ALLOCATION OF EMISSIONS TO CUSTOMERS IN ACTIVITY-BASED COSTING IN RAIL LOGISTICS

Lappeenranta–Lahti University of Technology LUT

Master's thesis in Industrial Engineering and Management

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Eevi Antila

Examiners: Professor Timo Kärri

University Lecturer Leena Tynninen

ABSTRACT

Lappeenranta–Lahti University of Technology LUT
LUT School of Engineering Science
Industrial Engineering and Management

Eevi Antila

Allocation of Emissions to Customers in Activity-Based Costing in Rail Logistics

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Emissions calculation has a significant impact on the understanding, management, and reporting of the environmental impact of a company. With the growing importance of sustainability, customers and other stakeholders are increasingly interested in transport emissions. To promote and standardize emissions accounting, international agreements and regulations have been developed. In the coming years, companies will be required to report their emissions. The credibility of emissions calculations relies heavily on their accuracy and transparency. This thesis aims to describe and clarify the current emissions accounting process of the target company, with a particular focus on the calculation and allocation of emissions to logistics customers. Additionally, it aims to identify the factors that the company must consider when calculating emissions both presently and in the future.

The study is conducted as qualitative research and consists of a literature review, an empirical section, and an expert interview. The literature review investigates emissions and emissions calculation in rail logistics, activity-based costing, and regulatory factors that impact emission calculation. The empirical part examines the applicability of activity-based costing to emissions accounting and assesses the target company's emissions calculation and allocation to customers. The empirical part also identifies the most important factors that must be considered in emissions calculation now and in the future.

The study concludes that emissions can be calculated and allocated in activity-based costing by treating emissions as costs. In rail logistics, direct emissions are caused by the use of diesel. In VR Transpoint's calculation, emissions from diesel use are allocated to traction and handling activities based on their outputs. Emissions are allocated from activities to cost objects, such as customers and customer orders, through wagons. By calculating emissions as part of activity-based costing, emissions can be allocated at a precise level. In activity-based costing, emissions are included in continuous calculation and reporting and can be used for decision-making in the same way as financial indicators. In the future, the most significant factors influencing emissions calculation will be the Corporate Sustainability Reporting Directive and its standards. In addition to direct emissions, indirect emissions must be considered in future calculations. It must also be considered that future technological developments will allow more accurate data to be made available for emissions calculations. In addition, the use of cleaner fuels must be included in the calculations as they help to reduce emissions.

TIIVISTELMÄ

Lappeenrannan–Lahden teknillinen yliopisto LUT
LUT Teknis-luonnontieteellinen
Tuotantotalous

Eevi Antila

Päästöjen allokointi toimintolaskennassa asiakkaille rautatielogistiikassa

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Päästölaskennalla on merkittävä vaikutus liiketoiminnan ympäristövaikutusten ymmärtämiseen, hallintaan ja raportointiin. Kestävän kehityksen merkityksen kasvaessa myös asiakkaiden sekä muiden sidosryhmien kiinnostus kuljetusketjujen päästöihin on kasvanut. Päästölaskennan edistämiseksi sekä standardoimiseksi on kehitetty kansainvälisiä sopimuksia ja säädöksiä, jotka velvoittavat yrityksiä raportoimaan päästöjä lähivuosina. Päästölaskennan oikeellisuus ja läpinäkyvyys ovat merkittäviä tekijöitä laskennan uskottavuuden kannalta. Tämän diplomityön tavoitteena on kuvata ja selventää kohdeyrityksen nykyisen päästölaskennan logiikkaa, keskittyen erityisesti prosessiin, jossa päästöt lasketaan ja kohdistetaan rautatielogistiikan asiakkaille. Tämän lisäksi tavoitteena on tunnistaa tekijät, jotka yrityksen on otettava huomioon päästölaskennassa nyt sekä tulevaisuudessa.

Tutkimus on toteutettu laadullisena tutkimuksena ja se koostuu kirjallisuuskatsauksesta, empiriaosuudesta sekä asiantuntijahaastattelusta. Teoreettisessa osuudessa eli kirjallisuuskatsauksessa tutkitaan rautatielogistiikan päästöjä, päästölaskentaa, toimintolaskentaa sekä päästöihin vaikuttavia lainsäädännöllisiä tekijöitä. Empiriaosuudessa tutkitaan toimintolaskennan soveltuvuutta päästölaskentaan sekä arvioidaan kohdeyrityksen päästölaskentaa ja päästöjen allokointia asiakkaille. Empiriaosuudessa tunnistetaan myös tekijät, jotka on otettava huomioon päästöjen laskennassa nyt ja tulevaisuudessa.

Tutkimuksen tuloksena todetaan, että päästöjä voidaan laskea ja allokoida toimintolaskennassa käsittelemällä päästöjä kuten kustannuksia. Rautatielogistiikassa suorat päästöt aiheutuvat dieselin käytöstä. VR Transpointin laskennassa dieselin käytöstä aiheutuvat päästöt kohdistuvat veto- ja vaihtotyötoiminnoille niiden suoritteiden perusteella. Päästöt allokoituvat toiminnoilta vaunuille ja niiden tilaussidonnan kautta rautatielogistiikan asiakkaille. Päästölaskenta osana toimintolaskentaa mahdollistaa päästöjen allokoinnin hyvin tarkalle tasolle. Toimintolaskennassa päästöt ovat integroitu osaksi jatkuvaa laskentaa ja raportointia, ja niitä voidaan hyödyntää taloudellisten tunnuslukujen tapaan päätöksenteossa. Tulevaisuudessa merkittävä päästölaskentaan vaikuttavia tekijä on CSRD-kestävyysraportointidirektiivi, jonka standardit on otettava huomioon laskennassa. Suorien päästöjen lisäksi myös epäsuorat päästöt on tulevaisuudessa otettava huomioon. Teknologian kehitys tulee tulevaisuudessa mahdollistamaan tarkemman datan saatavuuden päästölaskentaa varten. Uusien, ekologisimpien energialähteiden käytön aloittaminen tulee myös vaikuttamaan osaltaan päästölaskentaan.

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This thesis concludes my four and a half years of study at LUT. I am grateful for the many wonderful memories, new friends, and new learning experiences that I have gained during this time. With the completion of this thesis, a new chapter of my life begins, leaving behind my life as a student.

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Helsinki 5.1.2024

Eevi Antila

ABBREVIATIONS

ABC	Activity-Based Costing
CO2	Carbon Dioxide
CO2e	Carbon Dioxide Equivalent
CSRD	Corporate Sustainability Reporting Directive
ESG	Environmental, Social, and Governance
ESRS	European Sustainability Reporting Standards
GHG	Greenhouse Gas
GRI	Global Reporting Initiative
GWP	Global-Warming Potential
HGV	Heavy Goods Vehicles
HVO	Hydrotreated Vegetable Oil
ISO	International Organization for Standardization
ISSB	International Sustainability Standards Board
NFRD	Non-Financial Reporting Directive
SQL	Structured Query Language
TTW	Tank to Wheel
WTW	Well to Wheel

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1 Introduction

The first chapter contains the steps that led to the writing of the thesis. The chapter provides background information on the study, including the research problem and scope, the methods used in the study, and the data collection. The last subsection also presents the structure of the thesis.

1.1 Background

With corporate social responsibility playing a critical role in today's business environment, sustainability is receiving increasing attention in the business sector. The achievement of overall sustainable development is dependent on the sustainability of businesses in the face of today's environmental, social, and governance challenges. Companies are increasingly adopting responsible practices and integrating sustainability principles into their strategic management as sustainability and corporate social responsibility become an integral part of everyday business operations. Sustainable business practices may benefit companies by creating both tangible and intangible benefits, including revenue growth, increased market share, new market opportunities, corporate reputation, and competitive advantage. In recent years, investor awareness of sustainability as a viable business strategy has grown. Both individual and institutional investors are expressing increasing concern about the environmental, social, and governance (ESG) practices of the companies in which they invest. Ethical business practices have now risen to the top of the list of valued attributes for investors, even surpassing strong management. (Jančiauskaitė, et al., 2019; Hill, 2020, pp. 1-2)

Emissions reporting is a crucial component of sustainability reporting, particularly in the context of environmental reporting. As the importance of sustainability has grown, so has the interest in emissions, and more and more companies are reporting their greenhouse gas emissions as part of their sustainability reporting. Emissions reporting has long been a voluntary choice for companies, but the trend is changing. Several regions and jurisdictions are now implementing mandatory reporting requirements (Dancey & Mendiluce, 2023). In January 2023, the European Commission implemented the Corporate Sustainability

Reporting Directive (CSRD), mandating large and listed companies to disclose their ESG information in accordance with the European Sustainability Reporting Standards (ESRS). Emissions are part of the new mandatory directive, which will require large companies to publish their emissions according to defined guidelines (European Comission, 2023a).

The disclosure of non-financial indicators responds to a growing demand from customers and investors for transparent information on the emissions resulting from activities related to their business. In the logistics sector, emissions disclosure requires documentation of the emissions associated with transportation, which affects the total emissions of the final product. Companies are responsible for reporting not only their own emissions, but also those associated with their respective supply chains, creating a demand for customer- and product-specific emissions data. Allocating emissions in rail logistics can be challenging as multiple trains and products from different customers can be involved in a single delivery. Since the emissions are generated by the locomotive unit, it is important to correctly allocate the emissions from the locomotives to the wagons and finally to the customers. In activity-based costing, emissions can be treated as costs, enabling their allocation down to a highly precise customer and order level. Activity-based costing provides an accurate and thorough examination of costs at the product, service and customer level by allocating costs to activities based on their resource usage. (Miller, 2017) In order to accurately allocate emissions at the customer, product or route level, VR Transpoint has developed its emissions calculation into an activity-based costing.

In May 2022, VR Group announced the issuance of its first green bond, marking an important step in the expansion of its financing strategy towards sustainable initiatives. The EUR 300 million, seven-year bond was offered to investors in both Nordic and Central Europe (VR Group, 2022). Green bonds are fixed-income instruments created to finance environmental and sustainable development initiatives. The funds are allocated solely towards new and ongoing projects, especially for infrastructure investments. A distinctive feature of green bonds compared to traditional bonds is their detailed reporting requirements of the projects they finance and their eco-friendly nature (Deschryver & de Mariz, 2020). Sustainability-linked bonds debuted in 2019 as a financial instrument promoting the transition to contractual sustainability goals. However, even with the adoption of standards and principles requiring third-party verification and sufficient reporting, greenwashing of sustainability-linked and green bonds remains a concern (European Comission, 2023b).

Transparency in the calculation and allocation of emissions is essential to ensure the credibility of the calculation. The recent legislative changes have led to a significant increase in interest in emissions logic from both internal and external stakeholders in rail logistics, which has increased the demand for information related to emissions calculation. VR Transpoint uses activity-based costing encoded in a cloud-based data warehouse to calculate customer-specific emissions. In the past, the logic used to calculate emissions has not been transparent to stakeholders. This is because the calculations are done and maintained in databases that are not accessible to the public. This study will enable VR Transpoint's stakeholders, especially customers, to understand the emissions allocated to them by understanding the emission sources and allocation methods of their transportation emissions.

1.2 Research problem and scope

The purpose of this thesis is to describe and clarify the logic behind the target company's current emissions calculation, with a particular focus on the process of allocating emissions to logistics customers, and to identify the factors that the company must consider in the calculation of emissions in both the short and long term. Environmental accounting encompasses several accounting and regulatory aspects; however, this study focuses on carbon accounting and its unique characteristics. This study examines the suitability of activity-based costing for carbon accounting, including the specifics of emissions treatment and allocation logic. The target company VR Transpoint calculates and allocates its direct emissions to customer companies using activity-based costing, and this work will document and analyze how this calculation and allocation is done. For confidentiality reasons, this study does not analyze individual emissions per customer or route. Instead, it defines the direct emissions resulting from rail logistics, identify their sources and generation methods, illustrate their customer allocation process, and investigate the factors influencing their allocation.

Accounting and reporting on corporate responsibility is at a crucial turning point due to upcoming and, in some cases, already enacted regulatory changes. Accordingly, the study analyzes existing approaches and explores current and future factors that will influence emissions calculation and reporting. According to Puusa & Juuti (2020), a well-defined study has two or three research questions. This thesis examines the calculation and allocation

of emissions through two research questions. The first question focuses on the allocation of emissions in VR Transpoint's activity-based costing. To understand the allocation logic, it is necessary to understand how activity-based costing works, where emissions are generated in rail logistics, and how they should be considered in the calculation. The second research question concerns significant emission-related factors now and in the future.

The research questions of this study are:

How are the emissions allocated to the customers in the activity-based costing of VR Transpoint?

What factors should be considered in emissions calculation now and in the long term?

This study focuses exclusively on the calculation of emissions in activity-based costing and examines the current and future factors that affect them. The focus of this research is narrowed to the calculation of emissions in the broad field of environmental accounting. The study focuses exclusively on direct emissions. Different types of emissions are explained and illustrated in the first section. In rail logistics, the only direct emissions are from locomotive's diesel consumption. Therefore, the study will focus on their emissions. Indirect emissions from electricity are briefly mentioned but are not examined due to their different nature. The study does not comment on the emissions resulting from the calculation but focuses only on the calculation methodology. In addition, instead of actual emission figures, the study uses illustrative figures from which actual emissions cannot be derived. The study concentrates on VR Transpoint's activity-based costing and emissions calculation. Nevertheless, the outcomes of this thesis can be applied to other similar industries and companies, especially to logistics. The theoretical aspect of this study has been developed from the point of view of rail logistics, but the conclusions can be applied to other modes of transport.

1.3 Research methods and data collection

This thesis is conducted as qualitative research focusing on understanding and clarifying the emissions calculation and allocation in the activity-based costing of the target company and the factors that the company must consider in calculating emissions in both the short and long term. The primary methods used for data collection in qualitative research include interviews, observations, and information gathered from various sources (Tuomi & Sarajärvi, 2018). In this thesis, theoretical information is collected from the academic literature of the subject area in the form of a literature review, and information on the logic of the current activity-based costing from its codes. The information collected from the literature and codes is combined and evaluated to answer the research questions. According to Tuomi and Sarajärvi (2018), an open, unstructured, conversational interview can be used as a data collection method in qualitative research. A conversational interview was conducted during the research to support the data collection and to clarify the factors used in activity-based costing.

A literature review is conducted to identify, evaluate, interpret, and synthesize existing knowledge. The aim of the literature review is to summarize the existing knowledge of scientific research in the field and to draw key conclusions for the research question. The aim of the review is to present a thorough and unbiased synthesis of the available information. (Vilkka, 2023) The literature review in this thesis uses the most recent and relevant academic publications as well as publications from official bodies related to standards, regulations, and guidelines. In addition, official publications of the target company, such as the annual report, and other reliable articles are included to obtain the most current information. Sustainability reporting and CO2e calculation is a rapidly evolving research field, with the latest and most comprehensive information derived from a range of publications and journals in the field.

VR Transpoint's activity-based costing is written in SQL and is structured in data tables that always refer to the previous ones. To understand the logic and correctly allocate CO2e emissions to customers, it is necessary to review the codes that are used in emission calculation and allocation. The data collected and documented during the review follows the appropriate naming conventions and calculations. However, to maintain confidentiality and clarity, simpler names are used for the purposes of this study. No modifications have been

made to the data or its logic. During the review, various structure and relationship diagrams were used to collect and comprehend the logic data, thereby clarifying the logic for the work. Eventually, the collected data is presented in an easily comprehensible, written format, with logical terminology. To avoid misunderstandings of the work and its very sector-specific terms, a Finnish-English glossary is provided in Appendix 1.

An expert interview was conducted as a means of data acquisition for the thesis. The interview followed a semi-structured, thematic format, with both parties understanding the purpose and subject area beforehand. Conducting interviews is a flexible approach to research as direct interaction with the interviewee creates opportunities to gather information as the situation arises. During the interview, it is possible to change the order of topics discussed and focus on specific issues. (Hirsjärvi & Hurme, 2022) The questions that served as the basis for the interview can be found in Appendix 2. The interview questions were defined in advance to clarify the interview topic, but the interview was conducted as a conversational interview and no strict framework was followed. The objective of the interview was to obtain an expert's impartial and knowledgeable perspective on the environmental variables impacting activity-based costing, which cannot be ascertained solely through data analysis. During the interview, emissions accounting in general and its prospects were also discussed. The interview was conducted as a conversational theme interview in which the questions were discussed in a casual manner.

1.4 Structure of the thesis

This thesis consists of six main chapters, along with their subsections, references, and appendices. The first main chapter is the introduction, and it presents the contextual background of the research, the research problem and scope, the research methods, and the structure of the thesis. The second main chapter begins with a definition of terms. There are numerous terms in rail logistics that can have different meanings in everyday language. For this reason, the first subchapter in the second main chapter establishes the definitions of the terms used throughout this thesis. Otherwise, the second chapter provides an overview of rail logistics emissions. It covers their generation, calculation, and allocation. The third main chapter focuses on activity-based costing in logistics and carbon accounting. The third main

chapter also examines how emissions can be handled in activity-based costing and what regulations and standards can be used in emissions accounting.

The fourth main chapter introduces VR Transpoint's operations and activity-based costing model from an emissions calculation perspective. The chapter starts with an introduction of VR Group and VR Transpoint and their business environment and customer base, before moving on to emission factors, data sources, and emissions calculation and allocation. The logic of the emissions calculation is demonstrated through fictional events and examples. The expert interview results are also presented in chapter four. The fifth main chapter evaluates the handling and allocation of emissions, the logic of the calculation, future developments, and areas for improvement. The sixth and final chapter of this thesis provides a concise summary of the main findings and addresses the research questions.

