Strategies To Decrease Emissions in Freight Transport

BSc Thesis Industrial Engineering and Management

Public version

by

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March 15, 2024

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Author Note:

This thesis was written as part of the graduation assignment for the Bachelor of Science in Industrial Engineering and Management educational program at the University of Twente.

Confidentiality Note:

For confidentiality, the thesis uses pseudonyms for products, suppliers, and carriers, such as Product X, Manufacturer A and Carrier 1. Any contextual information that allows a reader to identify the company or its partner companies, employees and business units has been left out.

Management Summary

This research aims to analyse existing sales data and find strategies to decrease the CO_2 equivalent emissions of the transport of product X of Company X. This software and hardware company wants to improve the carbon footprint of their products. Product X is manufactured, assembled, and packaged at two manufacturers, in Eastern Europe and Western Europe. It is then transported to a warehouse, and from the warehouse, the products are sent to the business partners. Reverse logistics are also implemented to allow business partners to return damaged products. The research question for this thesis entails: *What strategies should Company X implement to reduce their carbon emissions eq. of the transportation of Product X by 10%?*

The data analysis concludes that the first stage of the transportation flow of Product X, transport between the manufacturer and the warehouse, accounted for approximately 60% of all transport emissions of Product X in 2023. The emissions of the second stage of the transportation process, between the warehouse and the business partner, are for 80% caused by air transportation which is used for 20% of the orders. The last stage is the Return Merchandise Authorization (RMA) transportation between the warehouse, where the products are repaired, to the business partner. Even though this stage only contributes to 4% of the total emissions, 93% of the 4% of the total emissions are caused by air transportation. Moreover, 28% of the RMAs are sent back by plane. The total emissions for transportation of Product X type 1 are 0.655 KG CO_2 eq. per product and for Product X type 2, 0.283 KG CO_2 eq. per product. This distinction is created as Product X can be bought in two versions which have different weights.

A literature search finds possible strategies to reduce the emissions of the transportation of Product X. Together with the decision-makers at Company X, several KPIs were generated to assess the strategies generated with a scorecard. Every KPI is weighted on which is the most important. Combining the data analysis and the related literature gave a list of possible strategies that Company X could implement.

Via a scorecard, the best strategies are selected. The strategy that received the highest score is adjusting supplier agreements to rule out the use of 3.5-ton trucks, which is, according to the data analysis, the most effective way to decrease emissions, with a reduction of 26%. In addition, it is recommended to give the customers the option to make their delivery more sustainable. In this case, Company X's client can choose to offset the emissions, pay more for a more sustainable delivery, or choose to do nothing. Furthermore, to reach the 10% decrease that is stated in the research question, strategies can be combined. Collaborating with the carrier selection platform and adjusting the filters, educating the decision-makers, and choosing more often trucks, than airplanes as transport mode, could have a significant influence on the CO_2 eq. emissions. Lastly, it is recommended to use carbon offsetting but not on its own. Carbon offsetting is effective when it is combined with other reduction incentives. It is recommended to offset the emissions that cannot be reduced at the time.

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Abbreviations

B2B: Business to Business

CO_2: Carbon Dioxide

CSRD: Corporate Sustainability Reporting Directive

EMS: Electronic Manufacturing Service

FIFO: First In First Out

GCD: Great Circle Distances

GHG: Greenhouse Gas

ISO: International Standard Organisation

KG: Kilogram

KPI: Key Performance Indicator

MPSM: Managerial Problem-Solving Method

RMA: Return Merchandise Authorization

ROI: Return On Investment

SFD: Shortest Feasible Distance

SLR: Systematic Literature Review

UN: United Nations

WEEE: Waste from Electrical and Electronic Equipment

WtW: Well-to-Wheel

Reader's guide

The first chapter introduces the company, the problem and the product and gives insight into the problem-solving approach and the research design. The second chapter of this thesis displays the current situation of the transportation flows of Product X and previous calculations of the CO_2 eq. emissions. Chapter 3 dives into a data analysis of the currently available data where a new calculation is done for the carbon emissions eq. for transportation of Product X. In Chapter 4, a literature search is conducted to gather the necessary information for generating solutions. Chapter 5 portrays the generated solutions with the Key Performance Indicators (KPIs) made up by Company X and a scorecard to assess the solutions generated. Chapter 6 consists of the conclusion, the recommendations for Company X and further study options. The thesis is concluded with a discussion in Chapter 7.

1 Introduction

This thesis is conducted at Company X, a software and hardware company. This study involves analysing existing sales data and literature to suggest ways to reduce transport emissions at Company X. This first chapter introduces the company, product, and problem. Section 1.3.4 states the research questions that structure the thesis and define the outcome. After the problem identification, the problem-solving approach and research design are constructed to elaborate on the research methodology and structure.

1.1 Company Description: Confidential

Confidential

1.2 Problem Identification

Company X aims to analyze the departments for sustainable research subjects. A research objective is formulated within the fields of operations and sustainability, namely: the high carbon footprint of the up-and-downstream transportation of Product X.

1.2.1 Problem context

Company X has the ambition to be more conscious of its environmental responsibility. This is mainly due to the rise in their sustainable responsibility as a technological stock-listed company, and the implementation of the Corporate Sustainability Reporting Directive (CSRD) by the United Nations (UN). This CSRD states that from 2024, companies must report their impact on people and the environment (Spinaci, 2022). Company X has already instated teams in every department, to brainstorm about possible changes that can be made to decrease their carbon emissions. As their focus on sustainability is increasing, so is the focus on the carbon footprint of their products. A few years back, Company X hired a consultancy company to calculate the carbon footprint of the main products. However, when calculating the carbon footprint, the consultancy only focussed on the used materials in the hardware and made general assumptions about other aspects like transportation distances and waste. Company X then created a Life Cycle Assessment (LCA) for most products and created a Power BI dashboard that displays the product's emissions. In this LCA, Company X also made general assumptions regarding transportation mode and travel distance. In-depth research about the carbon emissions of transporting had not been conducted.

