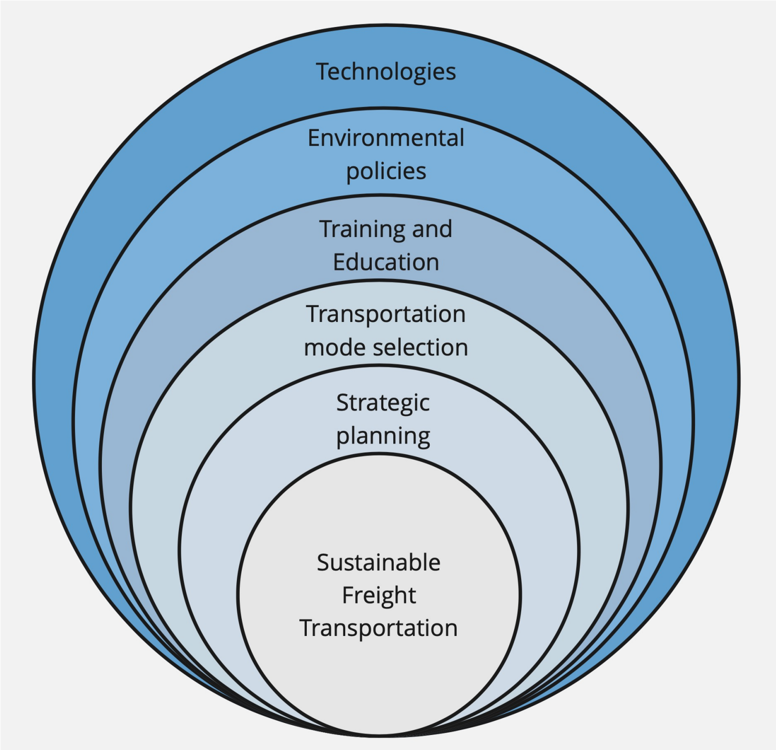

Figure 3. Improving the sustainable performance of freight transportation (adapted from Fulzele & Shankar, 2022).

In conclusion, there are numerous methods for measuring sustainability in the transportation sector. According to various studies discussed in this chapter, sustainability is evaluated based on emissions, accidents, damages, reliability, or the number of transports or modes of transportation used. To define sustainable development objectives, evaluation and measurement of sustainability are considered essential. The state of several factors must be changed simultaneously to decrease emissions, but even then, the change must be significant for just one factor (Zhu & Xiong, 2023). The most important methods to reduce emissions are considered to be the optimization of transport routes and cargo volumes, as well as the use of modes of transportation with the lowest potential emissions in relation to the volume and urgency of the delivered goods. More environmental benefits can be obtained by combining modes of transportation on the route.

2.1.4 Drivers and barriers to implementing sustainability

Implementing and attempting to achieve sustainability in organizations and industries are influenced by several factors, which can be described as either drivers or barriers. This chapter discusses a few factors that are discovered in the literature.

As drivers of sustainability, Evangelista et al. (2017) identify the efforts of competitors and consumers, as well as government and management support. According to Ellram and Murfield (2017), positive outcomes for environmental sustainability in freight transportation include reduced greenhouse gas emissions and potential savings in costs. Evangelista et al. (2017) also find internal cost reduction and potential company image improvement as additional drivers. Higher supply chain efficiency is also identified as a key factor (Evangelista et al., 2017). Ritvanen (2011) agrees that sustainability enhances the competitiveness of the company, and because stakeholders value it, sustainability builds appreciation. Therefore, it is beneficial to integrate sustainability as part of the strategy of the company (Ritvanen, 2011).

Evangelista et al. (2017) recognize in their research, that when adopting green logistics initiatives, customers have the most vital role and can be viewed as either drivers or barriers. Customers that are very aware of sustainability, can initiate efforts to increase the environmental sustainability of the supply chain and when this consciousness is minimal, they do not demand the development of sustainable logistics actions and are viewed as a barrier. Centobelli et al. (2020) recommend additional studies into how to improve communication between transporters and customers in order to make supply chains more environmentally sustainable. Customers may draw attention to green initiatives and circular thinking, and transporters may be able to have an impact on the sustainability of the supply chain by picking up on these issues (Centobelli et al., 2020). From the standpoint of freight transport companies, it would be crucial to research concepts that link the circular economy area and the management of sustainable growth of the environment (Centobelli et al., 2020). Furthermore, implementing sustainability requires more research because it is not always possible to show a direct link between environmental sustainability in freight transportation and its benefits (Ellram & Murfield, 2017).

According to He et al. (2017), the lack of competent professionals and management, as well as logistics companies' ignorance of low-carbon logistics or their view of its insignificance, are obstacles to the development of low-carbon logistics in China. Inadequate regulations and poor infrastructure also create challenges, resulting in inefficiency, additional costs, and emissions (He et al., 2017). Evangelista et al. (2017) agree that confusion around the implementation of more sustainable actions and lack of human resources are seen as barriers (Evangelista et al., 2017). In their study, Evangelista et al. (2017) examine how 3PL service providers implement environmental strategies. According to the study, adopting a sustainable strategy is not always a top priority for 3PLs and the importance of the strategy is not always clear. Evangelista et al. (2017) continue that although sustainability is acknowledged, there is no precise plan for putting it into action. In another research, Evangelista et al. (2018) bring together literature regarding the results of publications of 3PLs on environmental sustainability. They point out that this area has a huge research gap, and that is why the CO_2 emissions from 3PLs should be analyzed at the supply chain level, as well as continue future research to motivate smaller 3PLs to embrace environmentally friendly policies and study how that would affect to the performance of 3PLs and how that should be measured.

Various studies identify costs and financial concerns as significant barriers. The major barriers found in the research by Evangelista et al. (2017) are the high amount of investment to sustainability, limited financial resources, and the lack of assurance regarding when the investment will begin returning money to the company. He et al. (2017) continue and concur that some of the representative logistics companies in their study are concerned that the development would increase operating costs and, if successful, that the investments would require so much time to begin to generate revenue that they would first reduce the competitiveness of the company. Ellram and Murfield (2017) claim that there is a common disconnect between public views of environmental sustainability in freight transportation, which hold that it is both costly and that using it can result in cost savings. To determine where the line between costs and savings is and what circumstances allow it, more research is required, especially because costs are usually seen as a barrier (Ellram & Murfield, 2017).

In conclusion, it can be stated that implementing sustainable development in the company can enhance the efficiency of the supply chain, improve the company's competitiveness and image, and reduce greenhouse gas emissions. Customers can either encourage the company to develop sustainability or discourage it from doing so due to their lack of interest in it. Competent employees, as well as clear guidelines and regulations from the government, are all necessary for companies to become sustainable. Costs, which have been discovered to be unclear and uncertain, can be both a motivating factor and an obstacle. Additionally, some organizations are unable to recognize the advantages of sustainability. There are possibilities for additional investigation in the future.

2.1.5 Regulations and policies aimed at reducing carbon footprint in transportation

The effective implementation of emission reduction strategies must be ensured by the government (Franchetti & Apul, 2012; Chen et al., 2023), and therefore various emission regulations and policies have been created. The support of the government in managing and preventing environmental issues benefits both locally and globally (Franchetti & Apul, 2012). Chen et al. (2022) continue, that it is crucial to adopt policies and strategies that aim to lower carbon dioxide pollution to reach carbon neutrality. The need for policies has emerged, for example, as a result of greater environmental consciousness among stakeholders (Marchi & Zanoni, 2023).

Emissions-related regulations and efforts of countries and companies are frequently connected to broader climate-related agreements and The Paris Agreement is one of them. The primary objective of the Paris Agreement is to limit global warming, for which it has been stated that the average rise in global temperature should not exceed 2 °C compared to pre-industrial times, but preferably it should be limited to less than 1.5 °C (UN, 2023). The agreement has been signed by 196 nations all over the world and it is legally binding (UNFCCC, 2020). The Paris Agreement was approved at the climate conference in 2015 and entered into force in November 2016 (UNFCCC, 2020). Agenda 2030, which was introduced in 2015 (UNGA, 2015), is another well-known UN program for sustainable development (Fulzele & Shankar, 2022). It consists of 17 goals that must be achieved by 2030 (UNGA, 2015). Cleaner energy, climate acts, and a more sustainable industry are all among the objectives (UNGA, 2015; Fulzele & Shankar, 2022).

In order to decrease carbon dioxide emissions, regulations typically result in changes to the entire supply chain (Halat et al., 2023). According to Zhu and Xiong (2023), political regulations should prioritize long-term pollution reductions over short-term gains in the near future. Chen et al. (2022), emphasize the argument that policies aimed at reducing pollution need to be implemented on both the energy demand and supply aspects. Supply-side policies imply that the fuel would be substituted with low-carbon fuel (Chen et al., 2022). Additionally, Zhu and Xiong (2023) discover that by adjusting transportation and energy intensity as well as fuel price, it is achievable to control emissions. Nonetheless, the government has to consider the social and economic perspective of sustainable development and aim for social well-being with the support of policies, even though the primary objective of environmental-related policies is to decrease and limit the amount of carbon dioxide emissions (Halat et al., 2023).

In their study, Rout et al. (2021) describe approaches based on regulations to reduce carbon dioxide emissions and provide the need to assign carbon dioxide a price. This can be accomplished, for example, by taxing carbon dioxide, so that a business that produces emissions from each specified unit is required to pay a certain amount of tax (Rout et al., 2021; Halat et al., 2023). An additional choice is for the government to establish a cap on carbon dioxide emissions, and if that cap is exceeded, a tax for that part of the emissions must be paid (Rout et al., 2021; Halat et al., 2023). In the last strategy Rout et al. (2021) present, called cap-and-trade, companies are provided with a set amount of emission permits, based on which they have a pollution cap. With permits, companies can conduct business with government agencies or one another (Rout et al., 2021). Due to the need to purchase additional permits when pollutants exceed the limits allowed by the permits, it forces companies into a position in which they have to pay additional money (Halat et al., 2023). On the other hand, if the emissions are lower than the maximum allowed by the permits, companies can sell the excess permits to generate revenue (Halat et al., 2023). According to Rout et al. (2021), cap-and-trade is the most cost-effective method to decrease carbon emissions. Halat et al. (2023), on the other hand, argue that a carbon tax would be more suitable for lowering carbon dioxide emissions and that a cap-and-trade system might be preferable when aiming for a more sustainable supply chain.