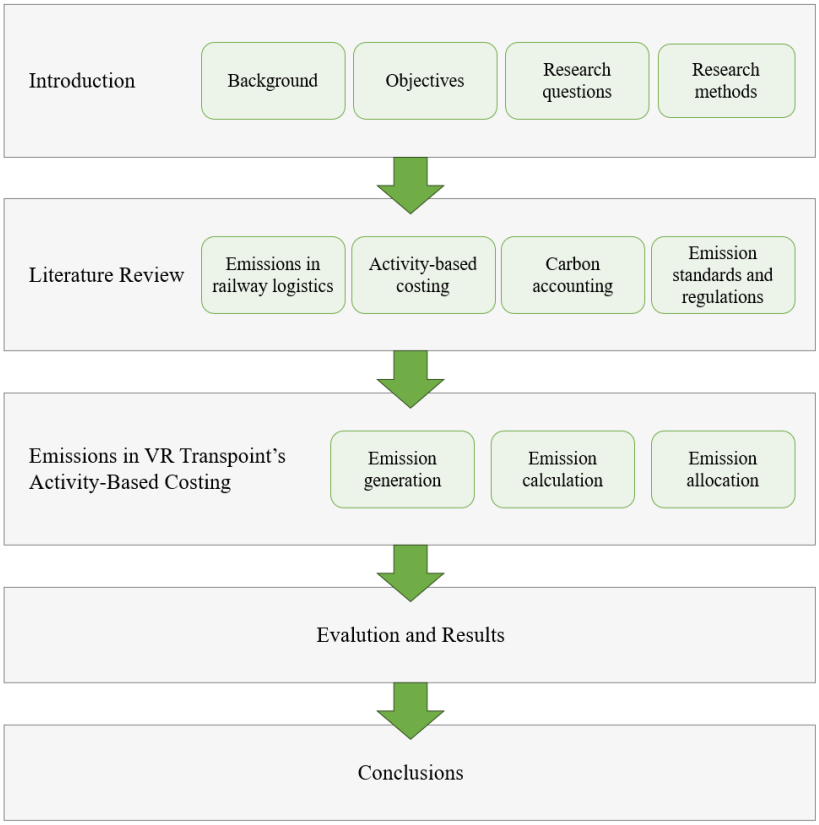

Figure 1. Structure and progress of the thesis

The structure and progression of the thesis by topic is shown in Figure 1. After the introduction, the paper proceeds to the theoretical section, followed by a company overview that includes a presentation of the company and its current approach to emission accounting. Subsequently, an evaluation and results will be presented.

2 Emissions in rail logistics sector

Rail logistics has unique characteristics that distinguish it from other logistics industries. Rail is an environmentally friendly option for freight transport compared to other alternatives, and the development of low-emission rail transport is constantly being explored (Balsen, 2021). This chapter begins by defining the terms utilized in rail logistics in Finland. This is followed by a closer examination of emissions in rail logistics, including their generation, calculation, and allocation.

2.1 Definitions

Rail transportation offers numerous economic, social, energy, and environmental benefits. Unlike other land-based modes of transportation, rail transport is not troubled by the same issues. It is safe, congestion-free, and has lower emissions and fuel consumption per unit transported. Railways also require less land, approximately one-third of the land used by highways on average. In addition, railroads have high transportation speeds, which allows for rapid transportation. Rail transportation activities are primarily related to freight transportation. There are currently three modes of rail transportation worldwide: rail unit, carload, and intermodal. The intermodal mode connects sea and road transport through the use of trailers, containers, and tanks. (Dincer & Zamfirescu, 2016)

Before an examination of the emissions of rail logistics, it is important to have an understanding of the terminology of rail logistics. In colloquial language, several terms in rail logistics are often misused. For example, the word "train" may refer to a locomotive, wagons, or a combination of both in casual conversation. Nevertheless, in rail logistics, a train specifically refers to a locomotive or locomotives with at least one wagon attached. The definitions of these terms are highly dependent on context. Thus, the following Table 1 outlines the definitions of rail logistics terms used in this thesis. In addition to these general terms, Appendix 1 includes a Finnish-English dictionary of rail logistics for reference.

Table 1. Rail logistics terminology

Term	**Definition**
Traction unit	The traction unit of a train, which moves the wagons. Almost always a locomotive.
Locomotive	A self-propelled railroad vehicle specifically created to haul and maneuver trains. Equipped with engine to provide power.
Train	A railway vehicle with a one or more traction units and a variable number of wagons.
Wagon	A wagon is used for transporting either passengers or goods when it is attached to a train.
Track	A railway line, which may consist of one or more tracks.
Locomotive kilometers	One kilometer traveled by the locomotive.
Train kilometers	One kilometer travelled by train.
Net tons	Weight of the transported goods.
Gross tons	The total weight of the transportation, including both the weight of the goods being transported and the weight of the transportation fleet.
Route	Total distance between the train departure and arrival station.
Subinterval	A segment of the route over which a locomotive or train travels.
Station	A place where trains stop to pick up and set down passengers and load or unload cargo.
Yard	The track area of a railway station where wagons are loaded and unloaded and where trains are assembled.

Many concepts listed in Table 1 are utilized in official rail logistics statistics, and their definitions can be found in Statistics Finland's concept database (Statistics Finland, 2023). In rail logistics, the terms 'station' and 'yard' are often used synonymously, but their meanings differ slightly. A rail yard refers to the section of a station area where rail wagons are loaded, unloaded, and moved. There is no passenger traffic in the yard due to the absence of platforms. Rail transportation operates between stations, with each transportation involving a departure and arrival station. However, in logistics, trains usually depart from and arrive at rail yards. In this study, focus is on logistics and not passenger transportation. As such, the terms yard and station are used interchangeably to refer to the location where wagons either leave, arrive or where they are shunted. The choice of term is influenced by the context in which it is used.

In addition to rail logistics terminology, there is a term in environmental accounting that has various definitions in the academic literature. Carbon accounting is defined differently depending on the context and the user. This relatively new term does not yet have a fully established definition, but for this study, we will adopt Tang's (Tang, 2017) widely used information-perspective definition of carbon accounting, which defines it as *"carbon accounting is a system that uses accounting methods to record and analyse climate-change information as well as account for and report carbon-related assets, liabilities, expenses, and income for decision-making purposes"*. Depending on the context, the term carbon accounting is also used as a synonym for greenhouse gas accounting in the literature, although some sources define them as different terms. It is important to note the possible subtle difference between these terms in the literature, but for the purposes of this work, the term carbon accounting is considered to be synonymous with greenhouse gas accounting. This paper will focus on the use of the term carbon accounting as it is the primary term in the literature and the empirical section will focus on carbon dioxide equivalents. Other greenhouse gases are included as carbon dioxide equivalents, i.e., their global-warming potential has been converted to the same form as carbon dioxide. (Peterdy, 2022; He, et al., 2022; Webber, 2023; IBM, 2023)

2.2 Background of emissions in rail logistics

The environmental, economic and health impacts of greenhouse gases have been the subject of intense study and debate by scientists, regulators, and other groups for several decades. Greenhouse gases are primarily emitted into the atmosphere as a byproduct of the burning of fossil fuels by individuals, households, and businesses (Fornaro, et al., 2009). The transportation industry ranks third in the world as a major source of greenhouse gas emissions. Freight transportation was responsible for 36% of all transportation emissions in 2015. By the year 2050, it is anticipated that freight transportation will be on par with, if not exceed, passenger transportation (Greene & Lewis, 2019, p. 7). Greenhouse gas emissions contribute to climate change, leading to global warming, melting polar ice caps, rising sea levels, and more frequent extreme events like floods and droughts. Increased atmospheric levels of carbon dioxide are a primary factor in the 1°C temperature rise since pre-industrial times. (Ahsan, et al., 2023)

Seven main greenhouse gases, that have also been classified in Kyoto protocol, are carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulfur hexafluoride (SF6) and later added nitrogen trifluoride (NF3) (Shi, 2017, p. 4). Due to their ability to trap the heat from the sun in the Earth's atmosphere, many scientists have identified GHGs as the primary contributor to global warming (Fornaro, et al., 2009). According to the greenhouse gas inventory of Statistics Finland, the greenhouse gas emissions from transportation in Finland in 2020 were approximately 10.4 million metric tons of carbon dioxide equivalent (Mt CO2e), which is approximately 7% (0.8 Mt) lower than in 2019. During 2020, road transport was responsible for generating around 95% of domestic transport's greenhouse gas emissions, while rail transport's emissions were about 0.06 Mt CO2e, accounting for less than 1% of domestic transport emissions. Emissions from rail transportation in Finland have decreased since 1994, in part due to the electrification of the rail network. (Traficom, 2022)

Rail logistics emissions consist mainly of carbon dioxide, which is a major greenhouse gas. In 2019, 98.8% of transport greenhouse gas emissions were carbon dioxide in the EU-27 area (European Environment Agency, 2022, p. 25). Carbon dioxide equivalent is commonly used unit that measure emission of logistic operations (Greene & Lewis, 2019, p. 14). A carbon dioxide equivalent (CO2e) is a metric unit that measures and compares greenhouse

gas emissions based on their potential for causing global warming. This is done by converting the amounts of other gases into the amount of carbon dioxide that has the equivalent potential to cause global warming. (European Environment Agency, 2001) The term global-warming potential (GWP) denotes the relative potency of a greenhouse gas, measured molecule for molecule, with regard to its longevity in the atmosphere. Currently, GWPs are calculated over a century. Carbon dioxide serves as the reference gas, assigned a GWP of 1 over 100 years. (Eurostat, 2023)

For sustainable development, it is important to integrate green logistics and transport practices into the freight logistics industry (Derbel, et al., 2020, p. 87). Rail is the least polluting option for freight transport, while heavy goods vehicles (HGV) are the least environmentally friendly option from the point of view of emissions minimization. The CO2 emissions of freight trains are 80% lower than HGV per one ton transported per kilometer. (Balsen, 2021) Figure 2 shows the changes in rail transport emissions in Finland over past three decades and the energy consumption by energy types, electricity and diesel. The emissions were measured and calculated by LIPASTO (2021), a former Finnish unit emissions database.

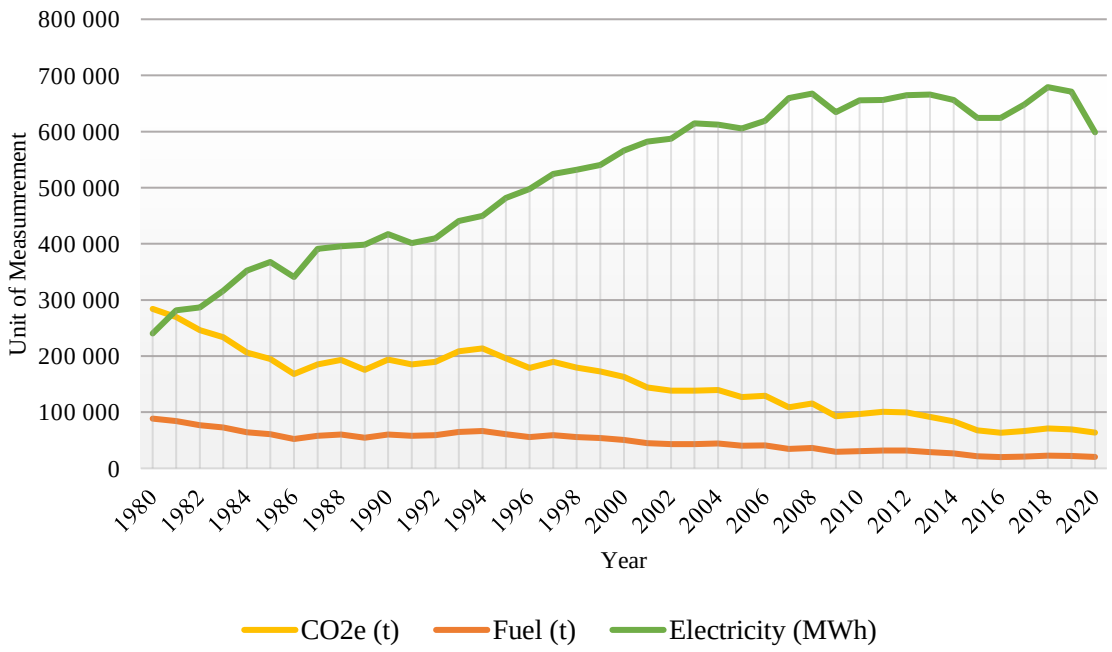

Figure 2. Finnish rail transport emissions and energy consumption from 1980 to 2020, calculated by LIPASTO (2021)

Rail technologies and their environmental impacts are continuously researched. The primary purpose of the study on current and future fuels for the rail sector is to examine the environmental impact of different rail technologies. Emissions from rail logistics can be influenced, for example, by fuel choice. According to a study by Dincer and Zamfirescu (2016), integrating a catalytic converter and increasing the use of biodiesel can achieve up to 50% lower environmental impact. In Europe, several rail operators have investigated alternative fuel options, and some have already changed to the use of alternative fuels. Hydrotreated Vegetable Oil (HVO) is one of the most prominent alternatives for diesel. For instance, in order to address concerns regarding the ecological effects of diesel-powered trains, Chiltern Railways initiated a program to implement HVO as a fuel source for their services in the United Kingdom. On July 27, 2023, the first passenger train powered by HVO began operating in UK. Greenhouse gas emissions can be reduced by up to 90% and particulate matter by 85% by using vegetable oils to power trains. Furthermore, depending on the type of engine and its usage, it can also minimize other emissions like nitric oxide and carbon monoxide. (Cech, 2023; Khan, 2023; Shell Catalysts & Technologies, 2022)

2.3 Emissions generation in rail logistics

Direct emissions from the rail logistics sector are caused by the fuel consumption of trains. Energy is an integral part of environmentally sustainable logistics operations (Abbasi & Nilsson, 2016). Rail logistics use two primary sources of energy, which are electricity and diesel. Steam was once the most popular source of energy, but nowadays, with the advent of newer technology and more efficient and greener alternatives, it is mainly used for tourism and historic purposes (Butterworth, 2022). Rail transportation emissions can be classified into two categories: direct emissions and indirect emissions. Direct emissions refer to those generated during fuel combustion, while indirect emissions are produced during energy production and distribution. Emissions from energy production and distribution include all emissions from the energy source (the well) to the point where the energy is in the tank of the vehicle ready to be used. Direct emissions result from the energy sources employed to power the train. Hence, they occur during the operation and movement of the train. In other words, fuel emissions can be divided into emissions from the well to the tank (WTW) and emissions from the tank to the wheel (TTW). Fuel lifecycle emissions include all emissions that occur when the fuel is produced, distributed, and combusted. Electricity is different from

fuels in multiple ways, including the fact that it only produces emissions during production and distribution. It is therefore considered to be emission-free during its use, since any emissions associated with electricity occur during the production and distribution phases. (Greene & Lewis, 2019, p. 17)

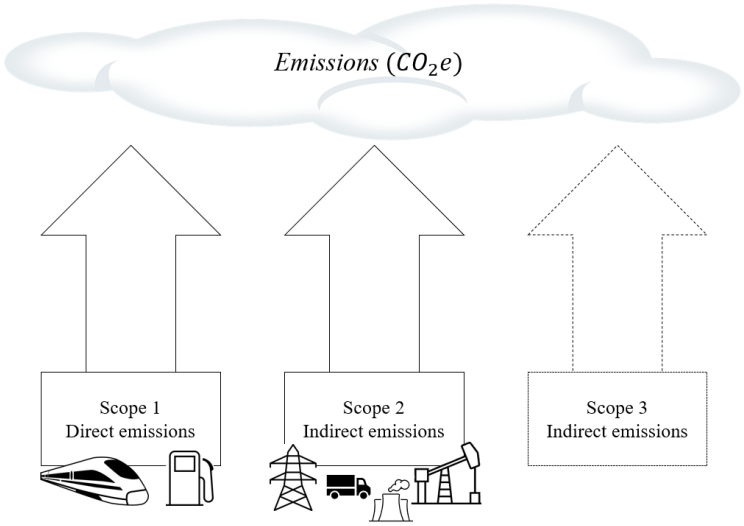

Figure 3. Emissions can be divided into three scopes

As presented in Figure 3, three emission accounting and reporting scopes have been established to help delineate direct and indirect sources of emissions, improve transparency, and provide benefits for different types of organizations and different types of climate policies and business objectives. Scope 1 covers direct emissions from company-owned sources, such as fuel used in transportation. Scope 2 covers emissions from the production of energy used by the company. Scope 2 emissions are therefore generated during the energy production phase at the production facilities, rather than directly during use. Scopes 1 and 2 ensure consistency in how various stakeholders manage emissions and prevent double counting. In addition to these two essential scopes, there is a third, optional scope 3 that focuses on upstream and downstream indirect emissions. Scope 3 emissions are the result of the activities of the company, but they originate from sources that are not owned or controlled by the company. (Huang, et al., 2009, p. 8509; Ranganathan, et al., 2004) These scopes are defined in Table 2.

Table 2. Definitions of emission scopes

Scope	Definition
Scope 1	All direct emission from fuel consumption (Greene & Lewis, 2019, pp. 17-18; Zhou, 2020, pp. 33-35)
Scope 2	Indirect emissions associated with the consumption of purchased energy. (Greene & Lewis, 2019, pp. 17-18; Zhou, 2020, pp. 33-35)
Scope 3	All other indirect emissions, such as upstream and downstream emissions and emissions from ancillary activities. Scope 3 emissions are optional to report. (Greene & Lewis, 2019, pp. 17-18; Zhou, 2020, pp. 33-35)

Railway transportation emissions are primarily composed of carbon dioxide, while other emissions can be converted to the standard unit of emissions measurement, carbon dioxide equivalent (CO2e). CO2e is a crucial metric since it is widely recognized as the benchmark for quantifying greenhouse gas emissions. (Peterdy, 2022; European Environment Agency, 2022, p. 25) In addition to quantifying greenhouse gas emissions, the use of carbon dioxide equivalents serves as a vital tool for communicating sustainability amongst various stakeholders. Emission quantification and monitoring allows companies to integrate emissions data into their decision-making processes and to use emissions as performance indicators for planning and setting targets in their operations and supply chains (Greene & Lewis, 2019, p. 9).