Currently, Product X hardware is manufactured by two companies, mainly by an Electronic Manufacturing Service (EMS) in Eastern Europe. The other manufacturer is located in Western Europe which only accounts for a smaller part of the production. The complete product is produced and packed at the EMS. Every week, the EMS in Eastern Europe sends a small shipment to the warehouse of Company X. This transportation is managed and scheduled by the EMS. In the warehouse the products are received, stored, order picked, and sent to the business partners. Reverse logistics are also implemented to allow the business partners to send their damaged products back. Company X fixes the product and returns it to the business partner or replaces the product with a new one if it is not reparable.

These return products are called Return Merchandise Authorizations (RMA). The transportation flows will be further elaborated in Section 2.1.

1.2.2 Problem cluster and core problem motivation

As can be seen in Figure 1, the starting problem is the high transport emissions of import and export of Product X. This can be divided into three stages, (1) the transport emissions from the manufacturer to the warehouse, (2) the transport emissions from the warehouse to the business partner, and (3) from the reverse logistics of the RMAs. The transport of the raw materials and other components to the manufacturer, and between the business partner and the end client is out of scope as there is no data available for this, cannot be affected by Company X and is not required for the CSRD.

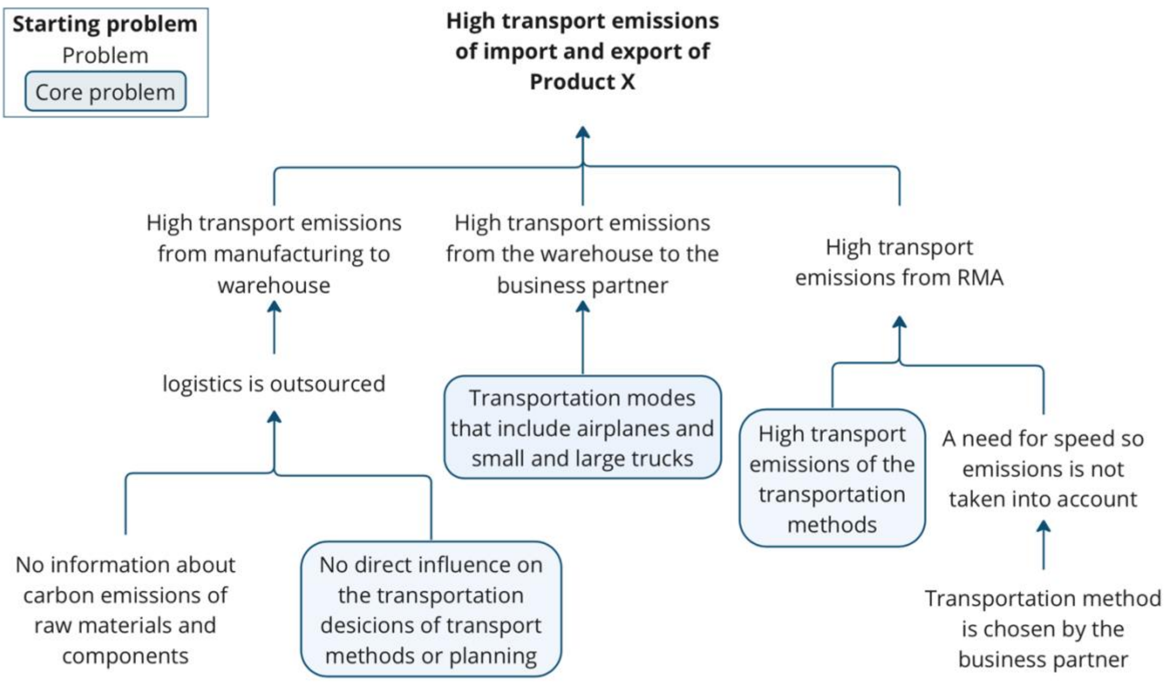

Figure 1: Problem Cluster.

Starting at the first stage, as logistics are managed by the EMS, Company X does not have a lot of say in the matter of transportation scheduling or the transportation modes used. However, Company X can advise or request to implement changes that could decrease the carbon footprint of the product. The problem with outsourcing is that the EMS can still reject their advice or request. If the logistics were not outsourced, Company X could have more impact on the carbon footprint of the product. One of the core problems that will be addressed in this thesis is this lack of influence. What can Company X advise the EMS to do or change in the process to reach the end goal of reducing the emissions of Product X?

Regarding the second stage, one of the parts that can be directly influenced by Company X is the transportation between the warehouse and the business partner. Transportation modes are chosen, and delivery schedules are created by Company X. The core problem in this category is the choice of transportation modes. Using other modes of transportation could reduce the carbon footprint of the product. Because this part of the transportation flow is directly influenced by Company X, this core problem is chosen, and in-depth research will be performed on the transportation modes.

The third stage in the problem cluster comprises RMAs. Company X dispatches these packages, and the mode of transportation and delivery schedules are chosen accordingly. These products can be combined with outstanding orders but could also be sent alone if necessary.

Combining these three core problems creates the big picture of the transportation process.

1.2.3 Measurement of norm and reality

Company X wants to improve its sustainable impact but has not done extensive research on the possibilities yet. They did calculate the total carbon footprint of Product X where quite a few aspects are assumed but not thoroughly researched. With online tools, these emissions can be measured (Auvinen et al., 2014). To calculate the effectiveness of the possible strategies constructed in this research, in consultation with the decision maker at Company X, a 10% decrease is set as a minimal required effect on emissions. For now, Company X does not have a target to reduce the emissions in scope 3. The target for scope 1 and 2 is net zero emissions in 2030.

The norm should be that Company X has insight into the carbon footprint of Product X and can act accordingly. Company X wants to reduce its carbon footprint as much as possible without disturbing the quality of its products (Company X Sustainable Value Creation, n.d.).

This gap, between norm and reality, highlights the desire to reduce the carbon footprint while lacking knowledge of the current situation.