Chen et al. (2022) and Marchi and Zanoni (2023) both contend that in addition to regulations and policies, governments should offer incentives and subsidies to companies to reduce pollution. According to He et al. (2017), cost savings would be a good incentive to develop low-carbon transportation. Their research focuses specifically on China, and He et al. (2017) recommend that China establishes more precise and current low-carbon logistics regulations, offer incentives, and support, and set tighter carbon dioxide emission criteria with related sanctions. It is beneficial for the government to encourage change, and for example, Chen et al. (2023) recommend, that in order to reduce emissions in the future, the government needs to encourage the development of multimodal transportation, substitute long road freight lines with trains or ships, and create energy improvements. According to Borén et al. (2017), government decisions that would encourage the development of new electric vehicle solutions could be able to assist aspirations to transition to electric vehicles from fossil fuels.

In conclusion, policies and regulations have a significant role in lowering the carbon footprint. Governments are required to control regulations as well as monitor and assess their implementation in organizations and across the country. Regulatory policies driven by governments are frequently a component of larger international climate policies and laws.

2.2 Utilizing transport management systems

Wang and Sarkis (2021) argue that the utilization of digital technology is evolving within the freight transportation sector. Digitalization generates changes both inside and between organizations, but also at the industry and ecosystem levels, such as when new products or service providers enter the market (Wang & Sarkis, 2021). In the field of freight transportation, information is processed digitally more and more with platform-based network systems, where information is collected from several different sources (Wang & Sarkis, 2021). One of the major challenges in freight transport systems can be assigned to the communication between stakeholders in the supply chain (Pathak et al., 2019). When the relevant data must be entered into the system just once and is then available to all stakeholders, platform-based network solutions save resources and lower the risk of mistakes (Wang & Sarkis, 2021). The study by Kayikci (2018) on the sustainability impacts of digitalization in logistics finds that waste, pollution, and greenhouse gas emissions are all reduced most significantly as a result of the environmental benefits of digitalization. This chapter describes transport management systems, their features, and their potential utilization in the transportation industry. Furthermore, the chapter discusses the role of transport management systems in transport performance measurement and emission reduction, as well as future development potential.

2.2.1 Definitions and features of transport management systems

Today's transport management systems (TMSs), as defined by Seiler (2012), are "transaction-based order management tools". TMS is a software application that supports transportation operations and aids in route planning and reporting (Helo & Szekely, 2005). According to Seiler (2012), transport management systems were earlier mainly utilized by a few large organizations, but their usage has become beneficial for small and medium-sized businesses due to the substantial part of transportation costs in total supply chain costs.

Managing communication between shippers and carriers is one of the primary objectives of TMS (Seiler, 2012). TMS improves the transparency and reliability of transportation-related data among supply chain participants (Santos & Piva, 2021). Another critical aspect is the selection of carriers, which can be influenced by factors such as cost and transport time (Seiler, 2012). In addition, if TMS is allowed to utilize future estimates from sources like production plans, TMS can help in budgeting transportation costs (Seiler, 2012). Moreover, TMS can support managing locations related to transports, invoicing, status tracking, scheduling, and freight rates (Helo & Szekely, 2005; Seiler, 2012). Overall, TMS acquires data and uses it to obtain control over logistical operations (Santos & Piva, 2021). Figure 4 shows the connections between organization, processes, and IT, which Seiler (2012) refers to as transport management dimensions. These dimensions work together to perform the functions of planning, control, and execution.

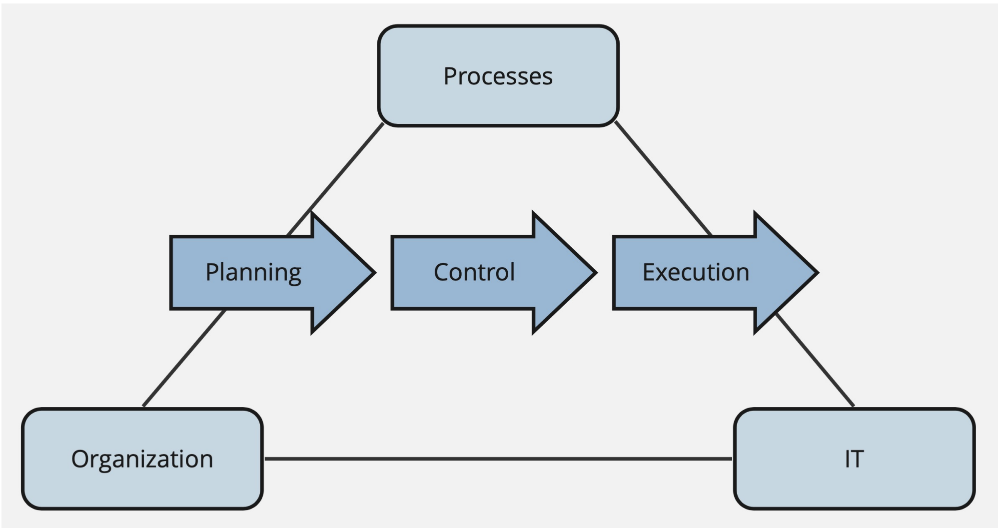

Figure 4. Dimensions and functions in transport management (adapted from Seiler 2012).

The most common foundation for a transport management system is a central database structure, which stores an extensive amount of data (Seiler, 2012). TMS can be accessed using an application running as a standalone program, which is directly connected to the central database, or TMS can connect to the central host version but without direct access to the database (Seiler, 2012). TMS may also be accessed using a web browser, with the calculations and analyses downloaded from the server in the chosen format (Seiler, 2012). The use of a web browser facilitates the quick distribution of TMS and communication among all participants in the supply chain (Seiler, 2012). Alternatively, TMS can also be accessed via another system, such as Enterprise Resource Planning (ERP) system (Seiler, 2012), which is an application software that companies employ to support fundamental operations such as material management and procurement (Klaus et al., 2000). When implementing a transport management system, it is critical to connect the TMS with the existing IT infrastructure of the supplier (Seiler, 2012). As a competitive advantage, ease of use can also be beneficial (Seiler, 2012).

Seiler (2012) divides and explains the typical transportation control process with a TMS into six steps. The arrangement of actions in the ERP and the TMS areas is shown in Figure 5, and the actions performed by the supplier, demander, and carrier are also separated. In the first step, a supply order from the demander side, such as a purchase order, is transmitted from the ERP system and passed to the supplier in their ERP system for confirmation (Seiler, 2012). The transport order is generated in the transport management system once the supplier confirms the order (Seiler, 2012). Transport order includes information on the shipment's origin, destination, load, and any other information needed, such as time limits or specific requirements for the transport (Seiler, 2012). Moving to the TMS side, some of the order's ERP-specific information may be absent, as TMS does not typically require comprehensive material information, although it can utilize it if such data is essential for the transportation process (Seiler, 2012).

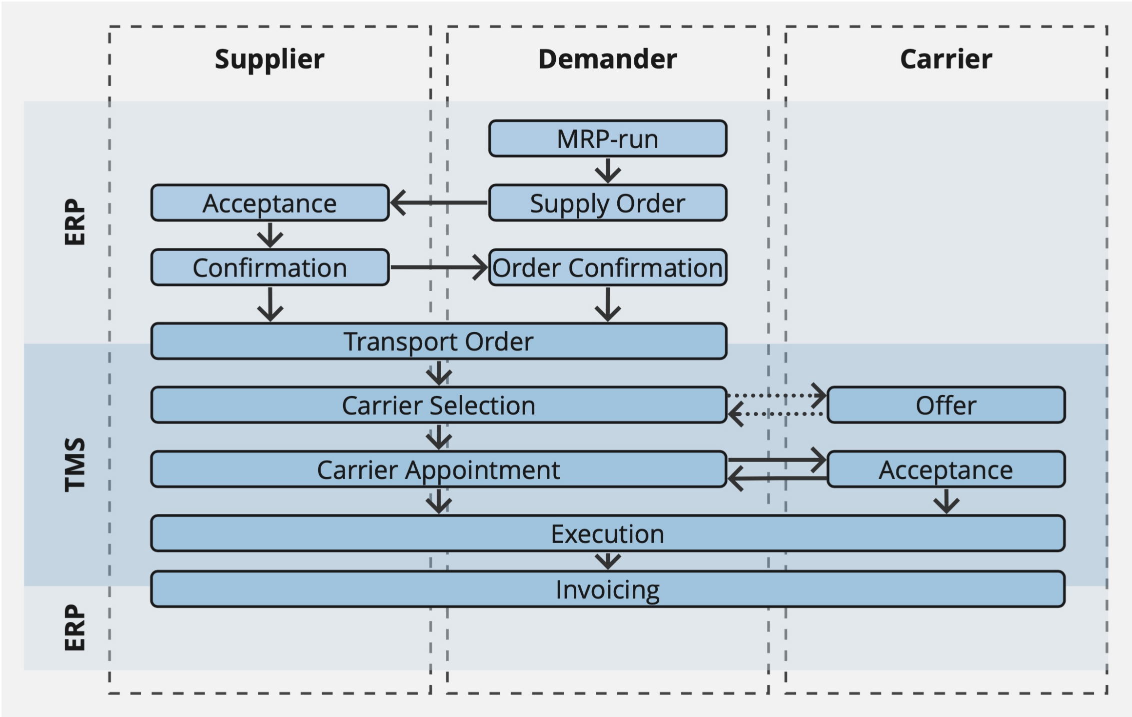

Figure 5. Transport management process (adapted from Seiler, 2012).