2.4 Emission calculation and allocation

The allocation of carbon emissions plays an important role in determining reduction responsibilities at the national economy level or emission permits at the company level. In recent decades, various methods have been developed and applied to calculate and allocate emissions at different levels, such as between companies or countries. (Zhou & Wang, 2016, p. 47) The commonly used method for quantifying emissions involves a multiple emission conversion factor calculation based on activity data, with subsequent summation of emissions data for each activity (Zhou, 2020, p. 36). The first step in calculating carbon emissions is to define the boundaries of the measurement. These boundaries refer to the

coverage and scope of the calculation, and therefore they determine what to include and what to exclude. Organizational boundaries define the activities, facilities, and units to be included in the inventory, while operational boundaries identify emission sources and categorize emissions from activities, facilities, and units within an organization, either directly or indirectly. (Zhou, 2020, p. 27)

Organizational boundaries refer to the activities owned or controlled by an entity for which emission activity is reported. Various approaches, such as the equity approach and the operational control approach outlined in the Greenhouse Gas Protocol: A Corporate Accounting and Reporting Standard, by the World Resources Institute and the World Business Council for Sustainable Development, can be utilized to determine a company's organizational boundary. (Young, 2010) In an equity share approach, a company records greenhouse gas emissions based on its percentage of equity in each activity. If this approach is chosen, all emission sources that are wholly or partly owned by the company must be reported according to its equity share in each source. Another common approach is the control approach. Under the control approach, an entity only reports emissions from activities over which it has control. Under the control approach, control can be defined in financial or operational terms. (Zhou, 2020, pp. 27-29) Operational boundaries define the direct and indirect emissions associated with activities owned or controlled by the reporting entity. The focus of the boundary definition is to identify and classify the emissions associated with an activity. Emissions can be categorized as scope 1, 2, and 3, where 1 refers to direct emissions, 2 refers to indirect emissions from electricity consumption, and 3 refers to other indirect emissions. (Zhou, 2020, pp. 33-36)

Activity data provides information on how much activity generates emissions within a certain period. For example, it may include specifics on energy use, manufacturing, deforestation, system administration, and chemical applications (The National Research Council, 2010). For corporate carbon audits, activity data is obtained from the reporting company and emission conversion factors from local guidelines. If the required emission factor is not available from local guidelines, other national standards or practices may be used. The collection of the activity data is important step in carbon calculation. The data can be collected in various sources depending on the maturity of the data. (Zhou, 2020, p. 36) Table 3 shows the data and data sources required to calculate scope 1 emissions in rail logistics.

Table 3. Activity data and its sources of emissions in rail logistics

Emission	Activity data type	Source
Emissions from mobility	Fuel consumption, liters Locomotive kilometers, km Train kilometers, km Freight weight, kg	• Service station card details • Fuel procurement data • Vehicle distance data. • Order information (Zhou, 2020, p. 37)
Emissions from shunting/handling	Fuel consumption, liters Shunting activities, minutes	• Service station card details • Fuel procurement data • Shunting data (Zhou, 2020, p. 37)
Emissions from stationary combustion	Fuel consumption, liters Time, minutes	• Fuel procurement data • Time data. (Zhou, 2020, p. 37)

Assessing the environmental impact of processes related to energy consumption, such as transport, is a complex task. There are various tools and methodologies for assessing environmental impacts, such as life cycle assessment (LCA), which allows emissions to be estimated over the entire life cycle, including extraction, production, use and disposal of raw materials (Ahsan, et al., 2023). One of the primary issues in allocating emissions is determining the allocation principle to be applied. These principles can be roughly divided into two categories, namely fairness and efficiency principles. More general concepts of distributive justice are often associated with the principle of fairness. The efficiency principle is mainly relevant to the economic efficiency of emission reductions, e.g., minimizing the total cost of emission reductions. While fairness and efficiency principles have specific emphases, efficiency can also be considered a type of fairness. (Zhou & Wang, 2016, p. 48).

3 Activity-based costing and carbon accounting

Activity-based costing is a versatile accounting system enabling precise cost calculation and allocation to cost objects in rail logistics (Troche, 2009). This chapter presents a theoretical perspective on activity-based costing, carbon accounting, emissions management in activity-based costing, and the various emissions accounting standards and regulations.

3.1 Activity-based costing in logistics

Activity-based costing is not an invention of this millennium, as accounting methods that refer to activity-based costing have been used since the early 20th century. Activity-based costing was developed in the 1970s and 1980s as a solution to problems that could not be solved by traditional methods of calculating margins and increments. Robin Cooper and Robert S. Kaplan were among the most significant contributors to the development of activity-based costing, and their articles on the subject have become known worldwide. (Alhola, 2016; Cooper & Kaplan, 1988) The goal of activity-based costing is to produce information that is as relevant and accurate as possible for decision making. The information provided by activity-based costing is particularly useful when a company's accounting-based costing system has been developed for profit and loss accounting. (Pellinen, 2019)

Activity-based costing, abbreviated as ABC, provides reliable information on the total cost of products, providing a sustainable basis for long-term profitable pricing. ABC can also be used in the design of business models, where information on product and customer profitability and operating costs is useful (Pellinen, 2019). Traditional costing methods do not consider some of the factors that affect indirect costs, such as the diversity of transportation companies' businesses, the complexity of processes, and changes in customer requirements. In contrast, activity-based costing takes these factors into consideration (Xu, et al., 2020). The basic idea of activity-based costing can be illustrated as follows: the use of resources incurs costs, activities use resources, activities receive costs corresponding to the use of resources, products use activities, and products receive costs corresponding to the use of activities. The logic of activity-based costing is that costs are incurred more in relation to the workload of the activities than, for example, the volume of production. However, the use

of activity-based costing requires sufficient information on the causes and consequences of the costs incurred. (Pellinen, 2019)

Since the 1990s, the two-dimensional approach has been used to analyze a company's activities both vertically and horizontally. In the two-dimensional approach, also known as CAM-I cross or CAM-I ABCM Model, the vertical approach takes a cost assignment view, while the horizontal approach takes a process view. In the cost assignment view, resource costs are allocated to activities through the use of resource drivers. Activity costs are then allocated to cost objects using activity drivers. A driver is a measure or allocator utilized to assign a resource cost to activities (known as a resource driver) or to assign an activity cost to a calculation object, like a product (known as an activity driver). (Alhola, 2016, pp. 27-47; Turney, 1991; CAM-I, 1990) The two-dimensional approach is illustrated in Figure 4.

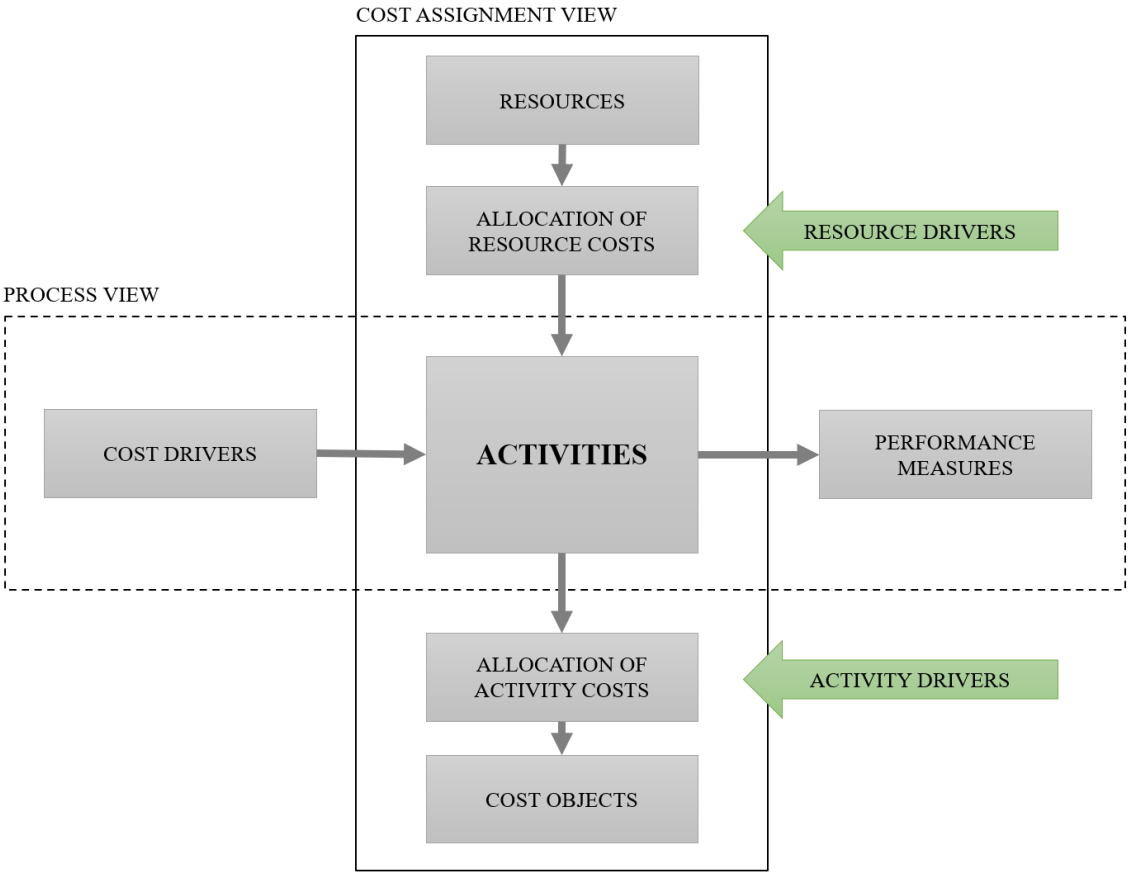

Figure 4. Two approaches on activity-based costing (CAM-I cross), figure adapted from Alhola (2016, p. 37)

Activity-based costing increases awareness of costs and promotes accountability for cost-effecting actions. By tracing costs to specific objects, ABC allows individuals to take ownership of the costs they generate. ABC employs a cost driver to distribute activity costs among cost objects. A cost driver is a factor that causally affects costs and a non-financial element. Unlike volume-based allocation, ABC uses a cost driver to allocate activity costs to cost objects, making the relationship between activity costs and cost objects visible and understandable. This provides transparency into how costs are being tracked and allocated. The ABC system is more flexible than the traditional costing system because it allows for multiple cost objects depending on the system's objectives. Cost-benefit analyses or profitability analyses can be developed by utilizing cost information regarding different cost objects. The data from ABC can also be used for strategic decision making and planning, as it provides precise cost information that is applicable to various company operations. (Kim, 2017, pp. 134-136)

Activity-based costing is an efficient technique for enhancing the quality of services provided and process complexity of railway companies, whether they operate regionally or internationally (Stopka et al., 2021). Activity-based costing in railway freight transportation has numerous advantages over traditional cost accounting. ABC can produce precise results while also providing the opportunity to analyze the data collected as ABC establishes a more direct linkage between costs and cost drivers. (Troche, 2009, p. 3)

The key benefits of ABC in railway transportation according to Troche (2009, p. 3) are:

- ABC is an accurate methodology.
- ABC focuses on indirect costs, making indirect expenses direct.
- ABC traces expenses to cost objects rather than allocating each expense category to a specific cost object.

ABC is ideal for companies with high overhead, multiple product lines with high complexity, volume, and direct labor, where costing errors are common, and competition is intense. The rail freight industry meets all these factors (Troche, 2009, p. 3).

3.2 Carbon accounting

The term carbon accounting can have a variety of meanings depending on the context. In academic literature, it is frequently used interchangeably with greenhouse gas accounting, and is a widely used term for emissions accounting. While some variation in terminology still exists within this relatively new field of research, literature has agreed that carbon accounting refers to the utilization of accounting methods by companies to collect, analyze, verify, and present climate change information. This enables the accounting of carbon assets and liabilities, managing of carbon risks and reduction of carbon emissions. Its main aim is to evaluate carbon reduction efforts and support informed decision-making by both management and external users. Both direct and indirect carbon emissions are included in carbon accounting. Carbon accounting takes its name from carbon dioxide CO2, the most abundant greenhouse gas, and the main driver of global climate change. In many cases, emissions of other greenhouse gases are quantified in terms of their carbon dioxide equivalent CO2e. (Peterdy, 2022; He, et al., 2022; Webber, 2023)

Greenhouse gas accounting is a measure used to generate data on greenhouse gas emissions from the activities of companies and individuals. In the logistics industry, providing transparent information on emissions in the transport chain enables stakeholders to make informed decisions based on reliable data. The availability of reliable and transparent information on the emissions of the rail logistics sector encourages sustainable decision-making and promotes behavioral change towards sustainable transportation. (European Comission, 2023c, p. 1) There are several greenhouse gases, such as carbon dioxide, methane, nitrous oxide, and hydrofluorocarbons. Emissions may stem from any of these gases, but CO2e, or carbon dioxide equivalent, is the standard measurement unit for emissions. All greenhouse gases can be converted to CO2e for carbon dioxide equivalent calculations, but it is important to note that CO2e is used only to simplify the accounting process, as all greenhouse gases have varying degrees of warming effect. (Peterdy, 2022)

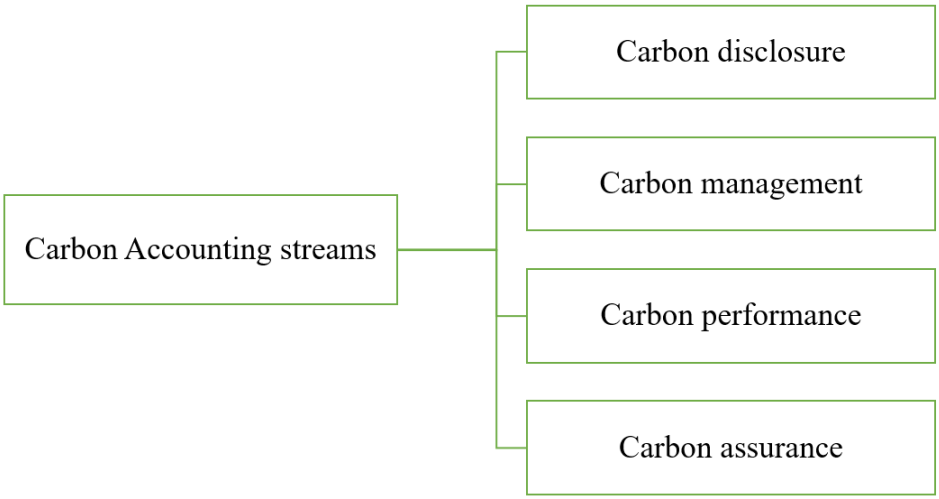

Figure 5. Carbon Accounting streams (He, et al., 2022)

Carbon accounting has become distinct area of research, with four primary streams: carbon disclosure, management, performance, and assurance, as seen in Figure 5 (He, et al., 2022). Companies disclose information related to climate change through various channels. Some companies report their greenhouse gas emissions to government agencies under specific regulatory regimes, while others include climate change information in their annual reports or in separate sustainability or social responsibility reports. Additionally, some companies voluntarily disclose even more detailed information (Huggins, et al., 2011). Companies are susceptible to a variety of external influences, such as social, economic, regulatory or market pressures, which can have an impact on internal factors and the disclosure of climate change information (He, et al., 2022).

Carbon assurance differs from financial auditing in various ways, including differences in the legal and regulatory environment, organizational involvement, materiality threshold, required qualifications, users of assurance reports and accounting methods (Olson, 2010). Accounting firms and consultants are the primary carbon assurance providers due to their expertise in both auditing and the subject matter. Although there are articles and studies available on carbon assurance, additional research is still required to fully develop carbon assurance methodology. (He, et al., 2022)

Carbon management refers to the practices that a company implements to mitigate its operational emissions. Proper carbon management can contribute to the reduction of a company's ecological footprint and improve its sustainability. Carbon management methods

can be employed to collect and document carbon-related data, assess performance, facilitate environmentally conscious decision-making, and manage carbon expenses (Hartmann, et al., 2013; He, et al., 2022). Kumarasiri and Jubb (2016) found in their study that regulations which impact the economic interests of firms are likely to prompt the adoption of carbon accounting methods, including setting targets, measuring performance, and offering incentives to decrease emissions.

Carbon performance refers to a firm's proficiency in managing and controlling emissions. The literature surrounding the topic mainly concentrates on the complexity of measuring carbon performance and the factors that influence carbon performance (He, et al., 2022). Measuring greenhouse gas emissions is an extremely complex process, largely based on estimates, as it is almost impossible to measure actual emissions. For example, CO2e cannot be determined by releasing a kilogram of carbon dioxide and measuring what happens over a century, but is a mathematical function generated by a standard model. The reliability and comparability of the results calculated by companies is questionable when different estimation methods are used. (MacKenzie, 2009) The term carbon performance can vary in meaning depending on the assessment's purpose. It can serve as an absolute measure of emissions or as a measure of efficiency in describing emissions per unit of production (He, et al., 2022).

The publication of emissions has long been voluntary and there has been uncertainty about the quality and accuracy of the data (He, et al., 2022). Europe is currently at the beginning of a new era, as the European Commission is introducing new European Sustainability Reporting Standards. On July 31, 2023, the European Commission implemented the European Sustainability Reporting Standards (ESRS) as a component of the previously established Corporate Sustainability Reporting Directive (CSRD) to enhance sustainability reporting. (European Comission, 2023d) Qian and Schaltegger (2017) argue that regardless of the motive for disclosing carbon emissions, carbon disclosure encourages firms to reduce emissions and make decisions that promote constructive change in emissions reduction.