1.2.4 Research questions

According to Cooper et al. (2014) and Saunders et al. (2019), a research question states what the issue or problem is that will be studied and what the research project will seek to find out, explain, and answer. It should be answerable and researchable, cover the whole problem, and have a logical relationship with the problem statement (Saunders et al., 2019). A research question should also be able to be divided into multiple sub-research questions. The research question of this bachelor thesis is;

"*What strategies should Company X implement to reduce their carbon emissions eq. of the transportation of Product X with 10%?*"

Following Thuan et al. (2019) and Wisse & Roeland (2022), the sub-questions should give insights into the deliverables and methods used. To guide the research and give insight into the deliverables and methods used, the following sub-research questions are constructed.

1. *What is the current transportation process and its carbon emissions eq., of Product X?*
2. *What strategies are stated in literature regarding the reduction of the carbon emissions eq. of a freight transportation process?*

   Knowledge question 1: What information is requested for the CSRD to be reported regarding the transportation of Product X?

   Knowledge question 2: How can the carbon emissions eq. of freight transportation be decreased?

3. *What KPIs regarding the transportation of Product X, are important for Company X?*
4. *What are possible strategies that Company X can implement to reduce the CO_2 eq. emissions of transportation of Product X?*

1.3 Problem-Solving Approach and Intended Deliverables

With the sub-research questions and the following connected actions and deliverables, the research question is answerable. To determine these research questions, the Managerial Problem-Solving Method (MPSM) was used, and a problem-solving approach was constructed, which can be seen in Appendix A (Heerkens, n.d.). The problem-solving approach dives deeper into the sub-research questions and gives an overview of all actions required and the final deliverables. Starting with the first two phases, the definition of the problem and formulation of the problem approach are explained in Sections 1.1 and 1.3.

The third phase of the research, where the problem is analysed, consists of defining the current situation and doing a literature study on related subjects. Through observations of data, and semi-structured interviews with the operations and purchasing teams, the current situation of the transportation flows is put into perspective by the creation of a transit map. To give insight into the current carbon footprint of the transportation process of Product X, a recommendation is made to the LCA team to update the existing information on the emissions of Product X. The methodology and calculations behind the results are shared therefore, the sustainability team at Company X can implement this method in multiple departments.

In a literature study about sustainable supply chains, with a focus on transportation and aspects that are considered when improving the carbon footprint of a transportation process, answers to these knowledge questions can be found. A broad theoretical perspective can help with generating improvements in the current situation.

By having meetings with the Sustainability Manager (2024) and the Outbound Logistics Manager (2024) of Company X, a list is made of important KPIs that need to be considered when selecting possible solutions. A scoring card would then be a convenient method to use for selecting the best solution.

A list of further research objectives and a conclusion and discussion about this research is constructed to add the last phase of the MPSM regarding results, conclusions, recommendations, and discussion.

The problem-solving approach concludes with a list of the intended deliverables.

- A transportation flow map of the current situation regarding transportation.
- A more precise calculation of the current carbon footprint regarding the transportation of Product X.
- An analysis of the transportation flows of Product X, regarding transportation scheduling and modes, agreements with the manufacturer, and purchasing planning.

- Strategies to decrease the carbon emissions eq. regarding the transportation of Product X.
- As discussed with the decision-maker, recommendations, and implementation advice on the optimal solutions.

1.4 Research Design

This research aims to analyse existing data and generate optimizations to decrease the carbon footprint of Product X, considering the transportation process.

1.4.1 Type of research design

The research that will be conducted is descriptive and explanatory. Calculating the carbon footprint and analysing the transportation process, gives a descriptive analysis as a result, as the variables are measured without influencing them. Finding the right solutions to optimize the carbon footprint of the transportation process will be explanatory research, as patterns and trends in existing data that have not been previously investigated will be explored.

1.4.2 Research population and subjects

For this research, contact will need to be made with the supplier and Company X employees including but not limited to, warehousing, transportation, purchasing, sustainability, operations, and supply chain employees of Company X. Other parties that could be affected by this research include the end user of the product and the business partners.

1.4.3 Research strategy

Regarding the research strategy, contact with all subjects discussed in section 1.4.2 is too broad for this scope. Through contact with the purchasing and operations department employees of Company X, information from and about the EMS, business partners, warehousing, and transportation employees can be accessible, without the need to talk to them directly. In-person meetings with Company X employees are possible and preferred over digital ways. Through observations, data analysis and meetings, the right information can be extracted. In addition, participating in meetings within Company X, regarding sustainability and operations is preferred to gain more general information about the works of other colleagues, whom to contact about certain subjects, and to get a broad overview of the current situation.

1.4.4 Data gathering methods and analysis

For this research, literature study, observation, and a qualitative communicative approach are used to acquire the right information. To calculate the carbon footprint, a systematic literature review is used to find out how to calculate it, whereafter communication and observation approaches are used to get an overview of the transportation flows. To make an overview of the transportation flows, a transit map will be created. Data to include in this transit map is gained from the operations department of Company X. To evaluate which KPIs are important for the company, interviews will be held with Company X employees. This communicative approach contains semi- to non-structured interviews and meetings.

Together with the decision maker, who is also the company supervisor of this bachelor thesis, we will define the right KPIs that need to be considered.

Quantitative data processing ensures that the carbon footprint and the transportation flows are broad in perspective. With qualitative data processing, solutions can be generated to optimize the current process considering the sustainable responsibility of Company X. Combing through the data, interpreting its meanings, identifying patterns, and extracting the parts that are most relevant to the research question, need to be done. (Cooper et al., 2014).

1.5 Summary

Chapter 1 discussed the company on which this thesis is based; Company X. The software and hardware company wants to improve the carbon footprint of their products. This thesis has a focus on the carbon emissions eq. of Product X. This product is manufactured, assembled, and packaged in both Eastern Europe and Western Europe. It is then transported to a warehouse of Company X. In the warehouse the products are received, stored, order picked, and sent to the business partners. Reverse logistics are also implemented to allow the business partners to send their damaged products back. The research question for this thesis entails: "*What strategies should Company X implement to reduce their carbon emissions eq. of the transportation of Product X by 10%?*"

Company X does not have a target to reduce scope 3 emissions yet, however, in consultation with the decision maker at Company X, a 10% decrease is chosen to make an impact on the total emissions. Chapter 2 elaborates on the current situation of the transportation of this product and its transportation flows and emissions. Chapter 3 analyses the data of Product X transportation and calculates its carbon emissions eq. Chapter 4 states background information on the possible reduction strategies that are discussed in the literature. These strategies are in Chapter 5 discussed and compared to the current situation and data analysis of Product X transportation. These strategies are evaluated and ranked.