After receiving the transport order, TMS combines the transport orders into order combinations, taking into consideration the limitations of the pick-up and delivery times as well as the capacity restrictions of the chosen mode of transportation, such as how many pallets can be placed on board (Seiler, 2012). When compared to shipping each transport order separately, combining transport orders can be less expensive (Seiler, 2012). The second step is acknowledged as load building, where the mode of transportation and carrier for the order is selected (Seiler, 2012). Costs and order-specific variables, such as transit and lead times, may be taken into consideration while making the selection (Seiler, 2012). The transformation of transport orders to loads enables the automated assignment of the selected carriers (Seiler, 2012). The information on the created load must be provided to the carrier in the third step within the given lead time (Seiler, 2012). The carrier must confirm or reject the order within a certain time after receiving it (Seiler, 2012).

The actual physical transport is carried out in step four of the transport management process (Seiler, 2012). In this step, if the goods are damaged or delivered late, this information may be entered into the transport management system at either the dispatch or receiving location (Seiler, 2012). The fifth step, which comes after the transport is completed, is the invoicing process (Seiler, 2012). When invoicing is managed in a TMS rather than being done manually, the possibility of errors is decreased (Seiler, 2012). In the last, sixth step, the invoices are paid (Seiler, 2012). Typically, the payment data is transferred from TMS and paid in another system (Seiler, 2012).

2.2.2 Types of transport management systems for carbon footprint reduction

Literature finds various types of transport management systems that can be utilized for different kinds of traffic and transportation-related management. This chapter introduces several transport management system versions that are linked to freight transportation as well as private and public transportation and how they consider emissions.

Lv and Shang (2023) investigate the effects of Intelligent Transport System (ITS) on emissions and energy conservation in transportation networks in their study. ITS can be used to better understand, visualize, and control urban transportation to improve transportation services (Lv & Shang, 2023). By arranging drivers and vehicles for transport, the objective is to reach a balance between transport demand and supply and to minimize traffic jams as well as reduce accidents (Lv & Shang, 2023). ITS integrates various information technologies and the latest advancements in artificial intelligence and associated technologies have provided a solid foundation for the creation of transportation software (Lv & Shang, 2023). With the use of ITS, it is possible to strive for things like reduced energy usage per mile and no-load rate in traffic (Lv & Shang, 2023). The intelligent transport system provides scientific management of transportation infrastructure, which aids in decreasing emissions and conserving energy (Lv & Shang, 2023).

Costabile and Allegrini (2008) investigate in their research the connection between public and private transportation-related emissions and air quality values. In the research, the authors provide a framework with the aim of measuring emissions and air quality and using modeling to connect air pollution monitoring to an automated and real-time evaluation of air pollution transport. Costabile and Allegrini (2008) develop an integrated system in their research, and one of its four main system components is a Public Transport Management Subsystem (PTMS). The objective of the PTMS in the study is to improve the management of the public transportation fleet, which includes allocating vehicles and routes, optimizing the load carried by buses, and facilitating the sharing of real-time information (Costabile & Allegrini, 2008). Therefore, the employed PTMS is merged with other systems to create an intelligent transport management system that works toward reducing greenhouse gas emissions from transportation and the development of tools to assist in it.

In order to identify a method to lower carbon dioxide emissions, Namoun et al. (2014) present a TMS that utilizes the use of a multi-agent system. The system gathers real-time data on the traffic network from multiple sources, analyzes the physical characteristics of the network, and receives dynamic traffic updates to generate an overview of the transport infrastructure of the city. In their paper, the system is divided into traffic segments, which each have unique characteristics in terms of emissions and travel time (Namoun et al., 2014). Modes of transport employed in the system are walking, private vehicles, public transportation, and cycling (Namoun et al., 2014). The system offers commuters route suggestions and is intended to minimize traffic congestion (Namoun et al., 2014). The user may select the quickest or most ecologically friendly route (Namoun et al., 2014). The system is capable of recommending a mix of modes of transportation for the route (Namoun et al., 2014).

In their research, Lilhore et al. (2022) present an Adaptive Traffic Management (ATM) system, which development has benefited from machine learning and the Internet of Things. The system utilizes the location and average speed of vehicles to control traffic, which entails monitoring traffic volume and updating traffic lights as necessary. The purpose is to minimize travel time by reducing congestion and, consequently, traffic accidents. According to Lilhore et al. (2022), automated accident detection is a common objective of traffic management systems.

Taniguchi et al. (2014) investigate the adoption of the Road Freight Transport Management (RFTM) system to handle urban freight transport more efficiently in the public sector. The objective of the RFTM system is to evaluate and execute political initiatives aimed at improving the economic profitability and safety of cargo transport vehicles (Taniguchi et al., 2014). Additionally, reducing the impact on the environment and problems like transportation congestion are objectives (Taniguchi et al., 2014). These initiatives may involve optimizing freight transport route choices in the system (Taniguchi et al., 2014). According to Taniguchi et al. (2014), the RFTM system aims to choose low-emission vehicles for transportation and reduce traffic in urban areas. Furthermore, the system should select an appropriate time of day for transportation, which implies that loading and unloading activities, for example, should not take place during peak traffic congestion and highways should be prioritized over urban areas if there is no practical need for driving through them (Taniguchi et al., 2014). These features are intended to support efforts to reduce environmental impact and improve urban freight transport efficiency (Taniguchi et al., 2014).

Environmental issues have been considered throughout different types of transport management systems which are discussed in this chapter. Several studies state that the system can be used to optimize routes or loads, as well as utilize the tracking system in transport trucks and minimize congestion in traffic, which not only increases transportation efficiency but can also lower emissions. The papers also discuss enhancing energy efficiency and minimizing idle time as further emission reduction methods. Additionally, several systems pay attention to safety concerns to minimize traffic accidents.

2.2.3 Benefits and challenges of utilizing transport management systems in transportation

Among the primary features of a transport management system, Seiler (2012) mentions transport order management, which includes entering and specifying orders, carrier communication, and status tracking. TMS is additionally utilized to manage freight rates and costs, as well as invoicing (Seiler, 2012). Furthermore, TMS enables monitoring performance in the context of activities like location performance and carrier evaluation (Seiler, 2012). For instance, the amount of damage during transport or on-time performance may both be used to evaluate the carrier (Seiler, 2012).

According to Seiler (2012), different TMS providers offer add-ons to the system in addition to the primary features of TMS (Seiler, 2012). These add-ons may include location services, which make it possible to employ routing solutions (Seiler, 2012). Utilizing routing parameters allows for route weightings, such as a fast route or a short route, and takes into consideration vehicle characteristics, such as their speed limitations, in route selection (Seiler, 2012). These are beneficial in making decisions about routes and carriers (Seiler, 2012).

The research conducted by Santos and Piva (2021) examines the results of adopting a TMS in a large automotive component-related company. Consequently, they recognize that the TMS enhanced the accounting process completed at the end of the month, the company's gross income increased, and the freight costs of domestic road transport decreased. The TMS enhanced data dependability and efficiency of operations in the company (Santos & Piva, 2021). Important metrics, such as the percentage of freight costs in revenue for the company, are easily tracked due to the TMS (Santos & Piva, 2021). The research of Santos and Piva (2021) additionally finds that users of the transport management system in the company were pleased with the ability to download reports from the system and analyze shipments as a list or individually.

Lv and Shang (2023) evaluate the outcomes of employing an intelligent transport system to cut emissions. They emphasize the integration of information technologies into one system as a beneficial characteristic of ITS. Examples of these integrable technologies include wireless internet, cloud computing, the Internet of Things, and big data (Lv & Shang, 2023). As the digitalization of global information becomes more significant, Balueva et al. (2022) further investigate the advantages of transport management systems in the maritime transportation sector. By integrating data onto a single platform, it is possible for all supply chain participants who require the information to find it in one location and in real-time (Balueva et al., 2022). TMS allows ship loading optimization in the maritime transportation sector, as well as consistent and effective freight loading between vessels (Balueva et al., 2022). Furthermore, TMS improves order execution and speed, as well as intermediaries in the supply chain, and Balueva et al. (2022) anticipate that digitalization will improve the total performance and profitability of maritime transportation.

Lv and Shang (2023) perceive a challenge in the utilization of TMS when various cities or countries have different perspectives on the significance of emissions reduction. In this scenario, urban transport management may be inefficient, or administrative procedures may be overly complex (Lv & Shang, 2023). Another challenge is provided by Froese (2013), who claims that at least by 2013, transport management systems could only utilize a specific mode of transportation, such as concentrating on road freight or rail freight. Furthermore, while selecting a mode of transportation, logistics information systems are unable to consider both costs and transit time (Froese, 2013). As a result, Froese (2013) recommends that in the future transport management systems should be developed so that they may separate orders into those that do not have a time constraint or are not urgent, and then automatically suggest a more environmentally friendly mode of transportation for them, since usually, slower modes might be more sustainable.

The benefit of implementing a TMS is mentioned in various studies to be the usage of a common platform, which decreases the margin of errors and speeds up several operations across supply chain participants. Other beneficial characteristics include the location feature, which may be utilized to optimize transportation routes, as well as the reduction of emissions and costs. Challenges include divergent views on the necessity of lowering emissions amongst countries and the continuous need to enhance the systems to be able to meet the evolving market requirements.

2.2.4 Role of the transport management systems in transport performance measurement and emission reduction

Kayikci (2018) examines the impacts of digitalization on logistics from the economic, social, and environmental viewpoints of sustainable development. From an economic perspective, the digital system should be effective and economical, provide a variety of transport options, and support the local economy (Kayikci, 2018). When it comes to the environment, it is essential to make efforts to reduce greenhouse gas emissions, waste, and pollution, support technologies that recycle its components, and use less non-renewable energy sources (Kayikci, 2018). The social perspective draws attention to meeting the basic needs of individuals and communities so that they are equitable between generations and support good lifestyles (Kayikci, 2018).

In their research, Borén et al. (2017) investigate how integrating the objective of sustainability with other significant related industries can make it feasible to develop the transportation sector even more sustainable. Borén et al. (2017) develop a process model to aid in the development of a sustainable transport system. The goal of the process model is to develop the optimal use of land and natural resources from a strategic sustainability and life cycle viewpoint (Borén et al., 2017). It also seeks to include key stakeholders early in the planning process and to ensure that sub-goals and actions are taken to support the vision and its implementation as well as to ensure that solutions from other sectors do not conflict (Borén et al., 2017).