3.3 Emissions in activity-based costing

Environmental protection has been a persistent concern for years and is a matter of corporate responsibility. Therefore, it is essential to integrate environmental responsibility into business practices from the start to accurately measure and evaluate the environmental impact of the end product. The integration of environmental responsibility into traditional cost accounting can be a difficult task, which can lead to an inaccurate assessment of the environmental impact of some companies. Activity-based costing is a useful approach for calculating production expenses while considering environmental factors and constraints. Environmental factors can be integrated into the company's activity-based costing, allowing for the allocation of environmental factors to various objects in the same manner as costs. (Tsai, et al., 2012; Tsai & Jhong, 2019; Pember & Lemon, 2012)

Environmental costs may be obscured in overhead accounts or not recorded in the traditional accounting system. Employing activity-based costing can help in exposing environmental costs from overhead accounts, leading to more accurate allocation towards end products. ABC also enables tracking the emissions generated by the product. By tracing costs through resource use and activities, the activity-based costing generates precise estimates of environmental costs for end products. Additionally, activity-based costing represents a cost structure that can inform policymaking, pricing, and process improvement decisions with respect to the environment. (Tsai, et al., 2012)

Different cost models for carbon emissions have varying impacts on a company's optimal product mix and profitability. Activity-based costing can provide a sustainable competitive advantage by enhancing the accuracy of cost information and controlling emissions costs through operational features. Companies can use accurate environmental cost information obtained from activity-based costing calculations to make informed sustainable management decisions, such as determining product pricing, evaluating product lines, analyzing procurement practices, and assessing outsourcing options. (Tsai, et al., 2023)

Emissions can be considered and treated as costs in activity-based costing. In many ways, emissions resemble costs in that when a resource (fuel) is used, it results in a cost (emissions). In ABC, costs can be allocated according to the principle of the originator paying. This principle can also be applied to emissions, where emissions are allocated to the stakeholder responsible for them. In logistics, this means that the entity that orders the

transportation, and thereby causes emissions, is responsible for them. In international emissions accounting, the same logic is known as the polluter-pays principle, which requires all entities to be responsible for the emissions caused by their activities (Ambec & Ehlers, 2016). Emissions can be treated in activity-based costing by creating a separate cost category for them, such as *Carbon Emissions Costs* (Tsai & Jhong, 2018). The cost category is no different from any other cost, but instead of, for example euros or labour hours, it is expressed in terms of carbon dioxide equivalents.

Activity-based costing uses a variety of technical concepts to describe the cost allocation process. The cost assignment view provides information primarly about resources, activities and cost objects. The idea behind cost objects, such as a delivery order, is that they create the need for activities, which in turn create the need for resources. (Alhola, 2016, pp. 45-46)

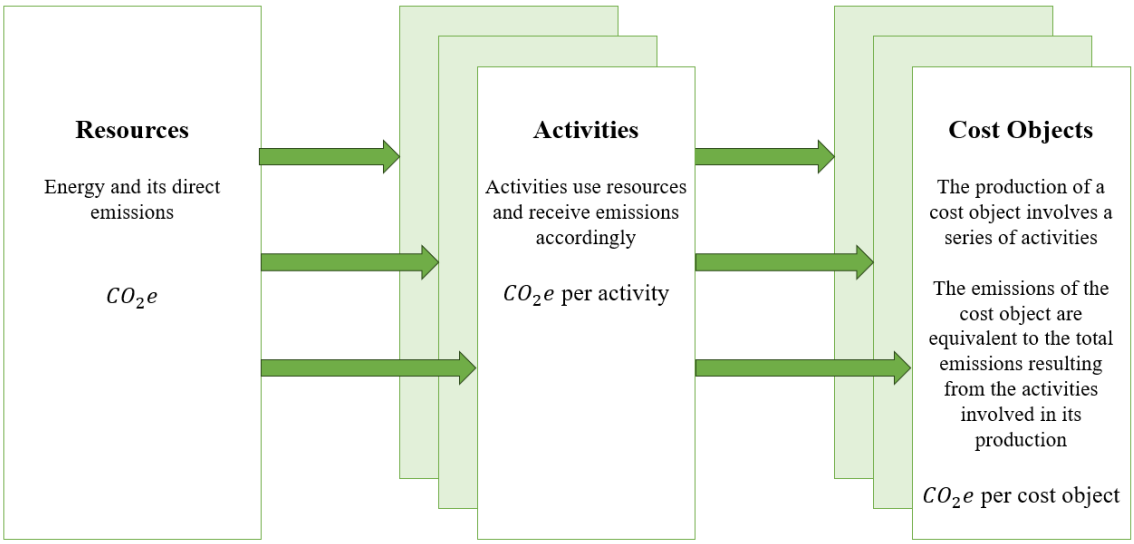

Figure 6. Emissions are assigned to cost objects via activities in ABC

As illustrated in Figure 6, the calculation and allocation of emissions process starts with the calculation of either the amount of energy used, from which the emissions can be derived, or the emissions themselves, if the latter can be obtained. Activities are allocated emissions based on their energy consumption, and varying energy usage results in different amounts of emissions being assigned to each activity. Thus, distinct activities have differing levels of emissions assigned to them. The end product, or cost object, is the outcome of the activities performed, and its emissions are the total emissions of the associated activities.

3.4 Emission standards and regulations

To account for and disclose emissions and other environment-related data, companies can utilize various accounting and reporting models that serve as the basis for environmental, social, and governance reporting. ESG standards are government-established guidelines for ESG-related activities and reporting or disclosure. They are designed to increase transparency and accountability and encourage the adoption of more sustainable business practices. ESG regulation can also protect investors from greenwashing, the practice of companies making misleading claims about their sustainability performance. Research shows a 155% increase in ESG regulation over the past decade, reflecting the rapid growth of sustainability-related policies. This trend is expected to continue as markets seek more efficient and transparent channels to invest in sustainable businesses and outcomes. (Burkinshaw, 2023)

Over the last few decades, the GHG Protocol has emerged as a leading model for ESG reporting. It offers a standardized framework for measuring and managing greenhouse gas emissions across private and public sector activities, value chains, and mitigation actions. Numerous companies have implemented its framework to enhance their non-financial disclosure practices. (Greenhouse Gas Protocol, 2023a) Europe is on the verge of a new era, as the new CSRD directive and its ESRS standards will affect a large proportion of European companies. Furthermore, alongside the updated standards laid out in the directive, the International Sustainability Standards Board (ISSB) has developed its own set of sustainability standards, and the global International Organization for Standardization (ISO) has created a family of standards that specifically target greenhouse gas emissions (International Organization for Standardization (ISO), 2018; IFRS, 2023a; IFRS, 2023b). Companies have the option to select the standard or accounting model for their calculations, although regulatory reporting obligations in their operating environment significantly impact this decision. The most common ESG standards are presented in Figure 7.

Figure 7. The most common ESG standards in Europe

The GHG Protocol is widely recognized as a leading early standard in emissions accounting. The protocol was initially released in 2001 and has since undergone revisions to address updates and improved expertise. The GHG protocol has had a significant impact on the emission scopes detailed in chapter 2.3. These scopes enable the classification and calculation of emissions. The standard encompasses the measurement and documentation of seven greenhouse gases accounted for by the Kyoto Protocol, which are carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), hydrofluorocarbons (HFCs), perfluorocarbons (PCFs), sulfur hexafluoride (SF6) and nitrogen trifluoride (NF3). (Greenhouse Gas Protocol, 2023b; Ranganathan, et al., 2004)

The protocol has been widely adopted by businesses, non-governmental organizations, and governments worldwide. It has been used as the basis for emissions accounting and reporting systems by many industries, non-governmental organizations, and government greenhouse gas programs. Industry associations such as the International Aluminum Institute, the International Council of Forest and Paper Associations, and the WBCSD Cement Sustainability Initiative have collaborated with the GHG Protocol Initiative to create industry-specific calculation tools that complement each other. The standard has been widely adopted because it was developed with input from a wide range of stakeholders. It is also robust and practical, drawing on the experience and expertise of many experts and practitioners. The Greenhouse Gas Protocol Corporate Accounting and Reporting Standard provides guidance and requirements for companies and other organizations that create a report of their greenhouse gas emissions. The objectives of the standard are presented in Figure 8. (Ranganathan, et al., 2004; Greenhouse Gas Protocol, 2023b)

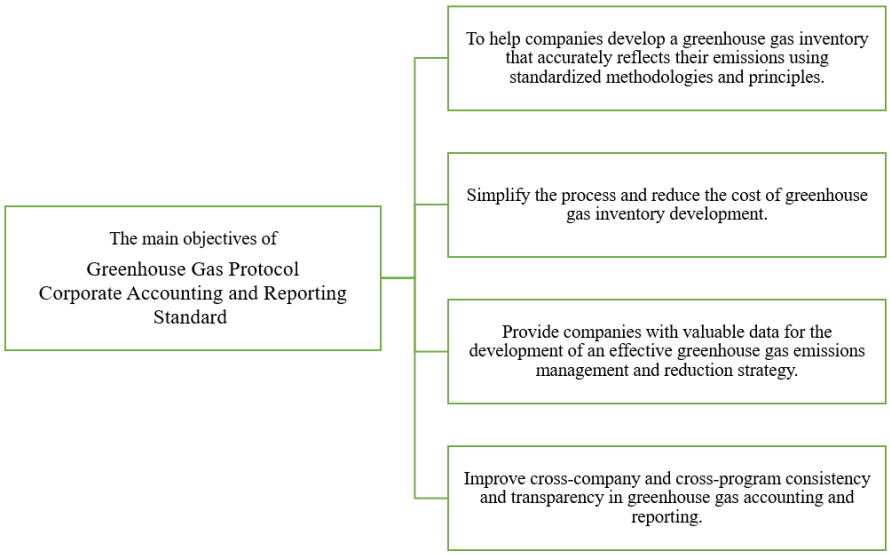

Figure 8. The main objectives of Greenhouse Gas Protocol Corporate Accounting and Reporting Standard (Greenhouse Gas Protocol, 2023b)

The Corporate Sustainability Reporting Directive (CSRD) is new legislation in the European Union that requires large companies to disclose their sustainability information in their annual report in accordance with the requirements of the directive and the European Sustainability Reporting Standards (ESRS). The legislation provides a means for stakeholders, including investors, consumers, and policy makers, to assess a company's non-financial performance. It also encourages companies to adopt a more responsible business model. The directive aims to promote sustainable business practices by requiring companies to report sustainability related performance indicators. This requirement will become an essential component of companies' operations, and CSRD will extend the EU's non-financial reporting system, which currently relies on the Non-Financial Reporting Directive (NFRD). The directive will initially impact companies that have reported under the previous NFRD and later be extended to smaller businesses. (Bureau Veritas, 2023; Stehl, et al., 2022)

The Corporate Sustainability Reporting Directive will affect nearly 50,000 companies, representing approximately 75% of the European Economic Area's commerce (Crabbendam, 2022). The CSRD applies to the following companies:

- Companies listed on EU regulated markets (excluding micro-enterprises) and large enterprises. A company must meet at least two of the following three criteria in order to categorized as large: have more than 250 employees, generate a turnover of more

than $40 million, and possess total assets of more than $20 million. These companies must also consider information at the subsidiary level.

- Listed small and medium-sized enterprises (SMEs) are offered a transition period until 2028.
- Non-EU companies that have a net turnover of €150 million in the EU and have at least one subsidiary or branch in the Union.

In Finland, it is estimated that there are approximately 800-1000 companies with reporting obligations, with these obligations commencing with the 2025 activity report. The first report is expected to be published in 2026. (Bureau Veritas, 2023; Crabbendam, 2022)

EU Commission published on July 2023 a regulation related to the sustainability reporting standards of ESRS in regard to the CSRD directive. The standards cover all aspects of environmental, social and governance (ESG), including climate change, biodiversity, and human rights. They provide investors with valuable information on how their investments contribute to sustainable development and how the companies they invest in approach corporate responsibility. To ensure a high level of compatibility between EU and global standards and to avoid duplication of reporting by companies, they also consider discussions with the International Sustainability Standards Board (ISSB) and the Global Reporting Initiative (GRI). (European Comission, 2023d)

In the summer of 2023, the International Sustainability Standards Board (ISSB) published its first standards, IFRS S1 and IFRS S2, marking the beginning of a new era of sustainability reporting in the global capital markets, with annual reporting periods beginning as early as January 1, 2024. Standard IFRS S1 outlines the procedures for an entity or company to prepare and present financial information related to sustainability. It specifies the essential elements of disclosure so that the information disclosed is useful to users in making decisions about allocating resources to the entity. The objective of IFRS S2 is to require entities to disclose in their financial statements' relevant information about their climate-related risks and opportunities that is useful to users of general-purpose financial reports in making informed decisions. The IFRS S1 focuses on disclosing information regarding sustainability risks, while the IFRS S2 focuses on providing information about climate risks. These

standards are intended to be used together. (Dancey & Mendiluce, 2023; IFRS, 2023a; IFRS, 2023b)

International Organization for Standardization (ISO) is a worldwide federation of national standards bodies, which have developed their own standard family for greenhouse gas emission quantification, monitoring, reporting, and verification. The published ISO 14060 family of standards enables objective and comprehensive quantification, monitoring, reporting, and validation or verification of greenhouse gas emissions and removals. It supports sustainable development through a low-carbon economy and benefits organizations, project promoters, and stakeholders globally. The ISO 14060 standard family includes multiple standards with different focus areas. (International Organization for Standardization (ISO), 2018) Figure 9 shows the main standards in the ISO 14060 family of standards and their relationship to the greenhouse gas statement.

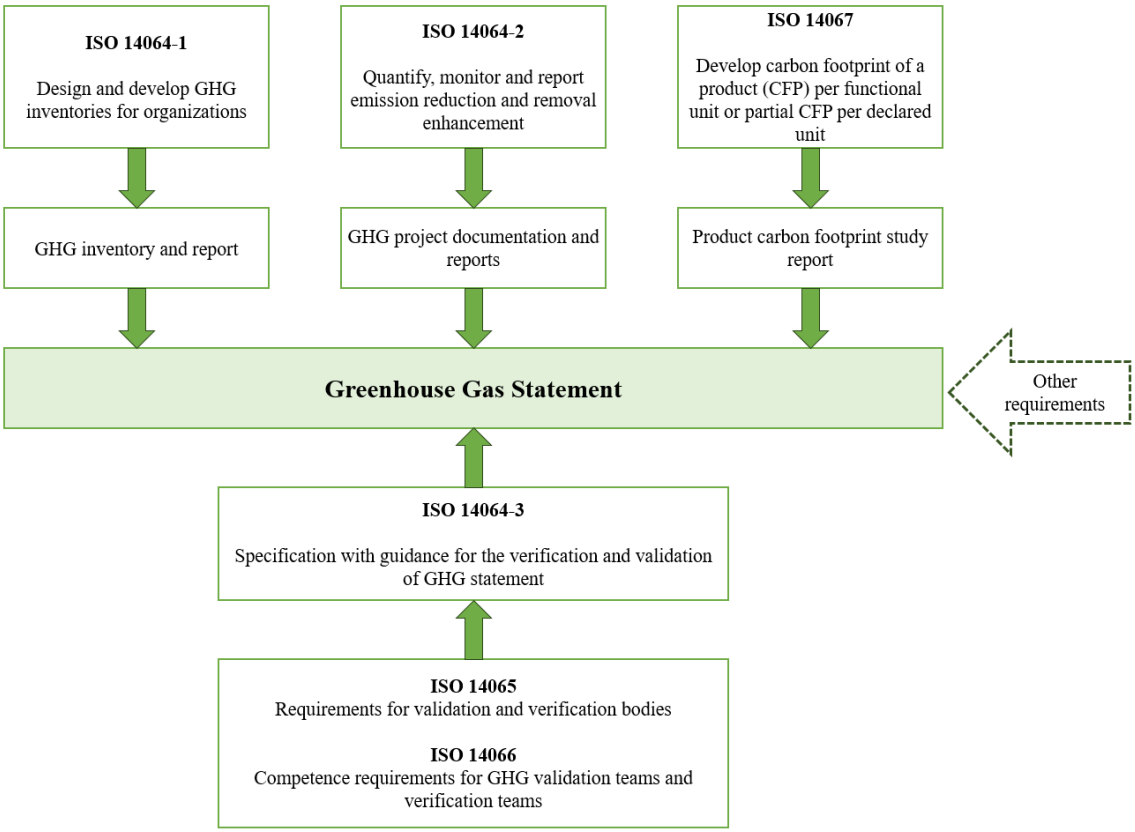

Figure 9. The ISO 14060 family of greenhouse gas standards, figure adapted from ISO (2018)

In addition to the ISO 14060 family of standards, the International Organization for Standardization has also developed other standards to support sustainable development. (International Organization for Standardization (ISO), 2018)

3.5 Summary

In activity-based costing, a company can view its activities either vertically or horizontally. The vertical approach uses the cost assignment view, while the horizontal approach uses the process view. The cost assignment view can be used to evaluate the costs assigned to specific cost objects or carbon dioxide equivalents in emissions calculations. Activity-based costing increases awareness of costs incurred and accountability for actions that affect costs, as ABC links costs to specific objects. In rail transportation and logistics, some research has been done on activity-based costing. The main advantages of ABC in this sector are the accuracy of the calculation, the attention paid to indirect costs and their transformation into direct costs, and the tracing of costs to specific cost objects rather than allocating them to a general cost category. (Alhola, 2016, pp. 27-47; Troche, 2009, p. 3)

Activity-based costing aims to precisely assign overhead costs to products. In the cost assignment perspective, the activity-based costing method assigns costs in two stages. Firstly, resource costs are assigned to different activities by using resource drivers. Each resource type traced to an activity becomes an element of an activity cost pool. Secondly, the expenses within every activity cost pool get attributed to cost objects via an activity driver, which measures the utilization of activities by the cost objects. (Tsai, et al., 2012) This allocation of resource costs is illustrated in Figure 10.