2 Current Situation

In this second chapter, the current situation regarding the carbon footprint and transportation flows is mapped and explained. This chapter will answer the first sub-research question:

“*What is the current transportation process and its carbon emissions eq., of Product X?*”.

The carbon footprint of transportation of Product X has already been calculated in 2021, however, after an in-depth examination it is concluded that this calculation was not precise because it made a lot of assumptions. Therefore, in this chapter, the previous calculations are examined and are made more precise with the data of 2023 in Chapter 3. In addition, the transportation flows are mapped to give a concrete overview of the current situation of the transport of Product X.

2.1 Transportation Flows

The transportation of Product X is managed by the manufacturers, Company X and the business partners. The following transit map is created to give an overview of the transportation flows and methods and to analyse what parts can be influenced by Company X.

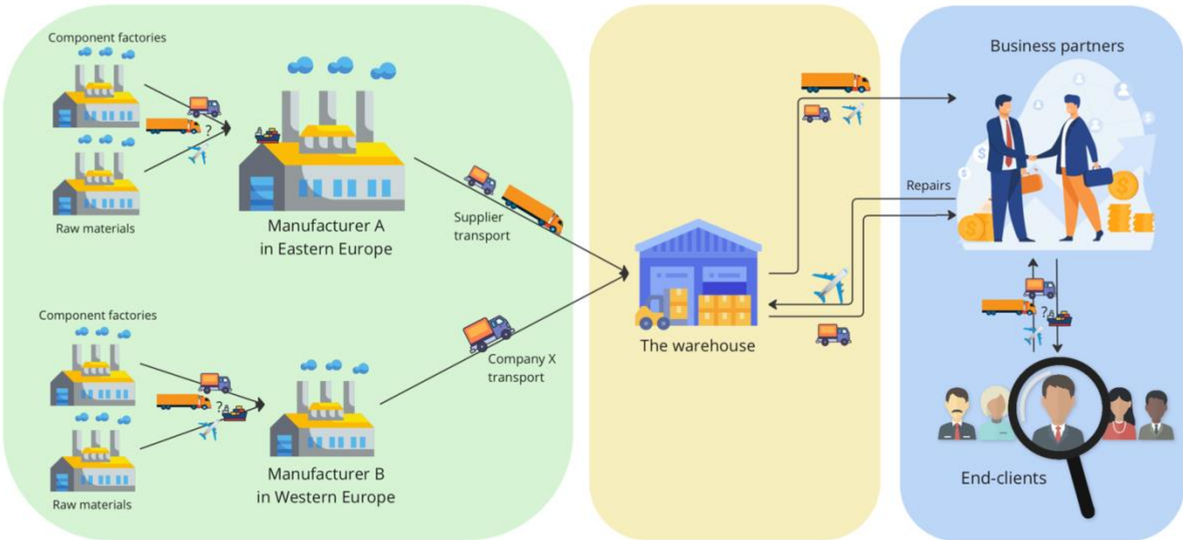

Figure 2: Transportation flows transit map.

Figure 2 consists of three sections, which explain the different stages in the transportation process. Green is transport from the manufacturers, yellow describes transport from Company X, and blue describes transport between the business partners and the end client. The corresponding forms of transportation accompany the transportation lines. As the raw material extractions and the component manufacturers are outside of tier 1 suppliers as stated in the CSRD (Royo, 2020), these segments are out of scope for this thesis. Moreover, there is no information on this at Company X and, if required, should be requested from the suppliers.

2.1.1 Section 1: the manufacturers

The first section is regarding the manufacturers. Product X is manufactured by two companies to minimize the risk of losing all production if a single manufacturer fails. Figure 3 shows the distribution between the two manufacturers. The biggest contributor is Manufacturer A, which is based in Eastern

Europe. Information concerning the transportation process, methods, and modes from Manufacturer A to the warehouse is delivered by Manufacturer A to conduct this thesis. The second manufacturer (Manufacturer B) is not in control of the transportation from them to the warehouse as Company X will retrieve the finished products when needed. The transportation flow of Product X starts, from a Company X perspective, at the EMS. Company X employees contact the manufacturer and deliver a bill of materials for them to acquire. The manufacturers manage the transport process for the materials and components. The manufacturers assemble and package Product X before sending it to the warehouse by truck.

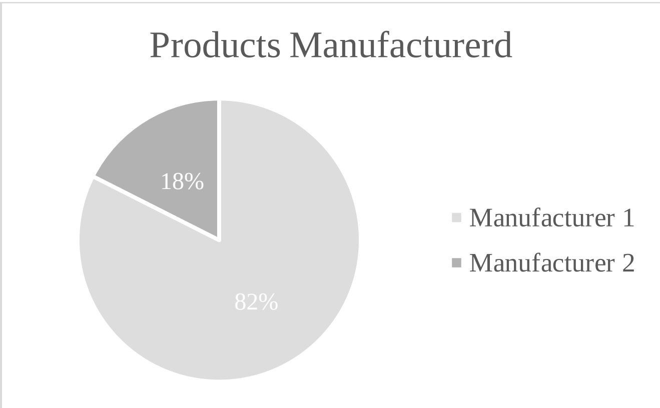

Figure 3: Distribution between the manufacturers.