In their study, Pathak et al. (2019) attempt to discover Critical Success Factors (CSFs) that affect sustainable freight transport systems. The study aims to understand the connections between the found CSFs and prioritize them, after which Pathak et al. (2019) develop a framework for assessing the sustainability performance of freight transport systems. The objective of this research is to support logistics and supply chain stakeholders in taking into consideration the CSFs whose promotion is essential to achieving the sustainability of freight transportation (Pathak et al., 2019). In addition to the three commonly accepted dimensions of sustainable development, economic, environmental, and social, Pathak et al. (2019) use three emerging dimensions in their study, namely efficiency, employing advanced technology, and safety. The results of the study emphasize the significance of paying more attention to these new dimensions in addition to the traditional dimensions to enhance the effectiveness of sustainability (Pathak et al., 2019).

In their study, Yazdani et al. (2020) provide a decision-support framework that includes sustainable components, addresses the performance measurement issue for the freight transport system, and develops a decision-making method. The framework should support freight transportation companies in evaluating and managing their core operations from an economic and environmental perspective, enhancing current procedures, and avoiding additional costs (Yazdani et al., 2020). Additionally, the carbon footprint is one KPI that can be evaluated with the utilization of TMS (Seiler, 2012). TMS enables carbon footprint assessment by estimating, for example, transport volumes, emissions from transportation, and the environmental impact produced by the customer and supplier (Seiler, 2012).

Taniguchi et al. (2014) recommend in their study that the Road Freight Transport Management (RFTM) system be optimized so that it recommends the use of larger roads between urban areas and the use of large transport vehicles on the outskirts of cities, as well as the use of smaller and lower emission vehicles for the last kilometer delivery at the transshipment terminal. Furthermore, the RFTM system should recommend the use of smaller transport vehicles for smaller quantities of goods, in which case all smaller loads are transported to the terminal and then transferred to a larger means of transport (Taniguchi et al., 2014). Rail and maritime transport should be used whenever possible to reduce environmental impacts (Taniguchi et al., 2014). Furthermore, Pathak et al. (2019) note that when evaluating transport system performance, factors such as load factor and distribution planning are examined. Seiler (2012) continues that the effectiveness and total expenses of the transportation process are taken into consideration while measuring with TMS.

In conclusion, many studies have been conducted to assess the performance of transportation with the transport management system from the TBL perspectives in terms of economic, social, and environmental sustainability, and various frameworks and models have been developed. The aim is to assist organizations in identifying the most essential functions of TMS and strategies to minimize emissions, as well as to aid in decision-making that promotes a sustainable transportation process.

2.2.5 Opportunities for future development of transport management systems to reduce carbon footprint

Lv and Shang (2023) draw attention to the possibility of combining TMS with social networks and public opinion to address urban traffic issues like traffic congestion and assess the effectiveness of the transport systems in the future. TMS can aid in understanding actual traffic conditions as well as the severity of the issues (Lv & Shang, 2023). Additionally, Lv and Shang (2023) highlight how significant it becomes to develop systems far more intelligent in the future, which would need to incorporate cutting-edge advancements like the Internet of Things, cloud computing, Big Data, and AI into intelligent transport management systems. The field needs ongoing research and development, as well as government involvement (Lv & Shang, 2023). Furthermore, Lv and Shang (2023) emphasize that when developing a strategy for TMS utilization, industrial transformation should be taken into account alongside the development of adjustments to energy use and the utilization of alternative energy, such as transitioning from diesel and gasoline to hydrogen energy and biogas.

The evolution of both industry and technology must be considered in the future vision and development of transport management systems. The modes of transportation and the goods that need to be delivered change as the industry evolves. This may impact the ratio of modes of transportation used in the future and likely so will the amount of emissions produced by those modes of transportation. Improvements in technology must include prospects provided by AI, which will modify the systems that are currently utilized as well as the way they are used.

3 Methodology

This chapter presents the research approach of the thesis. The aim is to describe the research approach and stages in the research process such that the research could be replicated in a similar case study. The subheadings provide more thorough descriptions of each stage in the research process, such as the selected design of the research and how the data is collected and analyzed. The reliability and validity of the research are also discussed at the end of this section.

3.1 Research design

The thesis is conducted as a qualitative case study. The qualitative method was chosen because the thesis focuses on the transportation process, the formation of the carbon footprint, opportunities to reduce it, as well as challenges in the process, and seeks to determine the most efficient utilization of the transport management system used by the case company to reduce the carbon footprint. Qualitative research investigates how changes impact interactions and processes (Barbour, 2013). The qualitative method is suitable for this type of research since it allows for interviews with those who are associated with the case company. An interview can be performed to gather information that is useful to the study objectives (Saunders et al., 2007, p. 312). Qualitative research is commonly used when conducting interview research because the qualitative approach allows respondents to highlight topics that are significant to them and describe how this influences their everyday activities or work (Barbour, 2013).

A case study is distinguished by the fuzziness of the research borders between the phenomena and the context under examination, and the use of several pieces of evidence to develop a thorough knowledge of the context under study (Saunders et al., 2007, p. 139). The case study is frequently used in both exploratory and explanatory research and can make use of a variety of data-collecting methods (Saunders et al., 2007, p. 139). This thesis is conducted as a single case study since it is completed for a specific company at a certain time in a specific scenario of the company and therefore cannot be replicated identically in another organization in the same way. The literature research conducted supports the case study because existing theory can be examined in a case study (Saunders et al., 2007, p. 140). Since the thesis concerns a specific phenomenon, the time horizon of the research is cross-sectional.

The research process of the study is shown in Figure 6. The research process began with the formulation of research objectives and research questions, which was partly done in cooperation with the case company. The second phase was to conduct a literature review, which relied on existing scientific literature on the research topic. The following phases included creating the interview questions and then contacting possible interview participants within the case company. After that, data was collected and analyzed, and lastly, conclusions were written using the results of the data analysis.

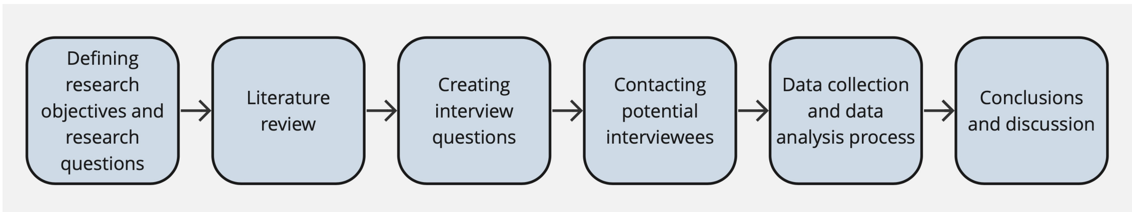

Figure 6. The research process of the study.

The interview phase is conducted using semi-structured interviews. Semi-structured interviews provide for a flexible interview in which the interviewees can share their opinions and reflections alongside the interviewer's agenda and the sequence of the questions can be adjusted (Barbour, 2013, p. 121). The semi-structured interview method allows for additional questions or the exclusion of particular questions for each interview (Saunders et al., 2007, p. 312). Another method used for gathering data is presentation materials, in which the TMS provider company presented an overview of the TMS. Table 1 shows all the methods used to collect data in order to answer the research questions of the thesis.

Data collection	Data format	Analysis	Note
Literature review	Qualitative	Content analysis	Theory of freight transportation, its carbon footprint, and TMSs based on scientific literature
Internal interviews (6 employees)	Qualitative	Content analysis	Interviewees from the case company
Presentation materials (2 presentations)	Qualitative	Content analysis	Presentations about functionalities of the TMS held by the TMS provider

Table 1. Data collection methods.

3.2 Data collection

In addition to the literature review, data was collected through interviews within the case company and two presentations, that were given by the company that provides the transport management system to the case company. Presentations were performed on the features that the TMS offers to measure emissions from transports.

3.2.1 Sampling

The purpose of qualitative sampling is to aid in the visualization of the phenomena being studied (Barbour, 2013, p. 47). Based on the sample, the generated data set can be compared (Barbour, 2013, p. 47). Purposive sampling was used in this study since it was apparent that the type of employees who would be most competent to respond to the questions were those who deal with the issues related to the topic of the thesis in their everyday work. Because the first four interviewees were asked about other possible interview candidates, the research also employs snowball sampling. In snowball sampling, additional interviews with similar individuals are obtained through the core interviewees' own networks (Barbour, 2013, p. 66). As a result, two additional interviewees were obtained for this research.

3.2.2 Semi-structured interviews

The semi-structured interview method was selected since the chosen interviewees in the case company work in various roles across several departments, and it was wanted to allow them to reflect on the topic in their own way throughout the interviews. This interview method enabled consistent questioning across interviews and provided space for additional conversations. After the respondents replied affirmatively to the interview request, which defined the purpose and objectives of the thesis, the questions were delivered to them in advance through email. The interview questions are divided into three themes, which are knowledge and operations, metrics, evaluation and assurance, and strategy, sustainability, and future prospects. The interview questions are found in the appendix. Teams was used to conduct individual interviews, which lasted between 30 and 60 minutes each. Only one interview had two interviewees present at the same time, while the rest had only one. The interviews were conducted in both English and Finnish and all interviews were recorded with the consent of the interviewees after which the recordings were transcribed. The interview questions focus on the present transportation processes of the case company, current utilization of the transport management system, carbon footprint and its assessment, as well as the implications of emission reduction objectives on those processes and the case company's strategy.

3.2.3 Presentation materials

Two separate presentations on the functionalities of the transport management system were held by the company that provides the TMS that is utilized in the case company and investigated in this research. The presentations were given in Teams and recorded with the acceptance of the participants. Both presentations involved three audience members, who were both from the case company side and the TMS provider company side, and one who served as the presenter. The presentations were conducted in English, and there was an opportunity to ask additional questions. The first presentation materials concentrated on the overall operation of the TMS, while the second concentrated on the features that allow for the measurement of the carbon footprint and the calculation of emissions.