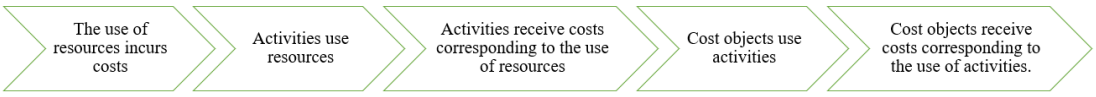

Figure 10. The basic logic of cost assignment in activity-based costing

Carbon accounting refers to the use of accounting methods by companies to collect, analyze, verify, and present climate change information. This enables the accounting of carbon assets and liabilities, the management of carbon risks, and the reduction of carbon emissions. The primary objective of carbon accounting is to evaluate carbon reduction efforts and support informed decision making by both management and external users. Carbon accounting includes both direct and indirect carbon emissions. Environmental accounting, such as carbon accounting, can be incorporated into a company's activity-based costing, enabling the allocation of environmental impacts to various objects using the same methodology as

cost allocation. This approach facilitates the integration of environmental factors into daily accounting practices, thus involving environmental factors in both accounting and decision-making processes. Emissions can be viewed as an expense in activity-based costing. As such, they can be managed and allocated in the same way as any other resource. (Tsai & Jhong, 2018; He, et al., 2022; Webber, 2023)

Various protocols and standards can be employed to calculate and report on environmental factors and non-financial metrics. Regulatory factors have a significant impact on ESG reporting and the associated calculations and methodologies. In addition, voluntary models can assist in the calculation and reporting process. These factors must be taken into account in order to produce accurate and unbiased ESG reports. A significant regulatory change affecting environmental reporting and carbon accounting is the new Corporate Sustainability Reporting Directive (CSRD), which requires companies to report on non-financial factors. The new European Sustainability Reporting Standards (ESRS) will encompass all ESG issues and standardize responsible reporting throughout the EU. The new standards, which will be widely used in EU, will also provide the basis for the publication of reliable and standardized data on the real impact on the environment. (European Comission, 2023d)

4 Emissions in the activity-based costing of VR Transpoint

This chapter provides a comprehensive presentation and documentation of VR Transpoint's activity-based costing, with a special focus on emissions. The first subsections introduce VR Transpoint as a company, its business environment, and the customers to whom emissions are allocated. In the following subsections, the activity-based costing and its data sources will be discussed in more detail.

4.1 VR Transpoint

VR Transpoint provides heavy industrial logistics services by rail and road in Finland. Services include rail and road transportation as well as customized logistics chains with additional services. VR Transpoint's customers are domestic and international companies that require logistics solutions for the transportation of raw materials and products. The majority of the company's turnover and profit is generated by rail transport. In particular, VR Transpoint transports raw materials and products for the forestry, metal and chemical industries. (VR Group, 2023a)

VR Group is a travel, logistics and maintenance services company wholly owned by the Finnish state. VR Transpoint is the VR Group's business unit responsible for providing rail and road-based logistics services in Finland. In addition to VR Transpoint, VR Group's business units are VR Long-distance Traffic and VR City Traffic. As part of the new strategy, VR changed the way the business segments are divided as of 1 January 2023, with passenger traffic being split into two units: Long-distance Traffic and City Traffic. VR Long-distance Traffic offers long-distance train travel services in Finland and restaurant and café services on trains and at stations for consumers. VR City Traffic provides commuter train, tram and bus services in Finland and Sweden. In addition to the business units, supporting function VR FleetCare provides maintenance services for passenger and freight transport fleets. VR FleetCare is no longer a separate business unit under the new strategy. (VR Group, 2023a; VR Group, 2023b)

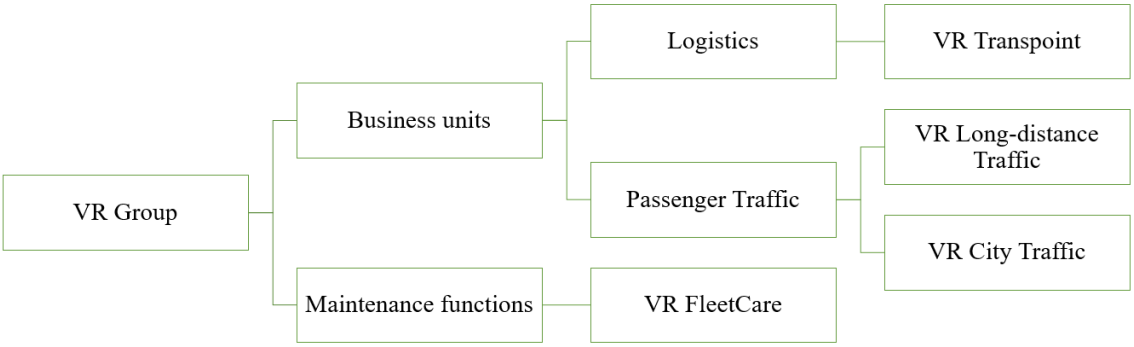

Figure 11. The structure of VR Group

In 2022, VR Transpoint transported 29.7 million tons by rail and employed 968 people. Despite a challenging year, the company had revenues of €386.2 million, resulting in an operating loss of €2.6 million. In recent years, VR has made significant investments in new fleet, with the acquisition of new electric locomotives being one of the most significant. In addition to the acquisition of new electric locomotives, new diesel locomotives were put into service on commercial routes at the beginning of 2023. (VR Group, 2023a)

4.2 The business environment and customers of VR Transpoint

The Finnish rail logistics environment is different from many other countries. In Finland, rail transport is affected by the extreme climatic conditions of the north. In winter, severe frost, snow, and ice affect daily operations. The exceptional winter conditions in Finland must be considered in the maintenance of the rail network, traffic operations and fleet characteristics. (VR Group, 2023c) Rail transport is most efficient for regular transportation of large masses. In Finland, these are mainly export transports of heavy forest and metal industries from production plants to ports and transit transports of metal and chemical industries from Russia through Finland. In addition to industrial transportation, the railways also transport raw materials for the forest, metal, and chemical industries. The railways are an important part of Finland's export industry, with a special focus on the forest industry. (Logistiikan Maailma, 2023)

VR Transpoint's largest transported product groups are raw materials and products from the forestry, metal, and chemical industries. VR Transpoint serves a diverse customer base of domestic and international companies seeking logistics solutions for the transportation of

raw materials and finished products. The majority of VR Transpoint’s customers are large forestry and industrial companies that rely on rail to transport raw materials such as timber and chemicals to their factories or finished products to logistics centers and ports throughout Finland. (VR Group, 2023a)

The length of the Finnish railway network is almost 6,000 km, of which more than half is currently electrified. Most of the network is single track, with the same line running in both directions. Passenger and freight traffic mostly use the same tracks, except for city traffic in the Helsinki area. Finland has a different track gauge than the rest of Europe. The condition and capacity of the rail network has a significant impact on the smooth running of rail traffic. Most delays are caused by track infrastructure failures, and the maximum speed of the fleet 220 km/h can only be used on a small part of the network. The capacity of the network in turn affects the number of trains. (VR Group, 2023c)

In Finland, there are many entities involved in rail transport. The Finnish Transport Infrastructure Agency (FTIA) is responsible for the country's rail system, its maintenance and development. Fintraffic is responsible for managing station traffic and providing passenger information (VR Group, 2023a). Finnish rail freight transport has been open to competition domestically since 2007, and a state agreement on rail transport between Finland and Russia opened eastern freight transport to competition in 2016 (VR Group, 2023d). VR is currently the only passenger rail operator in Finland, but there are several companies in the rail logistics market. However, VR Transpoint has by far the largest market share (VR Group, 2023a).

The conflict in Ukraine started by Russia and the global political uncertainty have had a significant impact on Finnish society as a whole and on VR Group's business at the same time. VR Group completely withdrew from eastern freight traffic in 2022. The Covid-19 pandemic, the prolonged conflict between Russia and Ukraine leading to the disruption of traffic to the east, escalating energy costs, inflation and rising interest rates had a significant impact on the operational environment of rail logistics in the early 2020s. (VR Group, 2023a)

4.3 Emission factors and data sources

VR Transpoint uses various data sources to model train activities and calculate the related emissions through activity-based costing. In addition to automatic and continuously updated data sources, consumption and emission factors are used, especially on a monthly basis. These factors are updated as new ones become available or as needed. The data is collected, stored, and analyzed in Snowflake. Snowflake is a global platform for data warehousing, data planning, data lakes, data science, data application development and secure sharing and consumption of real-time and distributed data. Snowflake is a platform that powers the data cloud, enabling organizations to manage data efficiently, regardless of data volume or workload. Snowflake is an easy-to-use platform that adapts to business needs, bringing the data together in one place. (SnapLogic, 2023; Snowflake, 2023) VR Transpoint's activity-based costing data is managed by the business unit's data and analytics team.

VR Transpoint’s activity-based costing is built using Structured Query Language (SQL). Activity-based costing model is constructed of tables and views that are built on top of one another. A view is similar to a table, permitting query results to be accessed as if it were a table, and can be used for a variety of purposes, including data combination, segregation, and protection (Snowflake Documentation, 2023). The calculation of emissions begins by extracting fundamental data into the initial table. Subsequent tables will then obtain the data from the prior table. Within each table, data is processed by delimiting, summing, or adding detailed information. The structure involves repetition, with tables interleaved or stacked on top of one another. Emissions are processed in multiple tables and views before being aggregated into a single view. CO2e emissions alone are processed through 15 tables and 4 views before being aggregated into a final view. In addition to these tables, the activity data undergoes processing and modeling in several other tables that impact the calculation of emissions.

The Railway Cargo System (RCS) serves as the main data source for activity-based costing. It contains all the VR Transpoint wagon events and precise information about the VR-operated trains in Finland. This includes detailed information on the VR trains and wagons that have moved on Finnish tracks, as well as order details such as customer and contents of each loaded wagon. RCS receives locomotive data from the Advanced Planning System (APS). Any errors or gaps in the data are corrected either through the analytics platform or

by utilizing official sources, such as Finland's transportation agency's Digitraffic and RataDW data, depending on the nature and quality of the issue. RataDW is a data repository utilized mainly by reporting systems, while Digitraffic is a website that brings together information from various open interfaces on the timetables, locations, configurations, and punctuality of trains on the Finnish rail network (Finnish Transport Agency, 2017). Figure 12 displays the primary data used in activity-based costing for the calculation of emissions.

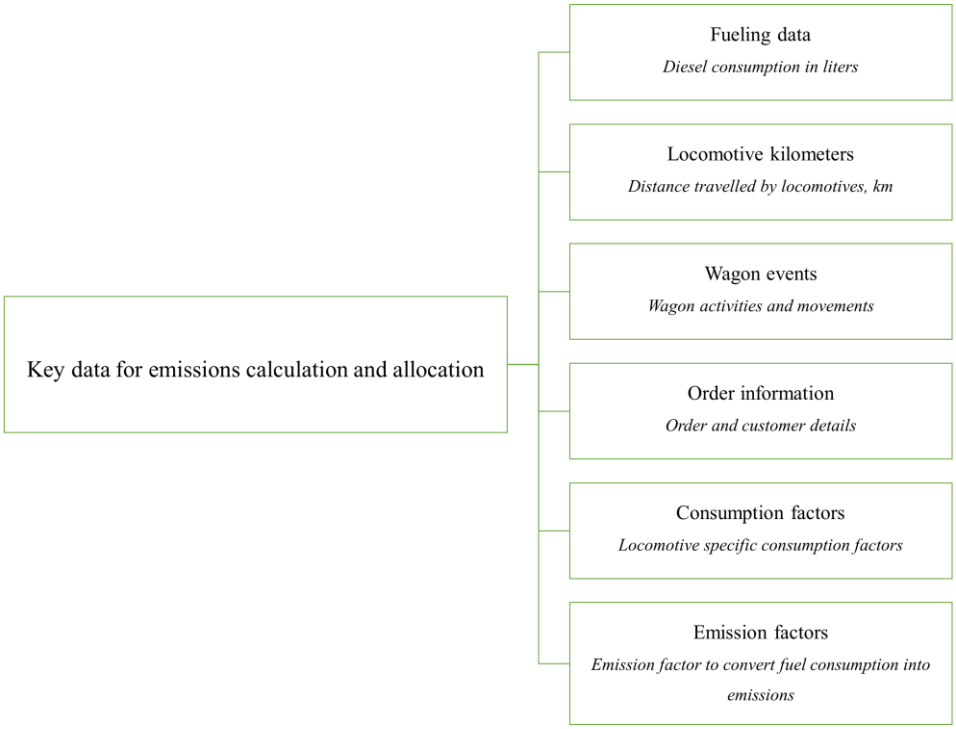

Figure 12. Key data for emission calculation and allocation

The diesel consumption of locomotives is determined in liters based on diesel refueling data. VR operates locomotives of varying ages, and their consumption varies from model to model. Every distinct locomotive model has its own unique consumption factor for train driving, locomotive driving, and handling. According to Head of Environment of VR Group (2023), the specific consumption factors for older locomotives have been determined by VR at the Hyvinkää machinery workshop after an in-depth study of the fleet. For newer locomotives, the exact consumption factors are received directly from the manufacturer. Whenever a new fleet is procured, a detailed environmental statement is provided, in which the precise consumption specifications of the locomotive are defined by the manufacturer.

The emission factors in the Defra database are used as the basis for defining the emission factors for rail logistics. Statistics Finland's fuel classification is also utilized in the definition

of the emission factors. The emission factors have been developed to include all greenhouse gases, as previously Statistics Finland's fuel classification system only considered carbon dioxide emissions and did not include other greenhouse gases. In order to calculate the emission factors for Finland, it is crucial to consider the Finnish distribution obligation, which prescribes the minimum percentage of renewable fuel (Energiavirasto, 2023). The percentage of renewable fuel in the fuel used has a significant impact on the resulting emissions and must be considered in the emissions calculation. The determination of the emission factors is supported by an external consultant. The accuracy of the emission factors is also verified by the external consultant. (VR Group Head of Environment, 2023)

All greenhouse gases, including carbon dioxide, methane, and nitrous oxide, which have the greatest impact, are considered in the emission factors. Although certain greenhouse gases have an insignificant impact on direct rail logistics emissions, they are included in the emission factor. The environmental declaration accompanying the purchase of newer locomotives also includes the emissions from the manufacture, transport, operation and decommissioning of the fleet. The exact emission factors for new vehicles are thus readily available, and more extensive, accurate environmental impact calculations are possible.(VR Group Head of Environment, 2023)

Currently, VR Transpoint's logistics-specific emissions calculation and VR Group's group-level emissions calculation are performed separately. The emissions calculations have slightly different goals. VR Group's calculation focuses on the emissions of the entire group, while VR Transpoint focuses on calculating and reporting direct emissions from rail logistics to customers. VR Group's emissions are currently calculated according to the GHG protocol, and they include all emissions. A number of projects are underway within the Group to improve emissions calculation methodologies. The development of emissions calculations is influenced by the changing regulatory environment and the increased demand for sustainability-related information. VR intends to adopt the ESRS standards of the Corporate Sustainability Reporting Directive for accounting purposes within the next year. Previously, responsible reporting at the VR Group level was in line with the GRI, but the reporting will now be extended to meet the new requirements of the directive. (VR Group Head of Environment, 2023)

4.4 Emission generation in activity-based costing

VR Transpoint's rail emissions can be divided into two main categories in the activity-based costing: traction and handling. Traction includes all emissions that occur when a locomotive moves from one place to another on the track, either alone or with wagons. Traction always consists of the train and the subintervals over which it moves. Handling, on the other hand, includes the emissions from the activities associated with transportation, i.e., shunting wagons and locomotives in the stations or yards and positioning them so that the train or locomotive can depart. Handling includes all movements that do not occur in subintervals.

4.4.1 Traction

Emissions from traction can be further subdivided into emissions from locomotive driving and emissions from locomotives during train drive. Traction can be either a freight (load) train or an empty train, depending on the loading of the wagons. Freight or load train is a train with at least one loaded wagon in addition to the traction unit. Empty train is a train that transports empty wagons either from the unloading yard or to the loading yard. The distribution of traction to the train and locomotive driving is illustrated in the Figure 13.