Transportation from Manufacturer A in Eastern Europe to the warehouse is managed by the EMS. Manufacturer A works with LEAN management principles. This means that they want to keep as little inventory as possible (Usepa, 2003), which results in continuous shipments to the warehouse. According to data analysed, orders from Manufacturer A come in multiple times a week with a 3.5 or a 7.5-ton truck. Ideally, the EMS uses 7.5-ton trucks to deliver the products with collect transport where they visit multiple customers in one round. During the COVID pandemic production has been on halt a few times, therefore inventory at the warehouse decreased, and a backlog arose, which has not fully disappeared yet. To fix this backlog and get back on an inventory level of three months, the EMS regularly sends a smaller truck with a max of 3.5 tonnes. When the 3.5-ton truck is used, the truck is filled exclusively with Company X products and drives back empty. The size of the truck is selected based on the order size, and the products are delivered together with other Company X products.

As Manufacturer A entirely manages transportation, Company X is not able to change the transportation medium or the process used by the EMS. Company X can, however, advise and ask about the process of the manufacturer. Company X has the authority to request specific modifications from the supplier, provided they are practical and do not cause any inconvenience to the EMS, according to a Procurement Manager of Company X (2023). Moreover, the supplier seems to have a keen interest in becoming more eco-friendly, according to a Purchasing Employee of Company X (2023). This indicates that there is a possibility of successful negotiation between the parties involved.

Manufacturer B does not manage the transportation between the factory in Western Europe and the warehouse. When an order is finished at this manufacturer, a Company X employee retrieves the products with a 3.5-ton truck. Again, the transportation of the materials and components to the manufacturer is managed by Manufacturer B thus there is no insight into this and is therefore out of scope.

2.1.2 Section 2: the warehouse

The warehouse is managed by Company X employees and is part of the company headquarters. In the warehouse, the finished Product X coming in from the manufacturer is stored as inventory. The warehouse works with the First In, First Out (FIFO) principle and ideally has an inventory of three months (Operations Manager at Company X, 2023). When a business partner creates an order, the products are order picked in the warehouse. Depending on the volume of the order and the order destination, a logistics company is chosen and contacted. Company X uses an online tool to pick the cheapest transport company for that specific order, out of three carriers. In this decision, only the price of the transport and the speed of the delivery are considered. According to the Outbound Logistics Manager at Company X (2024), transportation methods used by the logistics companies are large trucks (40 tonnes), small trucks (3.5 tonnes), and planes.

Carrier 1 is selected for pallet transport and only uses large trucks to transport the products. When Carrier 1 is selected, products are transported by a large truck towards the Carrier 1 hub and are transported further with a large truck to the next hub or the business partner. Carriers 2 and 3 offer the option to use a plane or (small)truck, and transport boxes with the products. No pallets are used. Therefore, smaller orders that do not fit on a pallet are usually sent with Carrier 2 or 3. When Carrier 2 is selected, the product will be picked up by a small truck and transported to a central hub. From this hub, the products are transported with a large truck to Leipzich, to the next hub, or to the business partner with a small truck. Products are transported to Leipzig if they will be transported by airplane. If the business partner is located in the selected area of the hub, the package is transported to the business partner with a small truck from that hub. Carrier 3 has the same logistics system as Carrier 2 but with the nearest hub in another destination in the Netherlands and the airport in Cologne, Germany.

Calculated from Product X order data, in 2023 19% of all products were transported by plane, of which 13% were via Carrier 2 and 87% via Carrier 3. As can be seen in Table 1, large orders in terms of weight are more often transported via large trucks, and small orders via airplane.

Transport mode	**Number of products**	**% of all products**	**Total weight transported (KG)**	**Max weight per order (KG)**	**Min weight per order (KG)**
Airplane	2253	19%	1,997	72	0.3
Small truck	5314	45%	5,131	74.9	0.35
Pallet by large truck	4299	36%	11,210	387	45

Total	11866	100%	18,338

Table 1: Transportation modes from warehouse to business partners 2023.

2.1.3 Section 3: the business partner

The transport from the business partner to the end client is completely managed by the business partner. Therefore, Company X does not have any information on this and does not have the power to influence these decisions. This part is also not included in the CSRD (Callahan et al., n.d.). Company X can, however, advise the business partners to transport the products as emission efficiently as possible.

When products are broken, business partners can send them back to the warehouse. Products that are sent back are logged in a Power BI dashboard with an explanation of why the products are sent back. The results of the examination of the products that are sent back are also documented, which is why data exists on the number of products that are repaired and sent back to the business partner. In 2023, a total of 4208 products were sent back to the warehouse, which is 3% of all sales of Product X. Approximately 5% of the returned items are not fixable and are therefore thrown away (Repair Employee Company X. January 29, 2024). This Waste from Electrical and Electronic Equipment (WEEE) is then recycled via an external partner. Transportation of the RMAs from the business partner to the warehouse is managed by the business partner. When the products are fixed and should be returned to the business partner, airplanes and trucks are used as transportation modes, which are managed by Company X. These reverse logistics are an attempt to create a closed-loop supply chain (Krikke et al., 2004). Recovery options in the warehouse include direct reuse if no problem is identified, repair or refurbishment to restore the products to working order and replace components, or scrap which is the disposal of the product (Krikke et al., 2004).

2.2 Current Carbon Footprint

In 2021, Company X hired an external consultancy firm to research the carbon footprint for the core products of Company X. One of these products was Product X. Company X later made an LCA of which results were published in a power BI dashboard. After examining the Company X LCA report and the consultancy report, it was found that both calculations were based on mostly estimations. To make sure that the strategies and recommendations of this research could decrease carbon emissions eq. by 10%, a precise calculation of the transportation of Product X is needed. In this section, the product technicalities are explained, and the previously conducted LCA by Company X and the emissions calculation done by a consultancy, are assessed.

2.2.1 Product technicalities

There are multiple product parts and types that fall under the collective name Product X, as shown in Table 2. Product X can be divided into two versions (types 1 and 2) based on weight. The product is shown in Figure 4.

Confidential

Figure 4: Product X. *Source:* (Product X, n.d.)

Product X consists of multiple versions of the product. Therefore, the products with 0.692 KG as weight will be combined under the name “Product X type 1” from now on. The product with 0.159 KG as weight will continue to be grouped as “Product X type 2”. Table 2 shows the different product weights.

Product Code	Product Name	Product Weight (KG)
Confidential	Confidential	0.087
		0.820
		0.692
		0.692
		0.692
		0.159
		0.159
		0.159

Table 2: Product names and weights.