3.2.4 Literature review

A literature review was conducted to gain a theory from both the transportation industry and transport management systems. It provides details on how transportation emissions are created and how they are measured using a transport management system. The literature review also seeks to process knowledge regarding how using a transport management system would be able to affect emissions. Information for the literature review was mostly gathered from scientific articles and books. Particularly Google Scholar was employed as assistance in searching for literature, with the search results mainly limited to the years 2018 to 2023. However, certain previous publications that were considered to be relevant to the paper have also been utilized as source material.

3.3 Data analysis

In this thesis, content analysis is employed as a method of data analysis, which Grbich (2013, p. 189) and Krippendorff (2019, p. 24) state is suitable for assessing written, visual, and auditory documents. Krippendorff (2019, p. 24) continues that the phenomena or practices under research can be better understood with the use of content analysis. The data analysis process began with the transcription of the recorded interviews into a text format. This procedure was aided by an automated tool that Word offers. Preliminary data analysis is the process of checking and examining the information that is collected to see where it goes and what the data implies to the researcher (Grbich, 2013, p. 21).

The preliminary data analysis started by examining the created text documents visually and fixing typographical issues. The process continued by highlighting the interview questions from the text, in order to make it easier to follow which parts of the interview took place in the text. Following that, all of the interviews were utilized to conduct the findings by referring to the themes in the interviews and the interview questions. The same procedure was then used to analyze presentations of the TMS. The transcriptions of the recorded presentations were performed using the automated tool provided by Teams and the transcribed texts were then checked visually for typographical errors. After that, the presentations were rewatched while significant points from the text were highlighted to help with writing the results.

3.4 Reliability and validity

3.4.1 Reliability

The subject matter, biases, or errors made by the participant or observer can make an impact on the reliability (Saunders et al., 2007, p. 149). Careful documentation and data assessment at every stage of the research has been used to ensure the reliability of the results. By recording the interviews and presentations, it was made sure that the findings from the discussions were not just reliant on memory and notes and that there would be an opportunity to analyze the recordings again in case it was found necessary. The reliability of the findings is further improved by the transcription of interviews and presentations. The consistency of the results obtained via data collecting and analysis can be used to define the reliability of the research (Saunders et al., 2007, p. 149). Furthermore, triangulation is a process of verifying the accuracy of information through many sources, strengthening its reliability and validity (Flick, 2018, p. 20). In this study, the literature review and the findings from the interview participants and presentations provide mutual support and therefore emphasize the reliability of the results.

3.4.2 Validity

The term validity relates to whether the observations obtained in the findings are caused by what is thought to be the cause and whether there is a causal link between the variables (Saunders et al., 2007, p. 150). Since interviews were one method for collecting data, the observations for the results were gained directly from the interviewees. Additionally, the fact that the respondents represent different departments within the case company enhances the validity of the research. Additionally, by allowing interviewees time to consider the information in advance, the validity and reliability of the data obtained from the interviews may be improved (Saunders et al., 2007, p. 320). This was assured in the study by emailing the interview questions to the interviewees in advance. The validity of the research is further enhanced by properly detailing the used research methodology. According to Saunders et al. (2007, p. 151), external validity refers to whether the results of the study are generalizable to other organizations. It is significant to highlight that the results of this case study apply only to the specific company in question and therefore the results of the empirical research cannot be generalized to other organizations.

4 Results

This section analyzes the findings of the empirical research conducted through interviews and presentations. The chapter explains how the company is currently utilizing the TMS and following that, the key themes and findings of the interviews are discussed. The basic overview of the TMS and the possibilities it offers for estimating carbon footprint are then covered in the chapter. Finally, based on the interviews and the introduced functions of the TMS, the chapter concludes with a discussion of the most effective ways to utilize the transport management system to reduce carbon emissions as well as the various factors related that could also be considered to succeed in the effective transportation process.

4.1 The current way of utilizing the transport management system in the case company

The transport management system is not used directly by the case company employees at the operational level but rather operates in the background of the transport booking process. This indicates that suppliers arrange transportation for orders using their own system, through which the information is then sent to the ERP system of the case company and further to the TMS. The transport management system serves as an intermediate in the process and it is integrated with the ERP system of the case company. Furthermore, carriers are asked to submit their own assessment of the emissions produced by their transportation services. However, the relationship between emission data and business is now quite tenuous, and the acquired emission data is not utilized in the TMS.

Figure 7 below illustrates simplified how the TMS connects carriers, suppliers, and the ERP system in the case company. A purchase order is transmitted from the ERP system of the case company to the Supplier portal, where transport booking for the order is routed back through the ERP and the TMS to the carriers' side. Transport-related information is included in Electronic Data Interchange (EDI) messages, and the final booking confirmation is sent from the TMS to the Supplier portal.

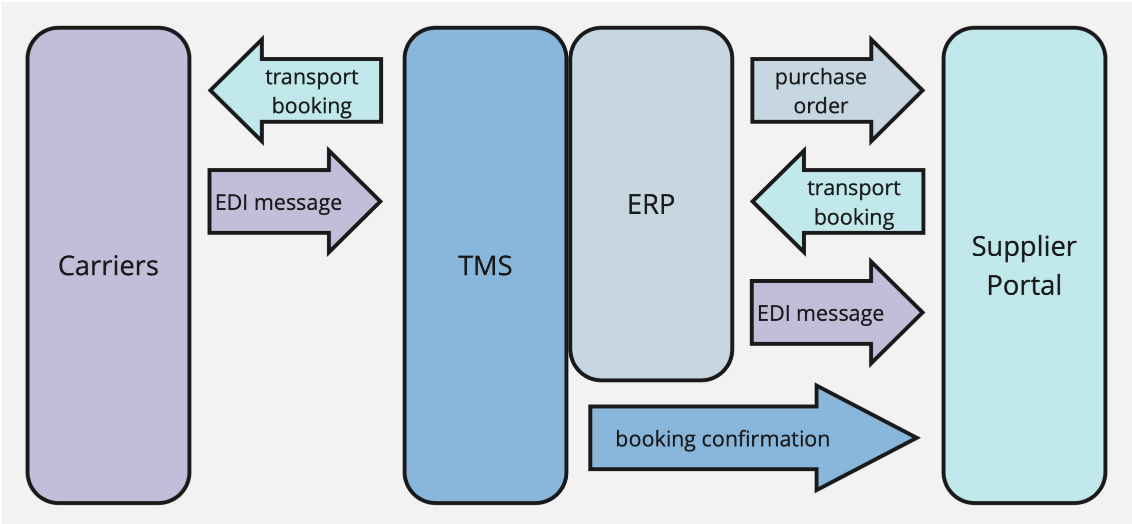

Figure 7. Connecting carriers and suppliers to the ERP system in the case company with the integrated TMS (adapted from Case Company, 2023).

4.2 Analysis of the interviews

The answers obtained from the interviews are analyzed in this section using the three themes utilized in the interviews. Data was collected through five interviews with a total of six participants. All interviews were conducted and recorded using Teams and the questions were sent to the interviewees in advance by email. All the respondents work in managerial positions connected to transportation or sustainable development in various departments of the case company located in Finland except one who works in a business unit in Europe. The interviews were conducted to obtain information about the transportation processes at the case company, the status of sustainability of transportation, and the current state of utilization of the TMS. However, it was discovered during the interviews that none of the participants had ever utilized the TMS that is being investigated in this paper. The main issues and points of discussion from the interviews are addressed in this chapter.

4.2.1 Knowledge and operation

As for transportation modes the case company uses maritime, air, and road freight transportation and it employs around 10-15 different carriers. Trains are rarely utilized. The case company additionally relies on multimodal transportation, such as when a truck travels to a ship in a port in Central Europe, the ship arrives in Finland by sea, after which the truck travels to the destination by road. The majority of the suppliers of the case company are based in Europe and there the case company also employs couriers. Couriers are typically utilized for smaller shipments, whereas road freight transport is used for greater loads.

In selecting a mode of transportation, urgency, cost, and freight volume are taken into consideration. The usage of maritime freight transportation is attempted as often as feasible. Sea transport is a somewhat sustainable choice even if vessels emit a lot of pollution because of their capacity for big volumes. When shipping anything urgently or with a short lead time, air freight is employed. Additionally, it is applied to shipments coming from America. FCA, or Free Carrier, is a common transport condition used by the case company, in which the seller passes over the goods to the carrier assigned by the buyer. The case company has less control over how the freight is collected by the carrier. However, in some circumstances, it has been possible to partially influence the routes taken, such as when favoring sea routes.

In one of the interviews, an example was established regarding outbound deliveries, when it is occasionally possible to handle a larger delivery to the globe, in which case the entire ship may be employed by the case company. If the route or speed may be chosen as the case company prefers, it might be able to reduce the environmental effect of the ship on the journey in this scenario. However, there is not much influence in the case of inbound transports because there are typically transports of other companies on board the vessel as well. In this situation, the case company has no control over the speed or route of the ship.

In the case company, there are several transportation processes because they are not unified among the various departments. The transport management system is a key component in various processes. There are many characteristics in the TMS that the system uses to determine the mode of transportation. Lead time, reliability, and efficiency are all parameters that might be considered. The TMS is linked to the ERP system via EDI messages, and the process is fully automated with invoices and shipping labels. Additionally, in case the required delivery time is shorter, or the volume is greater than the TMS can handle, the transport request can also be completed manually. The case company in this instance has contracts in place with a variety of transport providers that specify liability determinations and payment terms. However, based on the interviews, it would be possible to reduce the carbon footprint by standardizing transportation processes. The interviews showed that developing a process tool would be required in this scenario.