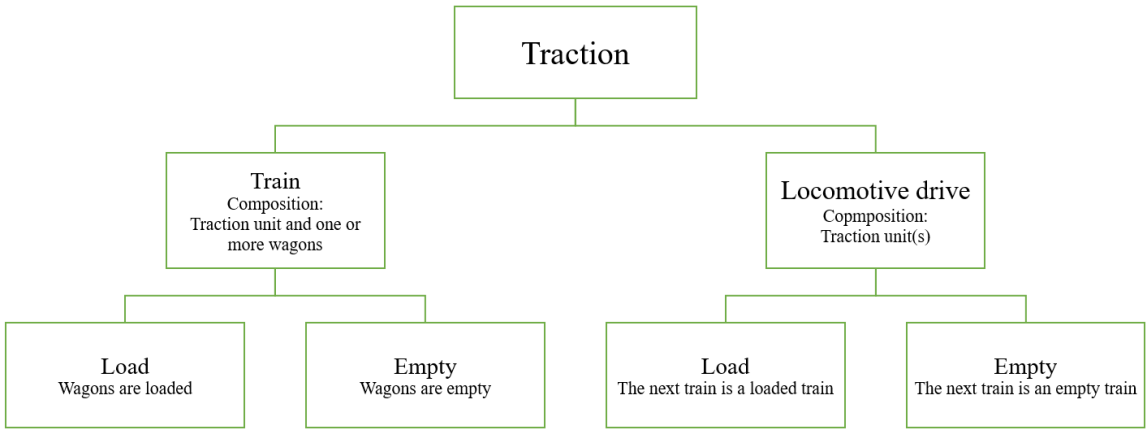

Figure 13. Traction is divided into train and locomotive drive

In the activity-based costing, emissions from locomotive drive are allocated to the train that causes the locomotive drive. As the locomotive drive is always allocated to the train that causes the locomotive drive, it can also be either empty or loaded, depending on the loading of the train. For example, if a locomotive drives from station A to station B to pick up empty

wagons, and transports them to station C for loading, the emissions from locomotive drive between station A and B are allocated to the train that travels from station B to station C. Because the train that traveled between B and C was empty, the locomotive drive is also categorized as empty. Emissions from empty traction are always allocated to load traction that caused the empty traction. For this reason, the emissions of an empty train are allocated to a freight train that travels from station C to station D in the example. The load train, which travels from station C to station D, has caused the locomotive drive from A to B, as well as the empty train from B to C. Without the transport order in question, these traction events would not have happened. For this reason, emissions from locomotive drive and empty train are allocated to the freight transport in question. The transport in question is illustrated in Figure 14.

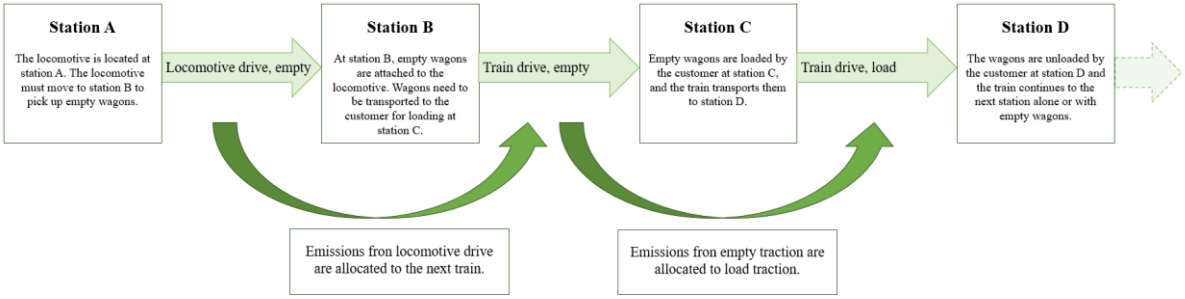

Figure 14. Allocation of locomotive driving and empty transport for freight transport

VR Transpoint's professional planning, however, aims to maximize energy efficiency and prevent unnecessary traction and handling events, such as locomotive drives and empty trains. For example, empty wagons can be moved from one station to another as part of other freight trains, and customer transport orders are scheduled in advance, eliminating unnecessary extra movements of locomotives and empty wagons. (VR Transpoint, 2023) Traction subinterval is the distance a train or locomotive travels without making any changes to its composition, such as the number or order of wagons or changing the locomotive. Therefore, stopping at a station does not end the subinterval if no changes are made to the train. A change of driver also does not constitute a subinterval. The route of the customer order consists of one or more subintervals, during which some train changes may occur. In addition, the order may be transported in more than one train in order to expedite the trip from the departing station to the arriving station.

4.4.2 Handling

Handling involves activities that occur within the railway yards or stations, such as moving wagons or locomotives from one place to another. These actions, commonly referred to as shunting or handling operations, are divided into five distinct phases, illustrated in Figure 15.

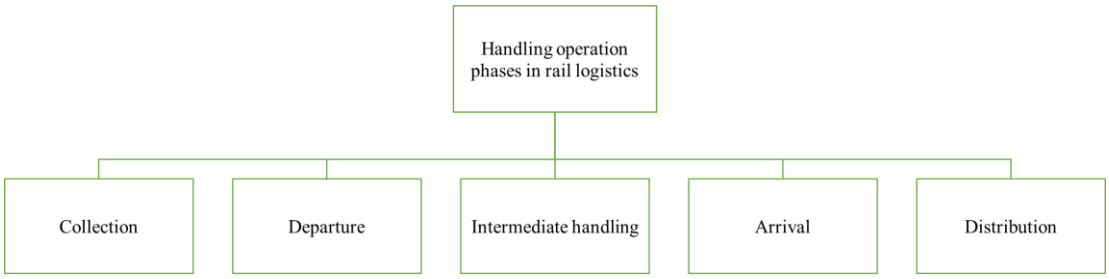

Figure 15. Handling operation phases in rail logistics

During collection, the shunting locomotive retrieves outgoing wagons from the customer tracks as part of its shunting activities. Each wagon that is loaded on a customer track is collected once per order, even if the wagon needs to be moved multiple times. An exception to this collection process is made for wagons whose first train departs directly from the customer track, also known as the collection track in this case. For such cases, the wagon is assigned only one departure activity event without a collection event. In the collection process, wagons are grouped together if they are placed on the same track with a maximum difference of five minutes between the previous and next wagon event and are loaded with customer delivery or contain an agreed-upon container. For each such group of wagons an actual handling time is allocated. However, if the handling time is not found for the event, a default of 30 minutes is used. Wagons transporting hazardous materials are granted an additional handling time in the collection yard to accommodate for the special handling procedures.

In the departure yard, each loaded wagon receives a departure yard event. Wagons belong to the same wagon group if they are from the same collection wagon group. Each wagon group in the departure yard gets 20 minutes of handling time. Wagons transporting hazardous materials receive an additional handling time in the departure yard. The handling time is divided evenly among all wagons in the group. A wagon may have multiple

intermediate handling events during its journey, but only one of the other events. At each intermediate station, the arrival event of a train arriving at the station is compared with the corresponding event at the next intermediate or destination station. Intermediate handling has occurred when the wagon order number, train number, or locomotive configuration has changed. In such case, an intermediate handling event is allocated the wagon groups. Intermediate handling doesn't occur unless the wagons have actually moved in the yard or the train configuration has changed, and therefore no additional minutes are added by passing through the yard or station without an actual handling event.

For intermediate handling, wagon groups receive 20 minutes of handling time, evenly distributed among the wagons in the group. In the intermediate yard, the wagons that have the same destination for the next intermediate section and that were consecutively on the incoming train belong to the same wagon group. Hazardous material wagons are granted additional handling time in the intermediate yard due to special handling procedures. In descent yards, each wagon is given two minutes extra handling time if it belongs to a wagon group of less than 20 wagons.

At the arrival yard, each wagon receives an arrival event, and each wagon group receives 20 minutes of handling time. Wagons that belong to the same distribution group form a distribution wagon group at the arrival station. Wagons that are not part of distribution groups share a 20-minute handling event. The handling time is divided equally between the wagons in the group or between the individual wagons. Hazardous material wagons receive additional handling time during arrival handling to accommodate for the special handling procedures. Each loaded wagon receives a distribution event, which is an event where the wagon is transported to the customer track for unloading. Exceptions to this rule are yards, where wagons can be moved directly to the customer track. Distribution follows the same principles as collection, i.e., wagons belong to the same wagon group if they are placed on the same track with a maximum difference of five minutes between the previous and the next wagon. For each wagon group, the distribution handling time is allocated as it occurred and, if this is not known, a standard of 30 minutes is used. The handling time is divided equally among all wagons in the group. Hazardous material wagons receive additional handling time during distribution.

Table 4. Time allocation by handling type

Handling type	Time allocated
Collection	Actual time, 30 min
Departure station	20 min
Intermediate handling	20 min
Arrival station	20 min
Distribution	Actual time, 30 min

Table 4 displays the times allocated to the wagon groups for the different handling activities for the purpose of cost and emission allocation. Handling time is always allocated to a wagon group regardless of the number of wagons in the group.

4.5 Emission allocation in activity-based costing

Emissions are calculated based on the diesel consumption of locomotives. This requires calculating this consumption by type of transport at the locomotive level. Diesel consumption per month is obtained from diesel fueling data. The previous chapter 4.4 presents the activities of VR Transpoint's ABC to which emissions are assigned. Specific diesel consumption factors are determined for each model of locomotive and for each mode of transportation, including train, locomotive drive, and handling, as shown in Figure 16.

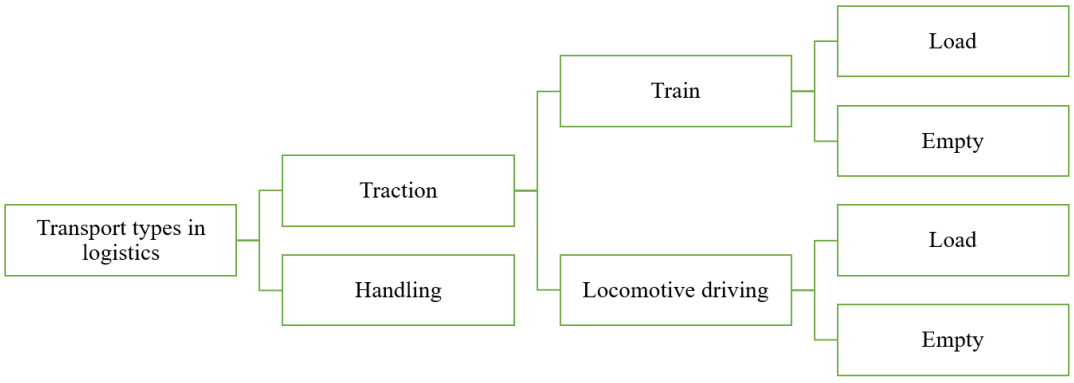

Figure 16. Transport types in emission allocation in logistics

To allocate diesel fuel to different types of transportation, actual kilometers and handling minutes are retrieved. These are used to calculate the calculated consumption of activities, which determines the ratio for allocating emissions. This ratio or share of emissions is

determined by first multiplying the locomotive's specific consumption factor by the distance traveled or handling time used on an event level. Then the calculated diesel consumption for each type of transport is divided by the total calculated diesel consumption to determine the share of calculated diesel consumption for each type of transport. The total actual diesel consumption is multiplied by the share to determine the actual proportion of diesel utilized by the transport type. The resulting liters are then multiplied by the emission factor to calculate the CO2e emissions. Table 5 shows an illustrative allocation event where CO2e emissions are derived from calculated consumption, considering actual diesel consumption.

Table 5. Allocation of emission to transport types and locomotives

Transport type	Train departure date	Loco-motive type	Distance or duration, km or min	Specific consumption factor, l/km or l/min	Calculated diesel consumption, l	Total calculated consumption, l	Share of calculated consumption	Total diesel consumed, l	Diesel consumed, l	Emission factor	KgCO2
Traction, train	2023-06-13	DR20	150	4.20	630.00	1994	0.32	1500	473.92	2.20	1042.63
Traction, train	2023-06-13	DR22	180	3.80	684.00	1994	0.34	1500	514.54	2.10	1080.54
Traction, locomotive driving	2023-06-13	DR20	25	2.80	70.00	1994	0.04	1500	52.66	1.80	94.78
Traction, locomotive driving	2023-06-13	DR22	75	2.50	187.50	1994	0.09	1500	141.05	1.70	239.78
Handling	2023-06-13	DR25	65	6.50	422.50	1994	0.21	1500	317.83	3.50	1112.40

Emissions allocation is based on the ratios between calculated and actual energy consumption. It varies for traction and handling modules, which are segregated after general allocation. Traction emissions are summed monthly, while handling emissions are summed by station pool.

4.5.1 Emission allocation in traction

Emissions result from energy consumption. Therefore, the calculation of emissions for traction events starts with evaluating the energy consumption of traction activities on a given track section. To allocate energy to trains and time, the distance traveled per specific time block is determined by calculating the time spent traveling and dividing the distance traveled evenly over the time traveled. Activity-based costing calculates the distance the train travels during each one-hour time block, taking into account the possibility that the train may depart

or arrive at the station in the middle of the hour. Table 6 illustrates the distribution of time and distance traveled on a hypothetical journey from Station A to Station B.

Table 6. Distribution of the partial distance between time blocks

Train ID	Departure station	Arrival station	Total subinterval distance, km	Time block start	Time block end	Train departure time	Train arrival time	Minutes on the time block, min	Distance on the block, km
12345@2023-06-15	A	B	150	2023-06-13 13:00:00.000	2023-06-13 14:00:00.000	2023-06-13 13:39:00.000	2023-06-13 18:30:00.000	21	10.82
12345@2023-06-15	A	B	150	2023-06-13 14:00:00.000	2023-06-13 15:00:00.000	2023-06-13 13:39:00.000	2023-06-13 18:30:00.000	60	30.93
12345@2023-06-15	A	B	150	2023-06-13 15:00:00.000	2023-06-13 16:00:00.000	2023-06-13 13:39:00.000	2023-06-13 18:30:00.000	60	30.93
12345@2023-06-15	A	B	150	2023-06-13 16:00:00.000	2023-06-13 17:00:00.000	2023-06-13 13:39:00.000	2023-06-13 18:30:00.000	60	30.93
12345@2023-06-15	A	B	150	2023-06-13 17:00:00.000	2023-06-13 18:00:00.000	2023-06-13 13:39:00.000	2023-06-13 18:30:00.000	60	30.93
12345@2023-06-15	A	B	150	2023-06-13 18:00:00.000	2023-06-13 19:00:00.000	2023-06-13 13:39:00.000	2023-06-13 18:30:00.000	30	15.46

The specific consumption factor of a locomotive is multiplied by the hourly distance of the train to obtain the calculated hourly consumption for the subinterval per hour. If the train has more than one locomotive, the specific consumption factors of each locomotive are multiplied separately by the hourly distance of the train and summed with the consumption of the first locomotive to obtain the total calculated diesel consumption per hour. Table 7 illustrates the calculated consumption for the imaginary train.

Table 7. Calculated hour level consumption of a train

Train ID	Locomotive	Subinterval	Specific consumption factor, l/km or l/min	Time block start	Train Departure time	Train arrival time	Distance on the block, km	Calculated consumption, l
12345@2023-06-15	DR20	1	4.20	2023-06-13 13:00:00.000	2023-06-13 13:39:00.000	2023-06-13 18:30:00.000	10.82	45.46
12345@2023-06-15	DR20	1	4.20	2023-06-13 14:00:00.000	2023-06-13 13:39:00.000	2023-06-13 18:30:00.000	30.93	129.90
12345@2023-06-15	DR20	1	4.20	2023-06-13 15:00:00.000	2023-06-13 13:39:00.000	2023-06-13 18:30:00.000	30.93	129.90
12345@2023-06-15	DR20	1	4.20	2023-06-13 16:00:00.000	2023-06-13 13:39:00.000	2023-06-13 18:30:00.000	30.93	129.90
12345@2023-06-15	DR20	1	4.20	2023-06-13 17:00:00.000	2023-06-13 13:39:00.000	2023-06-13 18:30:00.000	30.93	129.90
12345@2023-06-15	DR20	1	4.20	2023-06-13 18:00:00.000	2023-06-13 13:39:00.000	2023-06-13 18:30:00.000	15.46	64.95

The calculated consumption of the train in the subinterval is divided by the monthly calculated consumption of the traction to determine the share of the train activity in the calculated consumption. This ratio is the basis for the allocation of actual emissions. Actual emissions from traction are retrieved from transportation type and locomotive level data on a month level. The calculated hourly share is multiplied by the actual monthly diesel emissions to give the train's share of actual emissions. The emissions are summed over the train's subintervals, as shown in Table 8.

Table 8. Allocation of emissions according to calculated consumption

Train ID	Locomotive	Subinterval	Distance on the block	Calculated consumption	Monthly consumption	Share of monthly consumption	Monthly KgCO2e	Share of KgCO2e
12345@2023-06-15	DR20	1	150	630	50 000	0.0126	125000	1575

Once the emissions of each train per subinterval are determined, the locomotive drives are separated from the rest of the traction. The emissions of the locomotive drive are assigned to the subintervals of the next trains. In cases where more than one locomotive is involved in a locomotive drive, emissions are divided by the number of locomotives and allocated to the next trains. The emissions calculated for the train and its subintervals are divided by the number of traction units to determine the emissions per unit. At a train level, the emissions from the subinterval traction units are added together to obtain the total emissions from the traction units of the train. After calculating the emissions for the train and locomotive drives in their respective modules, the data is combined and assigned to the wagon level. The division factors and order for allocation are determined by analyzing data from wagon events in the subinterval. These division factors, along with the method by which they are calculated, are shown in the Table 9 below.

Table 9. Division factors

Division factor	
Subinterval division factor	Wagon gross weight / total gross weight of wagons on the train
Order division factor	Subinterval distance / Total route distance of the wagon

Emissions are allocated to each wagon based on its weight within subintervals. At the subinterval level, the total emissions of the train are multiplied by the subinterval division factor. This ensures that all locomotive emissions are allocated to each wagon according to its weight. The allocation does not take into account the weight of locomotives since the emissions are designated for the wagon level. The distribution of emissions is illustrated in the Table 10.

Table 10. Allocating emissions to wagon level with subinterval division factor

Train ID	Wagon	Wagon gross weight, tkg	Total gross weight of wagons, tkg	Subinterval division factor	Total KgCO2e	KgCO2e per wagon
12345@2023-06-15	123451	50	165	0.303	1575	477.27
12345@2023-06-15	234562	60	165	0.364	1575	572.73
12345@2023-06-15	345673	55	165	0.333	1575	525.00

Once the emissions for the wagons have been assigned, the empty wagon movements are separated. Empty transport is always associated with loaded transport as empty wagons are moved to and from loading yards. From the emissions per wagon data, all empty wagons and the locomotive drives associated with empty transport are collected into a separate module. Maintenance events are also separated because any maintenance-related emissions from wagon or locomotive traffic are excluded from the customer-specific allocation. Empty transport is categorized as empty in the module, and for each empty wagon, the next load train for which the wagon is transported is identified. Traction emissions are combined from all modules into a single table that combines load and empty trains and locomotive drives. Empty transport and locomotive drive emissions are allocated to freight transport and their emissions are distributed evenly over all train subintervals evenly. This is done by multiplying the empty traction emissions by the order division factor, which indicates the proportion of emissions allocated to each subinterval. This calculation is demonstrated in Table 11.