The first two products in Table 2 are out of scope for this research.

2.2.2 Previous calculations

The previous calculations include the consultancy’s assessment and Company X’s assessment of the emissions. Upon careful examination of the strategies and calculations, it appears that some sections were assumed instead of utilizing the available information.

The consultancy’s calculation in 2021

The consultancy researched a few products of Company X and calculated their carbon footprint. One of the three products they focused on was Product X Type 1. Regarding transportation, the following assumptions were made.

- All transportation is done with a truck of lorry size 16-32 tonnes, with emission factor EURO 5 in Europe, and EURO 4 in non-Europe.

- The distance from the business partner to the end client is excluded and so are the RMAs as they are likely to be insignificant.
- For transportation distances, they took middle-of-country estimates.
- They used sales data for 2021 to estimate the travel distances. The main sales destinations were France = 26%, Denmark = 13,5%, NL = 12%, UAE = 11%, Germany = 11%, Other European = 23%, Other Middle East = 4%.

As previously explained, Product X is transported by 3.5-ton, 7.5-ton and 40-ton trucks, and airplanes. Distances between the business partner and the end client are unknown therefore this assumption is accepted. Middle-of-country estimates are reasonable when calculating the transportation distance.

The consultancy results were 233 kg CO_2 eq. as the impact of one full lifecycle of Product X. Without the use phase, it would be 33kg CO_2 eq. which would include raw materials extraction, components manufacturing, distribution, transportation, and end-of-life. More precise results regarding transportation were not shared or calculated. A recommendation that the consultancy gave was to consider solely selling the product in Europe, to decrease the distribution impact of the product (Consultancy Report, 2021)

Company X's Life Cycle Assessment based on data from 2021

Assumptions included the following regarding transportation.

- Regarding transportation distance, Company X assumed distances of transportation of parts to the manufacturer (2000KM by truck or 8000KM for the containership), from the manufacturer to the warehouse (2000KM), from the warehouse to the business partner (2000KM by truck in Europe, 8000KM with containership outside of Europe), and from the business partner to the client (200KM). They made a distinction between these distances if they were global and if they were local (Europe).
- Transportation in Europe is done with 16–32-ton trucks with EURO5 as the emission class. Outside of Europe is shipped with a containership or a truck.
- For this analysis, it has been considered that there is a 50/50 division between the products sold in Europe and globally.
- Transport distance from material extraction to component production and the RMA transport is excluded.

According to the report of the LCA (2021), a transport average was calculated of 1.18 kg CO_2 eq. per KG material. Therefore, the transport phase impact was 1.18 times the transport weight.

As can be seen in Table 3, the LCA made a distinction between the two types of Product X, which is reasonable while the weights for all the products of Type 1 are the same: 0,695KG, and 0,159KG for Type 2. For the calculation, the LCA made several assumptions regarding transport mode and transportation distance. For example, "*It is assumed that within Europe products are transported* *by truck, and outside of Europe by truck and containership. The distances have been assumed by LCA experts and are based on information about the average journey that a Company X product follows."* (Company X, n.d.). This Life Cycle Assessment was made to represent most of Company X's products thus the calculations and results are not very precise.

Item Description (No.)	Production KG/CO_2	Transport KG/CO_2	Energy KG/CO_2	Disposal KG/CO_2	Total KG/CO_2
Confidential	9.43	0.93904395	119.88	0.39396944	130.64
	9.43	0.93904395	119.88	0.39396944	130.64
	9.43	0.93904395	119.88	0.39396944	130.64
	9.43	0.93904395	119.88	0.39396944	130.64
	4.36	0.26373653	79.92	0.09052188	84.63
	4.36	0.26373653	79.92	0.09052188	84.63
	4.36	0.26373653	79.92	0.09052188	84.63

Table 3: Carbon footprint Product X results in 2021.

Yet again, this calculation did not consider air travel. This is further examined in Section 3.2. It should be noted that Company X does not act on this LCA as they are aware that these calculations are not precise. Nevertheless, estimations could be useful to consider in this research, for example, the transport distance between the business partner and the end client (Company X, n.d.).

2.3 Summary

The transportation flows of Product X are divided into three sections; (1) the manufacturer, (2) Company X, and (3) the business partner. The first section consists of transportation between the manufacturers and the warehouse. The manufacturer in Eastern Europe manages the transport between them and the warehouse, with 3.5-ton and 7.5-ton trucks. Transport from the manufacturer in Western Europe to the warehouse is managed by Company X, these products are retrieved by Company X employees in a 3.5-ton truck. Company X also manages transportation between the warehouse and the business partner where they choose for every shipment the carrier which is the cheapest and can deliver the products fast. They can choose between three carriers. The last section between the business partner and the end client is managed by the business partner, therefore, Company X does not have any data on this and is out of scope for this research. Company X does offer the option to repair broken products which are called RMAs. Transport of these RMAs is managed by Company X and is done in the same way as transport in section 2.

The carbon emissions eq. of Product X have been calculated before by Company X and by an external consultancy company. These calculations both consist of several assumptions regarding transportation modes and distances. Chapter 3 elaborates on the assumptions made for the carbon emissions eq. calculations and gives the calculations of the emissions of the transportation of Product X over 2023.

3 Data Analysis

As stated in Chapter 2, Company X already performed an LCA and hired an external consultancy to calculate the emissions of core products of Company X. However, these past calculations are not accurate as they include a lot of false assumptions, according to an LCA Expert Employee of Company X (2023). Therefore, in this chapter, a data analysis is conducted to analyse the current situation on the carbon emissions eq. of the transportation of Product X.

For this calculation, the procurement and sales data of 2023 is used. For the calculation of the emissions of transportation of Product X, we divided transportation into three stages. (1) transport from the manufacturers to the warehouse, (2) transport to the business partner, and (3) transport of the RMAs back to the business partner after the products are repaired or replaced. Raw materials and component transportation to the manufacturer are disregarded as this does not fall under tier 1 of suppliers from the CSRD. As the business partners are spread worldwide and sell to clients in their region, and this transportation is not measurable or adjustable by Company X, it is assumed that transport from the business partner to the end client can be disregarded. Therefore, these sections of transportation are out of the scope of this research.