The interviewees were unfamiliar with the TMS being studied in this paper. Many participants had never heard of it, while others were unaware of how it operates specifically. It became evident that a few of the participants were more familiar with or had previously used a TMS other than the one being examined in this research. This allowed some of the participants to assume that the investigated TMS operates based on computing the average of the emissions data it receives. It was also assumed in the interviews that emission reports can be pulled out of the system and used once transport providers enter an estimate of the carbon footprint of transports into the system. Therefore, data collection is required for the TMS to operate effectively, and the objective is to compile comprehensive data on emissions from transportation providers and then compare them to one another. Transport companies can provide primary data on the amount of emissions, while secondary data is information collected from freight forwarders when, for example, both a truck and a ship are used along the route. Although it is challenging to affect the emissions from specific transports, by taking volume into account, it may be possible to use optimization models to affect the overall picture of emissions.

The TMS is now utilized by the main transport companies of the case company, and it is intended to add additional carriers to the system in the future. The TMS examines the specifications of the placed order to determine which transport provider can handle the order most effectively, ensuring that the timetable for delivery is reached and that the transport is as cost-effective and reliable as feasible. The TMS allows for the communication of real-time transport information between the parties for the case company, the supplier, and the transport company. The TMS displays information about when the goods are ready to be picked up, when they are picked up, and when they arrive to the destination.

Currently, lower-emission transportation is seen as more expensive by the interviewees, but it was stated that this may change in the near future. Costs may occur, particularly in the early stages of investing in greener transportation, such as electric automobiles or alternative fuels. The revenue is not generated immediately in this instance. When tracking costs and transport data, it is also important to consider and compare the fact that if compensation for emissions is paid for transportation, it may make sense to gradually transit to more environmentally friendly transportation if costs are incurred from both alternatives regardless.

It was discovered in the interviews, that in a way, more environmentally friendly transportation is being marketed as a product, making it possible to purchase such transportation as an extra service. In the case company, request for transportation service quotations is one strategy that enables the total cost of ownership to be analyzed and compared across various transport options and transport providers. However, when it comes to reducing emissions, one option noted is to consolidate transports. Consolidation typically decreases costs, and therefore greener transportation is not always automatically more expensive. However, choosing a mode of transportation with lower emissions may not always be hampered by cost. Instead, difficulties may arise from the customer experience when trying to adhere to time-sensitive delivery requirements.

4.2.2 Metrics, evaluation, and assurance

It has not been thoroughly measured for how effective the transport management system is, and it is currently believed that it is too early to evaluate its performance. In addition, the necessity for measurement has not always been discovered in inbound shipments since, for instance, domestic transports in Finland arrive usually in about a day and because it has been assumed that meters are costly. However, with the TMS some measurements can be made for transports using the transport time. Other possible metrics include claims and purchase order accuracy. The requirement for measuring and objectives varies between different business units in the case company. However, performance measurement has been carried out for outbound project transports, where transport events, the performance of transport providers, and the success of the transports are tracked.

The interviewees believed that transportation emissions could be monitored in a TMS in such a way that transport companies provide data and reports on transportation emissions and emission values for transportation. At some level, the process of requesting emission data from freight forwarders is already underway, but according to the interviews, not all carriers are ready to provide reports related to transportation emissions yet. Emission reporting can be handled without a TMS, for instance, on a per-shipment basis. In contrast, with another transport management system used by the case company, which is employed in a different department than the TMS under investigation, it is possible to get an emission report for a certain period at any moment. The report is based on the transport distance, and the TMS also includes a commonly recognized indicator in data processing.

According to the assumption of all the interview participants, air freight is the mode of transportation with the highest emissions, especially when the emissions are compared to the weight or volume of the goods being transported. Air freight is employed particularly when the cargo being transported has to be delivered quickly. However, such transports in which a small part is urgently transported by truck are also discovered to be non-environmentally friendly. Transportation emissions per kilogram in this scenario can potentially be higher than in the case of air freight. Another reason why air freight could be chosen is because it best satisfies the requirements of the shipment. Air freight is also frequently utilized for the transportation of spare parts. When spare parts are delivered by air courier in small quantities to numerous locations, a significant amount of emissions are produced.

Efforts to decrease carbon emissions from transportation must be ensured to be aligned with the sustainability objectives and strategies of the case company. Planning and continuity across the entire supply chain are considered necessary in the interviews to achieve the lowest carbon footprint feasible in transportation. It is essential to create development initiatives when implementing strategy and goals into practice. In such initiatives, it could be considered for instance, if it is feasible to work with carriers that provide more environmentally friendly alternatives for transportation, such as alternative fuels or electric vehicles. Furthermore, it is important to ensure that customers can receive information about logistics emissions in the case company.

Every interviewee highlighted the value of data and its collection during the interviews. Data can be utilized to evaluate the past and present as well as establish strategies for future development. Data enables informed decision-making, and data management is a key factor contributing to transportation emissions. Data processing is also necessary, and at least in one department, an overview of emission data has now been included in the schedule of at least monthly business reviews. This enables a review of emissions of last month and how they have changed, as well as consideration of whether something could be addressed promptly.

Furthermore, the interviews revealed that it is considered necessary to develop a comprehensive tool for the whole transportation process to guarantee that efforts to minimize carbon dioxide emissions from transportation are following the case company's goals and strategies for sustainable growth. The tool would make it achievable to examine emissions by departments, by mode of transportation, by routes, and overall. Therefore, it would be feasible to optimize emissions if thorough data on emissions was available.

4.2.3 Strategy, sustainability, and future prospects

The interview participants view cost as being the most significant factor in freight transportation from the perspective of the case company. However, since fuel accounts for a sizable portion of transportation costs, cost optimization, and carbon footprint are related. Cost is an essential aspect since eventually everything is related to business, and cost can be a deciding factor in the context of competition. According to the interviewees, if achieving the emission goals is only achievable by doubling the costs, alternative options should be considered, such as if it is practicable to offset emissions or offer customers a more expensive carbon-neutral mode of transportation as a choice. In the interviews, it was also discussed what is most beneficial for the environment if a company loses a bidding situation with a more expensive low-emission transport to a competitor with a cheaper offer, but a transport that produces twice as many emissions. This creates concerns when environmentally friendly transportation is made mandatory for customers rather than a choice.

Customer contracts and partners that are dedicated to international emission targets and standards are further essential elements in freight transportation for the case company. This implies that contracts are to be made only with transport companies who are committed to low-emission transportation. In addition to emission levels, it is important to consider and make every effort to fulfill the requirements of the customers, such as those related to schedule, emissions, and reliability.

According to the interviewees, the objective of decreasing emissions does not yet influence the daily activities of the case company in terms of choosing the mode of transportation on an operational level. However, it is believed that when a tool can be created for this, selecting the mode of transportation based on emissions at the operational level can become an option. This might be implemented in such a way that when requesting transport offers, the average emissions are calculated, and the most beneficial mode of transportation is selected based on emissions and cost savings. On an individual level, it would be possible to set targets for employees, such as reducing emissions by a particular amount in a year by choosing modes of transportation. On the other hand, making the greenest transportation choice is not always achievable. If a customer requires a spare component within the next week, it is practically impossible to declare that they will have it within a month because it would be more sustainable to transport the component by sea.

Generally, the trend of environmentally friendly transportation is increasingly growing. Although it has been discussed previously too, sustainability is now given much more attention in the strategy of the case company than in the past. In implementing the strategy related to sustainability, it should be recognized that multiple employees must be involved in the case company's development of sustainable operating procedures because one person or a few certain people cannot be completely accountable for everything. Moreover, individual motivation and excitement for the topic are where sustainable growth begins. Additional issues that were brought up during the interviews were that the transportation strategy should also consider intermediary steps, such as intermediate warehouses, from which ship loading may be more efficiently accomplished. Furthermore, differences in culture make it challenging and slow down the process of strategically lowering emissions.

In the future, the transportation process of the case company is desired to operate with the least amount of expenses and emissions. Additionally, data collection is and will be crucial in order to make decisions, optimize transport flows, and discover new solutions. In the near future, lead time-increasing moves should be minimized, consolidation efforts should be increased, the partner base should be reviewed and managed to determine the most suitable carriers, and the TMS should be further developed to be utilized in decision-making. Additionally, employees and their ideas could be more implemented in team meetings and workshops.

Furthermore, purchase orders could be placed more efficiently so that multiple pieces are ordered simultaneously rather than one, which will likely result in a reduction in the carbon footprint of each individual piece. However, this is dependent on the cost and size of the item, and placing greater quantities will also have an impact on the value of the inventory. However, it is probable that in the future, when transportation is pressed for time, it will be forced to employ also non-sustainable modes of transportation.

The ideal scenario would be to gather as much information as possible on the transportation process from the whole supply chain in a single platform and to manage emissions, costs, and delivery times. A consolidated transport management system that can manage transportation and provide emission reports is found to be necessary for the transportation process in the future. However, it is important to keep in mind that a TMS is one particular system and is insufficient alone to accomplish the emission targets. To achieve greener transportation, it is crucial to understand how to utilize the system in alignment with the case company's vision. Generally, sustainability is no longer seen as just a burden but can be seen as an advantage that can stand out from competitors.

4.3 Analysis of the presentations of the transport management system

Two separate presentations of the transport management system were held by the company that provides the investigated TMS to the case company. The first presentation covered a general overview of the TMS, while the second addressed the potential emission solutions that the TMS has to offer. The presentations were held in Teams and were recorded.

4.3.1 General overview of the transport management system

The aim of the transport management system is to connect the user company's internal ERP system or warehouse management system (WMS) and transport companies. It enables transferring shipment-related data between the ERP system and the TMS and allows the user to select a carrier for the order placed in the ERP system of the user. The intention is to simplify the transport booking process and facilitate communication with various transport providers, each of whose systems are different. Therefore, the TMS gathers data from carriers, utilizes it to calculate information for transport orders, and attempts to improve the transportation processes of its customers. The TMS allows its customers to have a single platform that integrates the use of several transport systems of the carriers.

Customers can utilize the TMS in a way that prevents them from logging into the system directly. Instead, all data is routed through the user company's own ERP system before being sent to the TMS and then returned to the TMS, as is the situation with the case company and many other TMS provider company's customers. However, a transport request can also be placed directly in the TMS and there are various ways to accomplish this. It is necessary to input both the pick-up and delivery addresses for the goods into the system. Following that, the good's information is entered, including the package type, weight, dimensions, and quantity. The transport product is then selected, and the TMS then indicates whether any extra information is required to complete the booking of the transport. Different countries may use different validations.