Table 11. Distribution of wagon-level emissions over subintervals

Train ID	Wagon	Subinterval	Subinterval distance	KgCO2e total all wagons	KgCO2e per wagon	Empty wagon transportation	Order division factor	Empty transportation emissions KgCO2e
12345@2023-06-13	123451	1	150	1575	477.27	500	0.47	234.38
12345@2023-06-13	123451	2	70	750	272.73	500	0.22	109.38
12345@2023-06-13	123451	3	100	935	311.67	500	0.31	156.25

In the final table for traction emissions, all emissions are categorized by wagon and subinterval. As the wagon is always connected to the wagon order during transportation, its emissions can be combined for the order and the corresponding customer.

Figure 17. Key information for calculation and allocation of traction emissions to customers

Figure 17 shows the most important data dimensions for allocating emissions to customers in the final traction emissions table. In addition to these dimensions, it is possible to enrich the data with various information to support the calculation and allocation of emissions.

4.5.2 Emission allocation in handling

The calculation and allocation of emissions from handling activities begins with the separation of handling from traction. Each handling event has a unique reference number that can be used to assign it to a specific yard. Individual yards belong to station pools, which describe an area containing one or more nearby yards. Within a station pool, yards share resources such as shunting locomotives or workforce. Shunting locomotive activity may be recorded at the main station within the yard pool, typically the largest, although the locomotive may also perform shunting activity at smaller stations. As a result, emissions within a yard pool are combined on a monthly basis for more accurate allocation. Figure 18 shows that a shunting locomotive works in several yards within a yard pool, so its emissions must also be allocated to all the yards where it has shunted.

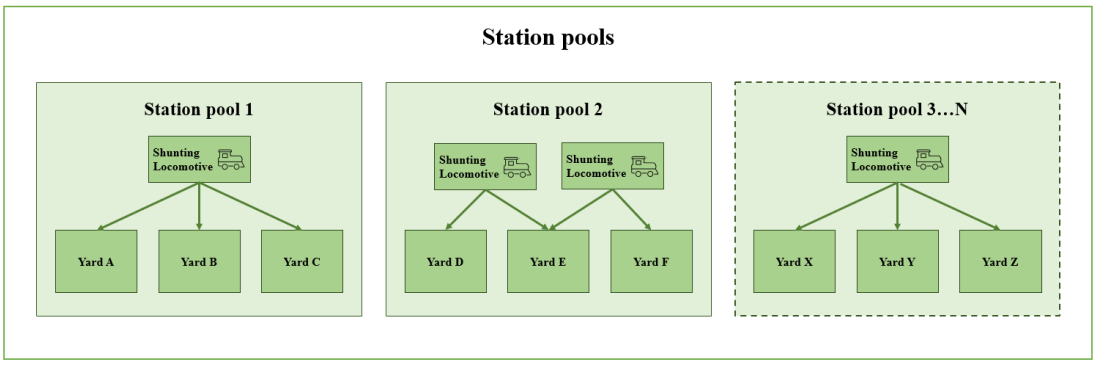

Figure 18. Yards in the same station pool share shunting locomotives

The handling times are derived from data obtained from the shunting yard. If the precise actual handling times are unknown, standard times are employed, as given in chapter 4.4. The total handling time for a group of wagons is divided by the number of wagons in the group to calculate the handling time for each wagon. The wagon's share of the weekly handling time is determined by dividing the wagon's handling time by the station pool's weekly handling time. The emissions for each week are obtained by dividing the monthly emissions of the station pool by the number of weeks in the month. Subsequently, the wagon’s share of weekly handling time is multiplied by the weekly emission figure to determine the allocation of emissions to each wagon group. This calculation is shown in Table 12 with illustrative numbers.

Table 12. Handling emission allocation to wagons

Handling type	Wagon	Wagon group	Wagons in wagon group	Wagon group handling time, min	Handling time per wagon, min	Station pool handling time per week, min	Share of handling time	Station pool KgCO2 per week	KgCO2 per wagon
Departure	123451	ABCD	3	20	6.67	1500	0.0044	2000	8.90
Departure	234562	ABCD	3	20	6.67	1500	0.0044	2000	8.90
Departure	345673	ABCD	3	20	6.67	1500	0.0044	2000	8.90

Once the emissions from both traction and handling have been calculated in their own modules, the emissions are combined in a single table. The emissions from handling are assigned to the customer via the order boundary of the wagon. That is, the customer for whom the wagon is delivering also receives the emissions.

5 Results and evaluation of emissions in VR Transpoint’s activity-based costing

Several rail logistics companies use activity-based costing as an accounting method. Based on the available literature and the experiences of rail logistics companies, activity-based costing is considered to be suitable for the rail logistics sector. The current literature does not yet provide extensive information on the use of activity-based costing to calculate emissions in practice. However, the idea of incorporating carbon accounting into activity-based costing is not entirely new. The integration of carbon accounting into the system of internal operational accounting enables a thorough analysis and detection of irregularities. Calculating emissions as part of activity-based costing allows for a more accurate calculation of emissions compared to traditional models such as the GHG protocol. For instance, the information generated by activity-based costing can help identify inefficient and high-emitting activities that can be improved to reduce overall emissions.

5.1 Emission handling and allocation in VR Transpoint’s activity-based costing

The basic principle of activity-based costing can be applied to carbon accounting by treating emissions as costs. When allocating emissions to customers, emissions are allocated through activities to cost objects as other costs in rail logistics. The allocation of emissions can be based on similar information to the allocation of costs since emissions and costs are allocated in a comparable manner. For instance, the way locomotive costs are allocated is similar to the way emissions are allocated. Activity-based costing has significant advantages in accurately calculating costs, which allows for precise emissions allocation.

The fundamental concept of ABC is to allocate resource costs to activities and allocate activity costs to cost objects. VR Transpoint’s activity-based costing uses a cost assignment perspective as the model starts with resources and allocates them through activities to cost objects. The calculation and allocation of direct emissions naturally require data from different matters, such as locomotive and wagon events. For the purpose of calculating direct emissions, the diesel consumption and the derived CO2e emissions are an important resource, as diesel is the only source of direct emissions. VR Transpoint's activity-based

costing model considers transportation orders fulfilled by customers and their dimensions as its cost objects. Emissions are allocated to customer orders, or more precisely to wagons bound to customer orders, from where they can be allocated directly to customers. Figure 19 illustrates the basic logic of how the use of diesel generates emissions that can be allocated to activities, which in turn can be allocated to rail logistics orders.

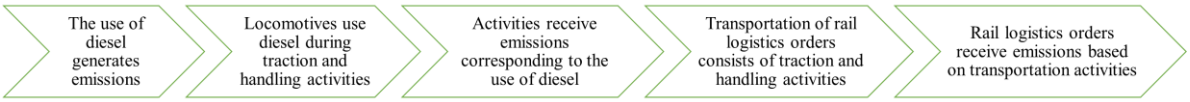

Figure 19. Emission assignment in VR Transpoint's ABC

VR Transpoint's emissions from rail transport can be divided into two main categories in the activity-based costing: traction and handling. Traction can be divided into train and locomotive driving depending on the number of wagons attached to the locomotive. A train can be either loaded or empty, and since the locomotive drive is always linked to the next train, it can also be categorized either empty or loaded. Traction and handling activities require resources, which in the case of direct emissions is diesel, and therefore the activities receive emissions according to the diesel consumption. Emissions are allocated to the activities through a resource driver, which is an allocator utilized to assign a resource cost to activities. Activities are allocated to cost objects through an activity driver.

Emissions are allocated according to the locomotive's outputs, such as travel distance and handling times. The resource drivers for emission allocation are based on locomotive activities, specifically how far it has traveled or the duration of handling activities. The activity driver refers to the transport order and its wagon bindings, used to assign emissions accurately to the suitable cost object. In practice, emissions are allocated at the wagon level and can then be allocated to the customer or other order dimensions through the wagon order and bounding. The allocation of activities to cost objects is based on wagon-level information, which shows which order the wagon is bound to and the customer whose products it contains. Figure 20 illustrates the allocation of resource costs to activities, followed by the allocation of activity costs to the cost objects in VR Transpoint’s activity-based costing.

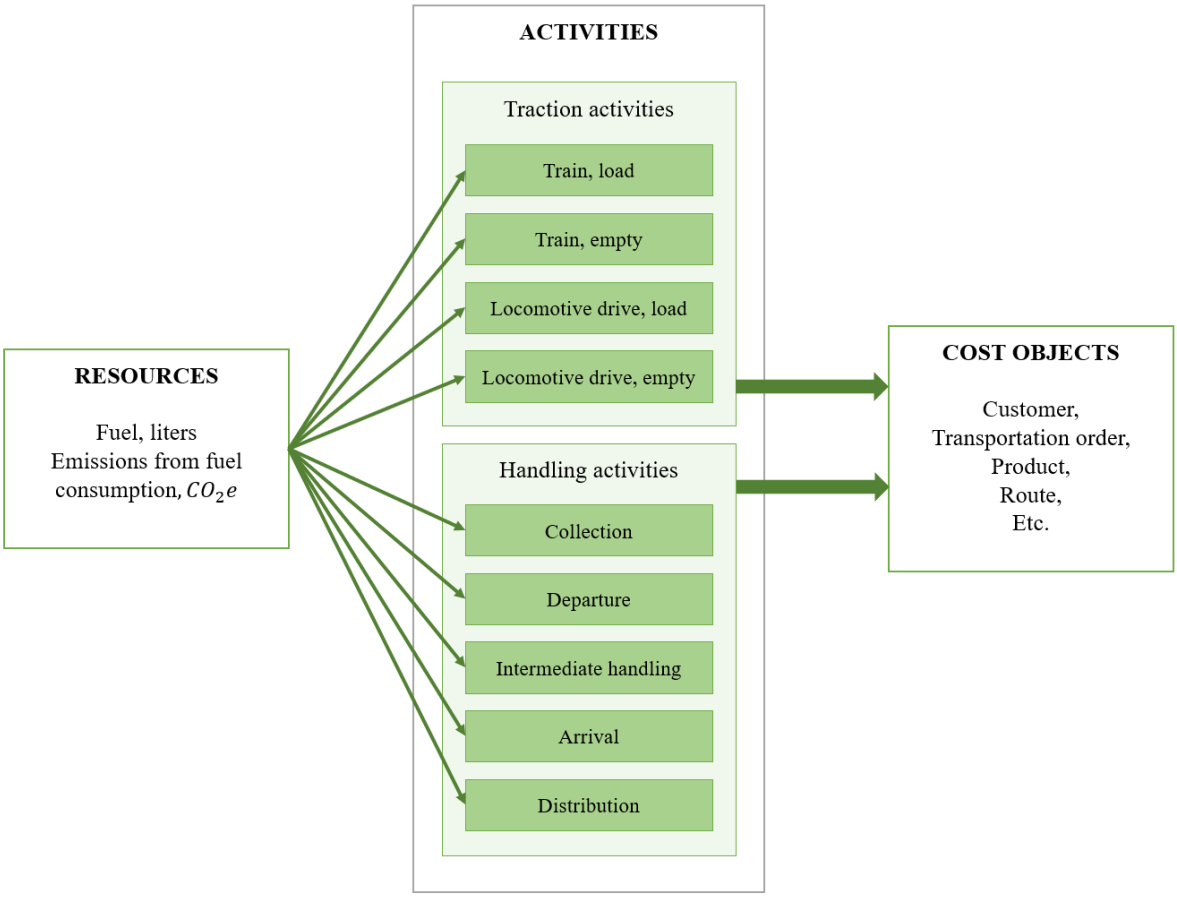

Figure 20. Emissions from diesel consumption are allocated to customers through activities, figure model adapted from Alhola (2016, p. 45)

The logic of activity-based costing is that costs are incurred more in relation to the workload of the activities than, for example, the volume of production. This is important when allocating emissions, as emissions are influenced by the conditions in the yard, efficiency, and many other factors, such as the composition of wagon groups.

5.2 VR Transpoint’s emission allocation logic

Emissions allocation is a complex process that considers the diesel consumption of different activities. The calculation of actual emissions begins by multiplying the diesel consumption of the month by the emission factor. The emissions resulting from consumption are subsequently allocated to transportation types, traction and handling, based on the calculated consumption ratios. Calculated consumption ratio is obtained by multiplying the travelled distance or handling time by the specific consumption factor of the locomotive, and then dividing the calculated consumption by the monthly calculated consumption. Once emissions have been allocated to different transport types according to calculated consumption, traction is separated from handling for more precise allocation.

Handling emissions are allocated to wagons based on the handling time of wagon groups. Wagons that are bound to the same order and are moved together form a wagon group. Many yards share resources, such as shunting locomotives, and therefore the handling times for each yard and the emissions from handling are aggregated on a weekly basis to a station pool. A station pool is formed by yards that share resources, such as locomotives, and are near each other. The handling time per wagon is calculated by dividing wagon group handling time with number of wagons. The allocation of emissions to a wagon is based on the ratio of a wagon's handling time to a station pool's total handling time per week. This ratio is multiplied by the weekly emissions of the station pool, resulting in the wagon's share of the handling emissions. Emissions are allocated based on wagon groups because coordinated movement of wagon groups requires less handling than individual movements. In principle, handling wagon groups requires the same amount of work, whether there are two wagons or ten wagons in a group.

Traction emissions are calculated in a separate module from handling, as the allocation logic is different. Traction emissions are calculated at train subinterval level from monthly traction emissions. The subinterval level emissions are allocated to the wagon level using the subinterval division factor, which takes into account the weight of the wagon in relation to the other wagons in the train when allocating emissions from the train subinterval level to wagons. Traction is a bit more complex than handling as traction can be either empty or loaded. Traction can also be either train or locomotive drive, depending on the number of wagons attached to the traction unit. The locomotive drive emissions are calculated

separately from the train traction and are allocated to the next train using an order division factor, which distributes the locomotive emissions evenly over all subintervals of the next train. Once the emissions per train subinterval are known, empty trips are subtracted and categorized as empty. The empty train emissions are assigned to the next train based on the order division factor, which distributes the empty train emissions evenly over all subintervals of the next train.

Finally, the emissions from traction and handling are combined at the wagon order level. Emissions can be attributed to the appropriate transport order, customer, product, route, or any other relevant wagon information. Emission categories are included in the final allocation, allowing breakdown of emissions from locomotive traction, driving, and shunting using the wagon-level data. Empty and loaded transport can be distinguished in the information.

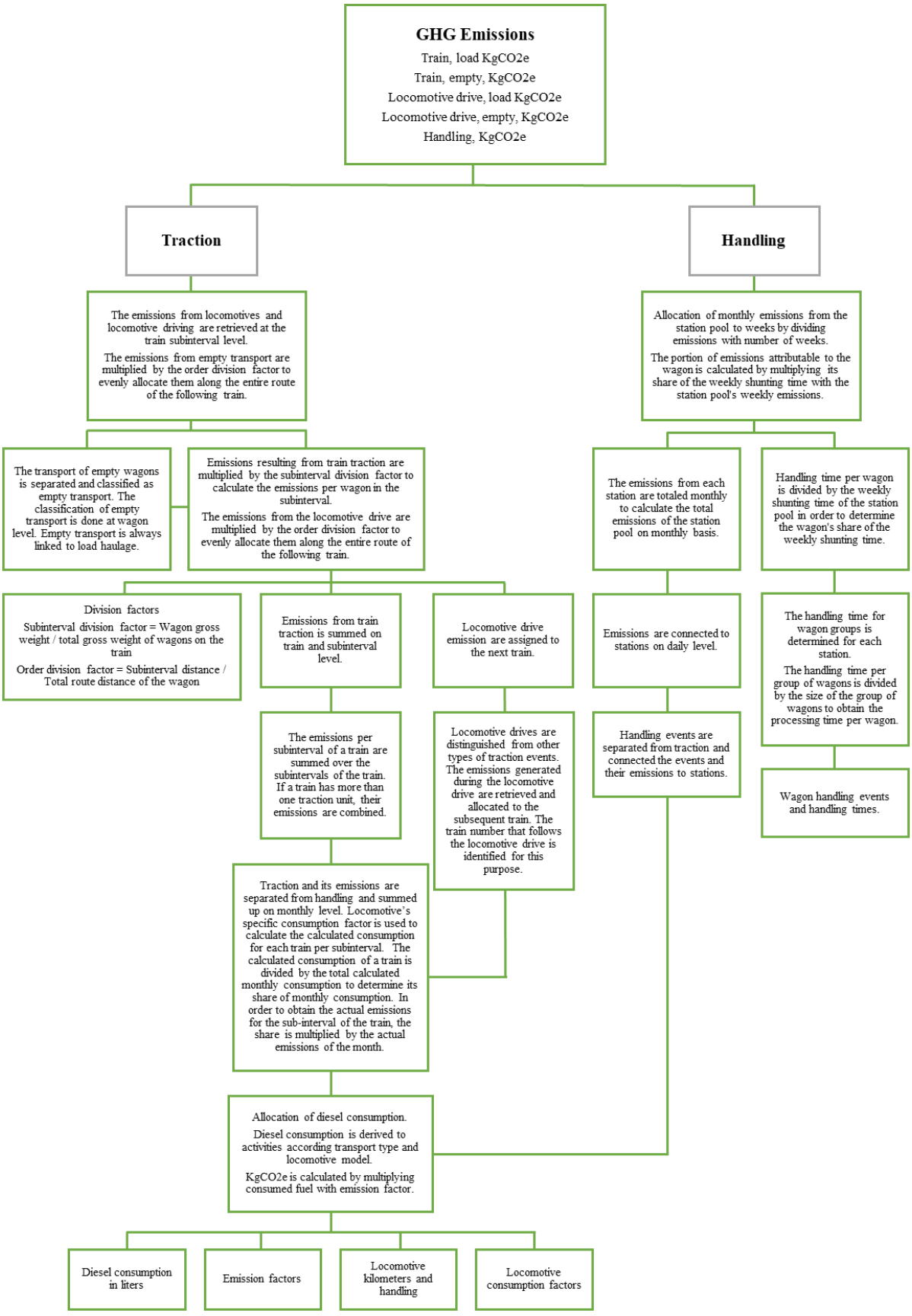

Figure 21. Structure and logic of VR Transpoint's emissions calculation

Figure 21 illustrates the process of calculating emissions in activity-based costing. Each green box represents a table or view that processes emissions data relevant to direct emissions. There are considerably more steps in the calculation of traction compared to handling due to the separate calculations required for locomotive drive, train and empty traction.