To calculate the CO_2 eq. emissions of the transportation part of an operation, tools and calculations are available. However, most of these calculations differ from each other, as they take different subjects into account (Auvinen et al., 2014). As stated by Zubair M, et al. (2023), there are two common approaches to estimating CO_2 emissions: one uses vehicle characteristics and speed to produce an estimate, while the other uses fuel consumption and distance travelled. Using an online tool can combine these approaches to get a precise estimate. For this thesis and its scope, an online tool is used to calculate the emissions.

This tool is CarbonCare.org which follows the ISO 14083:2023. "*In March 2023, the International Standard Organization (ISO) released the ISO 14083 standard that provides requirements and guidance for the quantification and reporting of GHG emissions along the entire transport chains for passengers and freight*." (Fancello et al., 2023). As can be seen in Appendix B, the tool considers multiple ISO classifications and focuses merely on freight transportation. This tool considers an average load factor of 80% and has multiple filters to adjust shipment weight, transportation mode, transportation type/size and destinations. All distances for transport activities are based on the Shortest Feasible Distance (SFD), except for air which is based on Great Circle Distances (GCD). A Well-to-Wheel (WtW) consideration has been made with this tool. A WtW analysis is commonly used to calculate the total effect of fossil fuels on the environment (Zhang et al., 2021). This analysis considers the emissions from the fuel extraction until the use of fuel to turn the wheels of a truck. This tool has been chosen as it uses the available information as input. Information on the trucks used such as the emission factor or load factor was not available.

3.1 Carbon Emissions eq. from the Manufacturer to the Warehouse

As Product X has two manufacturers, this section is divided into two; (1) Manufacturer A to the warehouse, and (2) Manufacturer B to the warehouse. As mentioned, transportation from Manufacturer A to the warehouse is managed by Manufacturer A. The size of the truck is based on the size of the orders. Ideally, Manufacturer A would send 7.5-ton trucks with the products however, a shipment with a 3.5-ton truck happens regularly. To perform this calculation, various scenarios are being considered, as the current reality is not the same as it was before the pandemic. Manufacturer A and Company X are working to get back to that situation. Therefore, three scenarios are considered; (1) the ideal situation which includes 7.5-ton trucks for every delivery, (2) 7.5-ton trucks for 80% of the deliveries and 20% with express deliveries with 3.5-ton trucks, and (3) a distribution of 50% 7.5-ton trucks and 50% 3.5-ton trucks. The results of this calculation can be seen in Table 4.

Manufacturer A	**7.5t truck**	**80% 7.5t | 20% 3.5t**	**50% 7.5 | 50% 3.5**
Total CO_2 eq. emissions Type 1	3,661.370	5,778.996	8,955.435
Total CO_2 eq. emissions Type 2	978.970	1,170.848	1,458.665
Total CO_2 eq.	**4,640.34**	**6,949.844**	**10,414.100**
Number of products Type 1	22,879		
Number of products Type 2	26,624		
CO_2 eq./Product X type 1	**0.160**	**0.253**	**0.391**
CO_2 eq./Product X type 2	**0.037**	**0.044**	**0.055**

Table 4: Carbon emissions eq. from transport between Manufacturer A and the warehouse.

As can be seen in Table 4, the decrease in the use of 3.5-ton trucks and the increased use of 7.5-ton trucks could halve the total emissions from transport between Manufacturer A and the warehouse.

Manufacturer B only manages roughly 20% of the production of Product X, and Company X employees collect these products in a 3.5-ton truck. Calculations of the CO_2 eq. emissions are shown in Table 5. These emissions are calculated with the online tool mentioned at the beginning of Chapter 3.

Manufacturer B	**3.5t truck**
Total CO_2 eq. Product X type 1	25.78
Total CO_2 eq. Product X type 2	5.55
Total CO_2 eq.	31.33
Number of products Type 1	5,079
Number of products Type 2	4,746
CO_2 eq./Product X type 1	0.005
CO_2 eq./Product X type 2	0.001

Table 5: Carbon emissions eq. transport Manufacturer B.

Calculated from Table 4 and Table 5, if all transport from Manufacturer A to the warehouse would have been done with a 7.5-ton truck, the total transportation carbon emissions equivalent in 2023 for Product X is 4672.09 KG CO_2 eq., of which 1% comes from transportation from Manufacturer B, which accounts for 17% of the products delivered. This calculation does not consider the deliveries from Manufacturer A with a 3.5-ton truck. However, even if 80% is transported with 7.5-ton trucks and 20% with 3.5-ton trucks was used for the calculation, it would still not project the real emissions in 2023 as, according to the Purchasing Manager of Company X (2023), the small trucks were used for more than 20% of all deliveries. The correct percentage is not available. As the size of the truck is selected based on the order quantity and is shipped together with other Company X products, it would be possible to combine all order receipts and figure out the most used size of the truck, however, as all Company X departments have different data systems, and because of the scope of this thesis, this is not researched.

When this data is combined, the CO_2 eq. emissions for transport between the manufacturers and the warehouse are calculated per product over 2023, which is shown in Table 6. The individual calculations are done with the online tool mentioned at the beginning of Chapter 3 and are calculated per Product X type (so type 1 or type 2) that is received in the warehouse from the EMS. According to a Warehouse Employee of Company X (2023), currently, 3.5-ton trucks from Manufacturer A come in more often than 7.5-ton trucks which can be explained by the current backlog which arose from the pandemic. As Company X and Manufacturer A are trying to increase the number of orders shipped with 7.5-ton trucks instead of 3.5-ton trucks, for the calculation of the total KG CO_2 eq. emissions for the transport between the EMS and the warehouse, a 50/50 division is used to portray a normal situation.

Transport CO_2 eq. (KG) per product from the EMS to the warehouse	
Product X type 1	0.397
Product X type 2	0.056

Table 6: KG CO_2 eq. emissions per product for transport between the EMS and the warehouse.