In order to avoid repeatedly entering the same information when booking transport for a specific good, it is also feasible to save templates in the system. According to the presentation, the majority of the customers of the TMS provider company accomplish this, at which point only the goods line must be completed, such as information regarding the quantity of the goods. Using templates is also possible through the ERP system. Furthermore, the TMS can determine whether the selected mode of transportation is appropriate for the order when booking transport, such as whether the goods are too large for the package or whether a pallet is necessary.

Viewing the booked transport orders is accessible in the TMS. The system displays the order's size, which supplier the order is requested from, the transport company that delivers it, and the order's status, including whether it has been picked up, transported to the terminal, or delivered to its final destination. The order status in the TMS is updated after combining the carrier and order information in real-time. By opening a particular transport order, it is possible to see the events taking place. Additionally, the TMS supports combining orders, which allows the system to combine two or more orders into a single order while still displaying the order lines independently.

The TMS enables rules to be created in the system. Rules for transport orders can be set based on what happens or does not happen with transport orders. Rules can be defined to only apply to the transports of a certain transport company or defined for a particular order type or product. The rule can, for instance, automatically issue an invoice after the transport has been completed or send an email reminder if the transport order has not been confirmed within a specified time. The rules can be defined in accordance with the demands of the customer and adjusted as necessary.

Carrier selection is a function of the TMS, which allows an evaluation of multiple transport providers. The system is filled out with the pick-up address, destination, delivered goods, and delivery date. It is also possible to limit the displayed results for a certain mode of transportation, like air or road. Alternative transport providers are determined by the TMS, and for each one, it displays the offered mode of transportation, price, transportation emissions, and, if available, details on the pick-up date and the estimated time of arrival. It is possible to examine the details of how prices and emissions are created when the shipments are saved to the TMS. The calculated emissions are estimations provided by an independent organization. If known, it is also feasible for the customer to add to the system a more accurate amount of emissions. In conclusion, carriers can be selected in the TMS based on which factors, such as lead time, price, or emissions, are thought to be the most crucial for the transport in question.

Instead of doing this directly in the TMS, a comparison of carriers and transports is also available through the ERP system of the customer. In this case, rather than booking one transport order, comparable transport orders can be saved. The TMS then accomplishes pricing and emissions calculations and transfers the results, along with other transport order information, such as the Estimated Time of Arrival (ETA) date, to the ERP system. The customer can then select the most suitable option from the saved alternatives and place an order for it, with the ability to afterward remove the other saved transport orders. Here, it is important to comprehend the distinction between a made and saved booking. However, if various alternative transport companies and multiple options for transport are available, the process can get more complicated.

4.3.2 Emission solutions of the transport management system

As stated in the previous section, the emissions created by transports can be viewed in the TMS. Emissions are visible in the system even before the transport order is placed. Additionally, the TMS offers the option to get emission reports, and data from the TMS can be transferred to the customer's own BI tool for analysis. However, in order to completely investigate data and obtain an actual emission value, the data must be extensive and detailed. Also, for a more efficient carrier selection, a lot of specific data is required. In the absence of precise input data, the TMS can also determine emissions on a general scale, but the outcome is an estimate that however presents a somewhat accurate picture of emissions.

The TMS employs emission calculation based on a tariff structure, allowing emissions to be estimated in real-time. It is feasible to employ a self-created and built tariff in the system by a customer. If the customer has detailed information on the emissions generated by the transportation services they use, the data can be uploaded to the system as a template, and the TMS utilizes this data to compute the carbon footprint of the transports. However, the system also provides a baseline tariff that applies to all modes of transportation globally. An independent, nonprofit organization calculates the tariff and works to ensure that the monitoring of emissions in the TMS adheres to European standards. The information in the transport booking alone is insufficient for determining the precise emission level, therefore applying the tariff results in a precise calculation of the emissions. To independently calculate the actual emission levels, companies must have specific knowledge of factors such as vehicle type, fuel type, routing of the shipment, engine type, and cargo load factor on the shipment. When transportation services are purchased from numerous different companies and when utilizing multimodal transportation, collecting this information might be difficult. The TMS enables this since the baseline tariff is determined as an average that varies across countries and the methods used to generate the tariff are available if required. The tariff is currently the most specific in the Nordic countries.

Figure 8 demonstrates the method for calculating the emission data of a transport. The emission tariff is created by using either the TMS baseline tariff, the custom tariff, or both. As a result, the TMS calculates emissions for transport by using the data from the transport order and the emission tariff, which are then run through the emission rate engine and returned to the TMS. Information can also be forwarded in real-time, or for instance weekly or monthly, to the customer's own ERP system. In the calculations, the TMS makes use of zones. A zone can refer to a region, such as a country or a postal-coded area. The calculation method for the payload is based on a line that connects the zones. There are regional variations in this practice. Emissions per tonne-kilometre can be calculated when payload, distance, and emission value are taken into account. This offers valuable data that can be further compared to each other to detect seasonal changes or progress.

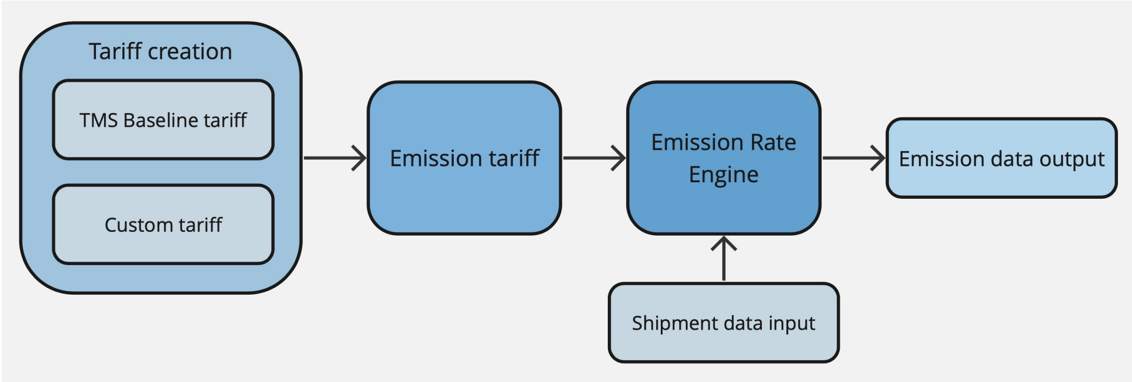

Figure 8. The process of calculating emissions in the TMS (adapted from TMS provider company, 2023).

4.4 Discussion on the most effective ways to utilize the transport management system

Based on the interviews and presentations, it is reasonable to conclude that the case company should first develop and devote resources to collect data on emissions. Data is required for reporting, development monitoring, decision-making, and efficient use of the transport management system. As indicated in the interviews, significantly more detailed data should be collected and further utilized in the TMS to improve the emissions calculation. When reliable data could be used from the TMS for the case company's practice, the BI tool of the case company could also be utilized in reporting via the TMS. In the case company, the emission data could be easily and comprehensibly monitored using the BI tool at specific time intervals, such as once a month, and the outcome of the previous period could be examined in terms of the carbon footprint in business reviews. In this instance, the monitoring of the emission data would become more efficient and accurate due to the regular processing of the data. Furthermore, the case company can directly add emission reduction targets to the TMS, enabling the system to monitor the progress.

The interviews revealed that a tool is being developed in one department of the case company to obtain estimates from the transport companies of the emissions produced by the logistics solution they use, as well as the price and time. The objective is for the operational employees of the case company to be able to choose greener transportation in their everyday job while simultaneously considering time and cost. On a strategic level, this implies that it would be feasible to investigate the major sources of emissions. Additionally, it would be possible to choose transport providers who are dedicated to operating under standards that are comparable to the strategy of the case company. Given that it is conceivable with the investigated TMS, the previously mentioned concept should be put into practice with it.

The first thing that can be done with the aid of emissions reporting is to identify the major transport modes or, for instance, transport companies as sources of emissions. On a strategic level, it would be possible to identify the greatest polluters and replace them with companies and modes of transportation that are more environmentally responsible after comparing emissions and their causes over a specific period. The case company currently employs pricing calculation at some level, and therefore this could also be employed in terms of emissions.

The baseline tariff provided by the TMS might be used as a starting point in the emissions calculation. It can assist in providing a realistic, generally relevant picture of transportation-related emissions, which can be utilized to guide future observations and decisions. If necessary, additional data concerning emissions can later be added to the TMS in more detail. Alternatively, the emission calculation process can be started with just one or a few of the most utilized transport companies or modes of transportation.

Utilizing the consolidation of transport orders offered by the TMS is one approach to reducing emissions. This is something that also came up in the interviews. Consolidating transportation allows to consolidate, for example, multiple smaller shipments, and therefore decreases the number of travels and emissions. Consolidation should be considered in the future, as it has the potential to save money as well. The case company should investigate the possibility of consolidation utilizing the TMS and, if feasible, employees should take consolidating options into consideration if examining transport orders. It requires foresight and planning to ensure that the advantages of the process outweigh its drawbacks, which might include the potential extension of schedules when a consolidated order waits for all goods to be ready to be dispatched at once.

The carrier selection function was discussed while outlining the features of the TMS in the presentations. This function can be a key factor in reducing emissions with the utilization of the TMS, and it could also be used to prioritize costs and delivery time. The case company must specify the deciding criteria for transport orders in specific circumstances so that a carrier can be selected either through the ERP system of the case company or directly through the TMS. On an operational level, the employee would be able to assess transport options, for instance, based on emissions, and select the mode of transportation and the transport company that would have the lowest emissions and that, at the same time, would also satisfy the required lead time. The carrier selection process could begin with a simpler formula, such as the transportation of a particular category of materials. It would be competent to proceed to a more thorough selection of the carriers with other types of goods as well if it were subsequently shown to be essential. Employees could be motivated to decrease emissions by selecting modes of transportation with goals that require emissions to be lowered by a specific amount in a specified period compared to the previous level of emissions.