5.3 Emissions in the future in activity-based costing

Emissions calculation and carbon accounting regulations are currently undergoing substantial reform. While VR Transpoint's customer-specific emission calculation and allocation is currently at a satisfactory level, it must continue to evolve in the near future due to changing standards and upcoming legislation. The forthcoming CSRD directive and its ESRS standards will bring the most notable changes to accounting and reporting. Although the implementation of the directive and its changes may seem daunting at first, it establishes a transparent framework and reporting requirements. This will minimize the over-utilization of diverse standards and clarify EU-level requirements. However, the introduction of new standards is a complex process that requires the development of calculations. The current status of the calculation is now well understood as a result of this study. With a clear understanding of the current state of the calculation, the immediate goal is to identify actions needed to implement standards and improve the calculation methodology to meet new regulations.

Looking to the future, expanding the emissions calculation to include indirect emissions is critical. Specifically for rail logistics, as electricity is a significant energy source alongside diesel. Calculating emissions from electricity is an essential addition, but since electricity emissions are classified as scope 2 emissions, expanding the entire calculation to scope 2 emissions is necessary. However, calculating electricity emissions differs significantly from other emissions calculations. As it is possible to produce electricity in an environmentally friendly manner, it is also possible to purchase emission-free electricity. If electricity is emission-free, scope 2 calculations are irrelevant. To do so, it is necessary to be certain that no emissions were created in the production of the power. The current calculation methodology already includes minute-level electricity consumption, which provides a framework for calculating electricity emissions if ever needed.

The current calculation focuses only on tank-to-wheel emissions, but with the extension of scopes, emissions from energy production and distribution must be included. Reporting and calculating scope 3 emissions has been voluntary until now, but changing legislation is now making it mandatory. This will be reflected in the future of emissions accounting, which will need to be expanded to meet changing regulations. Before extending the calculation in activity-based costing, it is necessary to have a precise definition of the different emissions and their allocation methods. When extending emissions calculations in activity-based costing, it is important to only include emissions that are to be allocated and analyzed at the detailed level, such as customer or route. The emissions calculation at the VR Group level already includes all emissions, and therefore it may not be necessary to include all emissions in the customer-specific calculation.

A significant upcoming development area in VR Transpoint's emission calculation is the adoption of alternative, more eco-friendly energy sources that must be considered in activity-based costing. Adopting hydrotreated vegetable oil as an alternative energy source and integrating it into calculations will be most likely to be the first step. The introduction of a novel fuel will require a reassessment of the allocation of emissions among locomotive activities. From a calculative perspective, the most straightforward method to launch a new energy source is to implement it on a specific route, where designated locomotives only transport the wagons of customers who have committed to using the alternative energy source. In practice, however, this is not so straightforward, as locomotives serve different customer orders, and a train may carry wagons from several customers. There are many business factors to consider when introducing a new fuel. Once the business case of the adaptation of new energy source has been established, these factors can be incorporated into the activity-based costing.

When VR purchases a new fleet, such as new locomotives, it receives detailed information from the manufacturer on the environmental impact of the fleet, which enables more comprehensive environmental calculations. The new locomotives will also allow more accurate monitoring of diesel consumption, and in the future, emissions per locomotive can be calculated based on actual consumption. In order to do this, it will be necessary to have energy consumption meters in the locomotives. However, using the share of calculated consumption to allocate emissions to transport types can be a viable alternative for emissions calculation and allocation. This approach helps to eliminate customer-independent

consumption spikes, creating a more even distribution across the entire operation. For example, challenging weather conditions can cause non-customer related spikes in energy consumption, which can lead to an increase in emissions. When allocating emissions according to the share of calculated emissions, these spikes doesn't get allocated to few customers unfairly.

5.4 Areas for development in emissions calculation

Activity-based costing is an excellent calculation tool for calculating emissions at an accurate activity or cost object level. VR Transpoint has achieved a good level of emissions calculation and allocation, as all major fuel consuming activities are already included in the allocation. However, carbon accounting is an evolving area of research, and the calculation of emissions in activity-based costing must evolve accordingly. It is also important to acknowledge that assessing the logic and accuracy of the activity-based costing can be challenging due to the lack of generally available benchmarks in the rail logistics industry. However, the end-users of activity-based costing at VR Transpoint are experts in their own business areas, and they are quick to identify any shortcomings or errors within their respective areas. Therefore, collaborating with experts from different fields to develop the calculation when needed and promptly resolve any errors that may arise in the future is important.

VR Transpoint's emissions calculation for diesel involves accurately breaking down consumption on an hourly basis in activity-based costing. However, the costs and emissions of diesel fuel are constant throughout the day. Since diesel emissions are calculated using the same modules as the costs and electricity usage, diesel consumption is also analyzed on an hourly or even minutely basis. From a cost and electricity usage perspective, the specific hour- or minute level time that work is conducted is significant. For instance, electricity costs can fluctuate hourly, and personnel expenses are higher during evening and nighttime shifts than during the daytime. Therefore, it is justifiable to calculate in minutes, despite this being unnecessary in terms of diesel emissions. If the emissions calculation was to be separated from the cost calculation in a separate module, the diesel calculation can be simplified and calculated on a daily or hourly basis instead of the current method.

In accordance with the principles of activity-based costing, emissions are allocated to the customer's transportation order. Emissions resulting from empty transportation are consistently allocated to the customer's load transportation, and if the empty transportation cannot be allocated, it is excluded from the calculation. Transportation of wagons or locomotives for maintenance or other events tied to fleet undergoing maintenance are not considered in the calculation of emissions. Maintenance and other movements that cannot be linked to the subsequent train or order are not considered into the final emissions calculations since they are categorized as unallocated. The number of such events removed from the calculation is negligible, as they are essentially avoided because it is not economically viable for VR to move a wagon or locomotive unnecessarily. However, wagons and locomotives sometimes need to be serviced and transported to a maintenance yard, or in difficult situations, they may need to be moved from one yard to another without a customer order. Although these movements are necessary for business operations and their emissions are not allocated to customers, they are included in the VR Group's group-level emission calculation. In the future, it is worth evaluating whether emissions from essential transportation should be considered in VR Transpoint’s emissions calculation and allocated equally to all customer transport. While emissions to individual customers, such as emissions resulting from maintenance, may have a negligible impact and may be considered insignificant from their standpoint, it remains crucial to establish a comprehensive approach that encompasses all emissions.

The current emissions calculation divides all emissions by the ratio of calculated consumption. In reality, many external factors such as weather, train weight, and driving style affect energy consumption. In the future, as more accurate energy consumption data from locomotives becomes available, the actual consumption data can be incorporated into the emissions calculation and actual consumption and emissions can be calculated on a train-by-train basis. This will help determine, for example, which train or order configurations are best for the customer to move their orders in order to minimize emissions per net ton at an even more precise level. This has already been examined from an energy consumption perspective, but the inclusion of emissions changes the perspective slightly as orders often travel on multiple trains and there may be multiple orders on one train. Including actual consumption per locomotive in the calculation also requires further development of the logic and calculation.

Activity-based costing enables precise assessment of emissions and their origins, even at a very detailed level such as by route or yard. To report on its emissions, VR Group employs its proprietary calculation aligned with the GHG Protocol. However, the emissions calculation for the activity-based costing approach is designed to meet a distinct requirement, prioritizing the measurement of emissions for individual activities rather than relying on a group-level, protocol-based calculation. There are valid reasons for separating the calculations, but it would be beneficial to assess whether there can be greater consistency in the future. There has been a notable rise in requests for emissions data and inquiries from external stakeholders. In the future, establishing clear links between the different emission calculations would be beneficial, particularly with the implementation of new directives and reporting methods.

The lack of transparency in the calculation logic has been a development issue in VR Transpoint's customer-level emissions calculation, which has already been partially addressed, for example through this work. Understanding the current emissions calculation requires a technical understanding of the codes and emissions in terms of generation and structure. The calculation of emissions for specific cost objects has been done in the hands of a small number of staff members, because the calculation takes place in databases that are beyond the scope of general review. However, with the increasing importance of emissions reporting transparency under the new EU directive, there is still room for improvement in the transparency of the calculation, as many external stakeholders are also interested in the calculation and what it is based on.

6 Conclusions

VR Transpoint's activity-based costing has reached a good level of emissions calculation, as it considers all crucial activities and allocates all emissions related to customer orders to the correct cost objects. In this thesis, the logic of the target company's emissions calculation and allocation was systematically examined and factors influencing the emissions calculation now and in the future were identified. This chapter summarizes the main findings of the thesis and briefly answers the research questions.

How are the emissions allocated to customers in the activity-based costing of VR Transpoint?

The emissions from VR Transpoint's rail transportation are calculated and allocated to the customer through activity-based costing. Direct emissions in rail logistics are a consequence of locomotives using diesel fuel to transport wagons on both tracks and in yards. There are two primary types of direct emission events in rail transportation: traction and handling. Traction refers to the movement of a train on subintervals, while handling refers to activities performed in rail yards. Traction emissions include both empty and loaded transportation. Emissions from empty wagon transportation are attributed to the next train. The emissions from traction include the emissions from locomotive driving, which applies if the locomotive must be moved from one yard to another without any wagons. Emissions from handling cover emissions from the collection, departure, intermediate handling, destination, and distribution of freight. The shunting locomotive responsible for moving the wagons generates these emissions. In handling, emissions are assigned to the customer's wagon groups based on their handling time. These emissions are then assigned to individual wagons based on the size of the group. Figure 22 illustrates a simplified picture of the allocation logic where emissions from energy consumption are distributed to either traction or handling. Transported wagons are always tied to a specific order, through which they can be allocated to a customer or order.

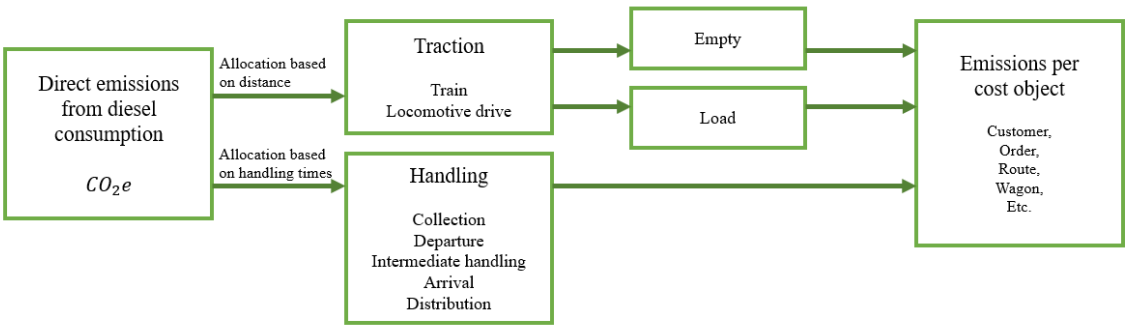

Figure 22. Simplified emissions allocation logic

VR Transpoint's emissions calculations are based on the calculated energy consumption, emission factors and actual consumptions. For traction and handling, the calculated energy consumptions are calculated by multiplying the kilometers travelled or the handling time for shunting activities by a locomotive- and transportation specific consumption factors. Actual energy consumption is used to derive actual emissions, which are allocated to traction and handling based on the calculated consumption ratios. The activity-based costing calculations identify the emissions generated during each subinterval and allocate them fairly to the wagons carried based on their respective weights. The emissions generated by empty trains and locomotive drives are distributed equally among the subsequent train subintervals. It is possible to separate these emissions from other traction emissions if only emissions from freight train are to be considered.

Each wagon on the track is always associated with a wagon order. Therefore, emissions are assigned to the customer through the wagon associated with their order. Emissions generated during traction and handling are assigned to the wagon and, in turn, assigned to the customer's order based on the binding of the wagon. All greenhouse gas emissions from diesel use are included in the calculation, as the emission factors used cover all such gases. The inclusion of greenhouse gases in the calculation allows energy consumption, specifically diesel consumption, to be converted into carbon dioxide equivalents, a widely used and comparable unit of measurement for emissions. All emissions included in the calculation are calculated as carbon dioxide equivalents.

What factors should be considered in emissions calculation now and in the long term?

The rapidly changing regulatory environment is a crucial factor to consider when calculating and allocating emissions, both presently and in the future. The new EU Corporate Sustainability Reporting Directive mandates that VR Transpoint report its emissions in accordance with the standards of the directive. As the directive takes effect, the company's stakeholders, particularly customers, will show more interest in emissions and their calculation in the future. Transparency in emissions calculation will be crucial, and inadequate reporting may have negative consequences for the company. Integrating the CSRD directive and its ESRS standards into the calculation is a main priority for the near future, and it will require a thorough mapping and definition of the reporting requirements of the company.

With the new regulations in place, it is necessary to evaluate the extension of customer-specific accounting to indirect emissions, particularly from energy use, in the near future. The calculation currently includes scope 1 emissions, which are emissions from fuel use. Electricity is a more complex energy source than fuel because its use does not directly cause emissions. However, emissions from electricity are related to its production and transport. Since there are different ways to produce electricity, it is possible to purchase emission-free electricity, which eliminates scope 2 emissions and renders the calculation of scope 2 emissions unnecessary. The calculation of Scope 3 emissions is a complex process that is dependent on the precise definition and allocation of indirect emissions. In the future, it will be necessary to expand emissions calculation to include relevant indirect emissions for allocation to customers. This will require a precise definition of indirect emissions and a decision on their allocation method in activity-based costing.

As technology advances and more precise data becomes available, emissions calculations must progress accordingly. Currently, VR Transpoint's emissions calculation relies on ratios of calculated consumption; however, future calculations can utilize actual consumption data for the most current and advanced calculations. The new locomotives and the data they collect on actual consumption will be crucial in the development of these calculations. Using calculated consumption can be a suitable approach when actual consumption data is unavailable. However, advances in fleet and technology have improved the accuracy of actual consumption data, providing an opportunity to take the calculation to the next level.

Additionally, utilizing actual consumption-derived emissions in the future may help identify problematic areas in logistics transport, which can subsequently reduce overall emissions.

Alternative, environmentally friendly fuels are increasingly prevalent worldwide, prompting a concern for their associated emissions. The use and emissions of alternative fuels must be considered in future calculations. In order to guarantee a smooth implementation of new alternative fuels with regards to emissions calculations, preparations must be made ahead of time. Thus, it is important that the calculation is developed before the new fuel is actually introduced. If Finland follows the lead of the rest of Europe, hydrotreated vegetable oil (HVO) will be the first environmentally friendly fuel to be introduced more widely in rail logistics. However, other energy sources must also be considered in the future as HVO isn't the only possible option.

In addition to the aforementioned factors such as emissions calculation and reporting under the new directive, the extension of customer-specific emission calculation to indirect emissions, and developments in emission calculation driven by technological progress and alternative energy use, additional factors are likely to affect emission calculation in the future. Environmental accounting and sustainability-related factors and requirements have undergone rapid changes in recent years, with no indication that similar trends will not continue in the future. In addition to the external factors that influence the calculation of emissions, the calculation must be technically maintained now and, in the future, to ensure that it always reflects reality as closely as possible.

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Appendices

Appendix 1. English-Finnish vocabulary of rail logistics

English	**Finnish**
Activity-Based Costing, ABC	Toimintolaskenta
Carbon Dioxide Equivalent	Hiilidioksidiekvivalentti
Cost Objects	Laskentakohteet
Descent yard	Laskumäkiratapiha
Emission factor	Päästökerroin
Global-warming potential	Lämmityspotentiaali
Greenhouse gas	Kasvihuonekaasut
Gross tons	Bruttotonnit
Handling	Käsittely
Locomotive	Veturi
Locomotive drive	Veturina-ajo
Locomotive kilometer	Veturikilometri
Net tons	Nettotonnit
Route	Yhteysväli
Shunting	Vaihtotyö
Specific consumption factor	Ominaiskulutuskerroin
Subinterval	Osaväli
Track	Rata, raiteet
Traction	Veto
Train	Juna
Train kilometer	Junakilometri
Wagon	Vaunu
Wagon group	Vaunuryhmä

Appendix 2. Interview questions

1	What is your role and area of responsibility at VR?
2	How are the consumption factors for rail logistics locomotives determined?
3	How are the emission factors for the rail logistics sector determined?
4	What are the emission factors for the rail logistics sector based on?
5	What emissions are included in the rail logistics emission factors and how are they considered?
6	How will the calculation and monitoring of emissions from rail logistics evolve in the future?
7	Are any standards or protocols utilized in VR’s reporting on sustainability, and if so, which ones?