It would also be conceivable to discover a way to use the rule functionality of the transport management system. For example, if assumed that data has been examined for regularly transported goods, and a low-emission transport provider and transportation mode for transport orders has been discovered and it is wanted to be used every time with these goods. Therefore, the rule could potentially be created so that the TMS always selects this specific transport provider and transportation mode for the shipment of the goods in question, eliminating the need to separate the carrier selection every time. Additionally, it would be possible to ask the system to notify with an email to the case company whenever the carrier confirms a transport order so that the actual emissions of the transport are higher than what the TMS predicted when the order was placed. The rules can be developed in many ways depending on the situation and the demands of the case company.

The case company has not performed an effective job of calculating the costs that reducing its carbon emissions can cause. However, it became obvious from the interviews that respondents expected that lower-emission transportation would be more expensive in general. Nevertheless, it was noted in the interviews that it may be necessary to pay an emission tax or compensation for higher emissions in the future, in which case there would be costs whether it was for decreasing emissions or compensating for higher emissions. Investing in less emitting transportation can therefore be beneficial. Furthermore, if low-carbon transportation becomes more and more common, the costs related might decrease in the future.

Finally, utilizing the TMS improves the reliability of transportation since transport orders can be tracked in the system when the status of the orders is updated in real-time. Furthermore, it enhances supply chain communication and decreases the number of mistakes when the same information is not entered into several systems multiple times. Simultaneously, when order-related issues are managed through the same system, the use of the TMS additionally improves time management and expedites the processing of transport orders.

In the interviews, it was noted that the case company would need to develop a comprehensive tool that would enable it to guarantee that its operational efforts to cut emissions are in line with its strategic objectives. The transport management system could potentially be the solution to that demand. All of the previously mentioned approaches for utilizing the TMS to reduce carbon footprint can be implemented gradually, as stated for example for a specific mode of transportation or supplier, or with particular categories of materials at first. Along with all the possibilities for reducing emissions and putting them into action, the case company should specify how the TMS will be utilized in the future. This refers to whether the TMS will be utilized directly or whether it will continue to be used through the ERP system of the case company, as it has so far now. It would be beneficial to evaluate these two different options, but if the TMS were to start gradually utilized to lower carbon footprint, it could be reasonable to continue utilizing the ERP system as previously for a while.

5 Conclusions and discussion

This chapter provides an overview of the results of the empirical research of the thesis. Additionally, it presents a summary and a discussion between the findings and the theory of the thesis. The chapter concludes by outlining potential directions for future study that may be utilized in investigating more about minimizing the carbon footprint of transportation.

5.1 Conclusions

The thesis began by defining the objectives and purpose of the research, as well as the research methods, the limitations set for the research subject, and presenting the case company for which the research is conducted in collaboration. The study then became acquainted with the literature on the transportation industry and transport management systems and examined them specifically from the standpoint of reducing emissions and carbon footprint. Following the examination of the literature, the methodology of the research was provided.

The main purpose of this research was to identify the most effective ways to use the transport management system to decrease the carbon footprint of transporting incoming material flow in the case company. Additionally, the study aimed to discover what factors contribute to the carbon footprint of transportation and how it can be measured utilizing the transport management system. The research questions of the study were:

1. What does the carbon footprint of freight transportation consist of?
2. How does utilizing a transport management system affect and measure the carbon footprint of freight transportation?
3. What effects does utilizing a transport management system have on time, cost, and reliability when choosing more sustainable transportation methods?

The carbon footprint of the transportation of the case company is significantly affected by air freight transportation, which is employed particularly when the shipment is in a hurry. The carbon footprint is further increased by road freight transportation, which is a commonly used mode of transportation for the case company, especially in Europe. A lot of emissions are generated as well by maritime freight transportation, but the amount of emissions relative to the volume of goods transported is lower than with air freight, which is why its use is favored.

The TMS in use at the case company provides many features which enable its utilization to influence the carbon footprint of the transportation in the case company. The baseline tariff of emissions offered by the system and the ability to report emissions are the most significant of them. The case company would be able to calculate an exact estimate of the emissions produced by specific transports with the use of the emission tariff. With the use of the reporting tool that the TMS provides, the case company could observe the evolution of emissions in the system or transfer the data directly to the BI tool that is used in the case company. Reporting makes it possible to analyze and monitor emissions, and the data could be used to identify the transport companies, routes, or modes of transportation that generate the highest emissions. Long-term decisions, such as those regarding contracts with transport providers, could be determined by the case company based on the reported emission statistics.

Carrier selection is another essential function that the TMS provides and that can be utilized for lowering the carbon footprint. The function allows the case company to assess multiple transport providers or transport orders within the system and select the most appropriate one based on the requirements of the shipment. The TMS calculates the delivery time, emissions, and price for the saved transport orders, which the case company can review before placing the transport booking. When the lowest possible environmental impact on transportation is desired, the transport with the lowest emissions in that situation could potentially be selected. Similarly, if the case company is interested in reducing costs, the cheapest alternative can be selected. In addition to allowing the selection of a carrier, the TMS enables the consolidation of transport orders, which may reduce not only transportation emissions but also costs when utilized efficiently.

The calculation of emissions in the TMS relies on the emission tariff, which is provided by a third-party non-governmental organization. The tariff calculation of the organization is based on regionally defined averages all over the world but produces a result that is quite realistic. If the case company has more accurate data on the emissions generated by the transport providers that it uses, it may add them to the system. In this situation, it is also possible to entirely rely on the custom tariff determined by the case company or a combination of the custom tariff and the baseline tariff. The TMS displays emissions per tonne-kilometre and can be calculated per transport, and it also allows users to view emissions by mode of transportation or during a certain period.

The expenses associated with employing low-emission transport strategies have rarely been estimated by the case company. However, it was recognized that the expenses of more environmentally friendly alternatives are likely to be higher. Future cost evaluation becomes feasible with the aid of the TMS. Additionally, with appropriate utilization, it is possible to reduce transportation costs and optimize transportation times. In conclusion, the TMS is most useful in reducing emissions when it is utilized comprehensively and long-term by monitoring emission calculations and reports as well as making choices and decisions based on them. The TMS enhances the reliability of transportation and reduces the margin of error in the supply chain.

5.2 Discussion and future research

It can be claimed that the theoretical and the empirical parts of this research support one another. The same results that were discovered during the data collection for the empirical part are found in the scientific literature. It was also discovered that the case company could utilize the transport management system in a variety of ways and choose the one that is most suitable for its needs since it allows for the analysis and selection of transport bookings based on cost, emissions, and delivery time. As previously mentioned, data is highly significant in this context, and its value was emphasized in each interview. When data collection begins, and it is anticipated that time-comparable data will be presented in the system, using the TMS to cut emissions can first take a bit longer. Additionally, specific functions, such as carrier selection, can require more time, especially immediately after implementation when the most effective ways of use are still being searched for. However, the advantages are more evident with time, and the utilization of the TMS improves and becomes routine as the best operational strategies and solutions are identified.

As concluded, the literature confirms the findings of the study, showing that the TMS in use would have the potential to affect the transportation emissions of the case company. The results of the research are important because, as previously said, transportation contributes significantly to the generation of emissions globally. In order to contribute towards a sustainable world, the case company should decrease its carbon footprint in its operations. The case company would benefit from learning how the TMS features described in this research can be used in the transportation process in the future.

Even though there were only a few interviews, the outcomes would barely have altered if the sample size had been larger. Since the system has only so far handled the transport bookings of the case company in the background, any new responses would have likely been identical to those that were received from the interviews conducted now. Therefore, it is reasonable to assume that the research methods and information employed provided an accurate representation of the current situation facing the case company and the research objective.

At the end of the interviews, speculation was given as to how the case company's transportation process could appear in the very distant future. There is an aspect that the entire transportation process may change considerably, for instance, if there were additional warehouses closer to customers, in which case there would likely be less transportation from the company. Furthermore, for instance, 3D printing opens new possibilities in the future that customers can take advantage of to produce certain parts themselves rather than spending time waiting for delivery. The implementation and purpose of the TMS could be significantly changed by this scenario.

Future research could be conducted to investigate how the transportation process changes if the investigated functions of the TMS are adopted in the case company. The research could then be conducted quantitatively, in which case accurate data on transportation emissions would be used, and the results would be specific numbers on how much emissions can be decreased in a specific amount of time or with a specific mode of transportation. There are also other options for further research in the same area. It would be possible to replicate this study and examine how using the TMS could influence emissions for a specific mode of transportation, such as air or road freight transportation. Alternatively, the research could focus on how the TMS can be used to impact transportation costs or emissions generated from outbound transportation. Additionally, it could be interesting to investigate the types of emissions produced by the movement of company employees, such as during international business trips.

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Appendices

Appendix. The interview questions

Knowledge, operation

1. Can you describe how your current role is connected to the incoming material flow in the case company?
2. What modes of transportation does the case company use, and when are particular modes preferred?
3. Can you describe the current transportation processes used by the case company and how they contribute to the carbon footprint?
4. Can you explain how the transport management system used in the case company works and how it reduces carbon emissions in freight transportation?
5. How are costs affected when a transport management system prioritizes reducing carbon emissions?

Metrics, evaluation, assurance

6. What metrics do you use to evaluate the effectiveness of the transport management system in the case company?
7. How do you measure the carbon footprint of industrial transportation within a transport management system?
8. Which modes of transportation result in the highest carbon footprint for the case company, and in what situations are they used?
9. How is it assured that the efforts to reduce carbon emissions from transportation align with the sustainability goals and strategies of the case company?

Strategy, sustainability, future prospects

10. What are the most important elements in freight transportation from the case company's perspective?
11. How does the aim to reduce carbon footprint affect the decision-making when choosing a certain mode of transportation or does it?
12. In what ways have transportation strategies been affected by the recent focus on sustainability?
13. What are your expectations for the future of the transportation process in the case company?