3.2 Carbon Emissions Equivalent for Transportation to the Business Partner

Sales data from 2023 of Product X is analysed and a distinction is made between transport mode, carrier and destination. Approximately 20% of the sales have been analysed as the data was incomplete. Because of the time scope of this thesis and the absence of complete data, the available data has been used to represent the data of 2023.

The transport modes used in 2023 are airplanes, small trucks (3.5 tonnes) and large trucks (40 tonnes). Company X can choose between three carriers with destinations worldwide. To get a precise calculation of the carbon footprint of transportation of Product X between the warehouse and the business partner in 2023, for every country per transport mode, the carbon emission equivalents are calculated.

Calculations are based on the data per transportation mode and country. For transport via air with Carrier 2, the distance between the warehouse, the hub and the airport in Leipzig, Germany, is bridged with a 3.5-ton truck to the hub and a 40-ton truck to Leipzig. This CO_2 eq. emission is added to the CO_2 eq. emissions from air travel, which distance is calculated by looking at the end location and finding the nearest airport. It may be the case that there are multiple destinations in one country and in that case, the average flying distance has been considered, with considering the weight of the orders to every city. As can be seen in Figure 5, 26% of the orders were destined for Germany, 21% for Poland, 16% for The Netherlands and 8% for Belgium. The first non-European country on the list is the United States with 0.52% of the sales in 2023. However, even though there are mostly European countries on the sales list, this does not mean that most of the transportation is done with trucks. According to the sales data, even flights from Germany to Belgium are booked, excluding express deliveries.

As shown in Figure 6, air transportation is commonly used in Europe. It is noteworthy that the

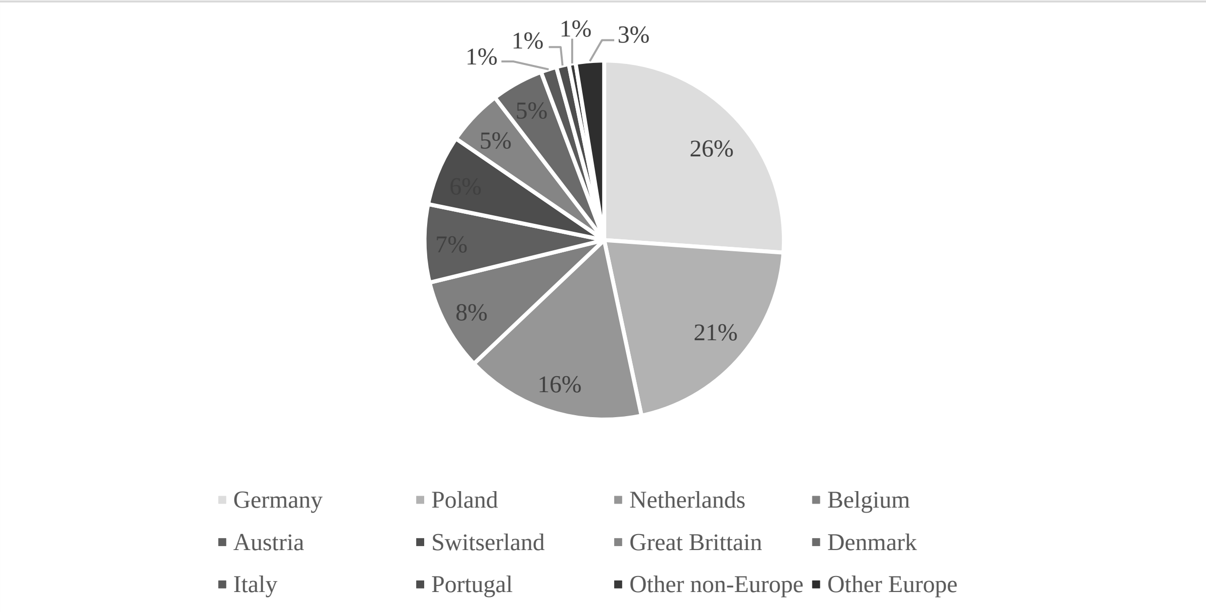

Figure 5: 2023 sales destinations.

destination does not necessarily dictate the mode of transportation. For instance, Belgium can be reached by airplane, as well as by both large and small trucks. According to the Manager of Outbound Logistics at Company X (2024), the transportation mode and carrier are chosen via an online tool (Transsmart) which takes into account the weight of the order, the necessary speed of the delivery, the destination, and the price. The tool gives multiple options to choose from where a Company X employee makes the decision based on the price and delivery speed.

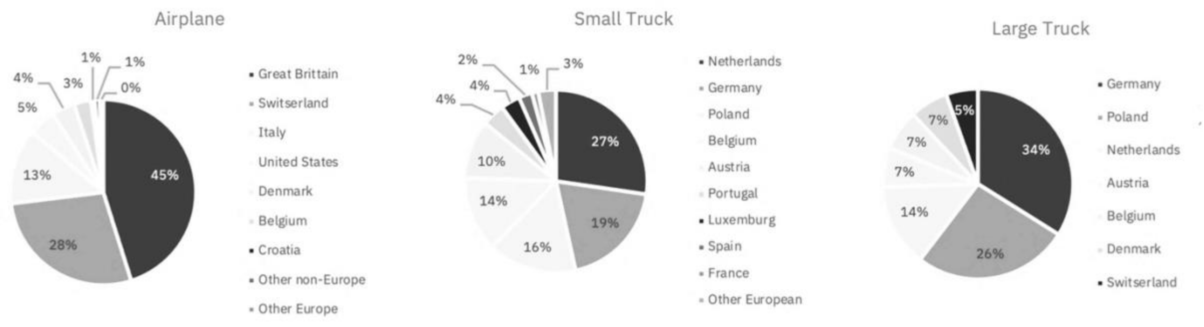

Figure 6: 2023 sales destination per transport type.

The transport between the airport and the end destination has not been calculated due to the level of complication in doing that for every order in the last year and because of the scope of this research. As Company X sells business to business (B2B) and the business partner sells within its region, this distance between the business partner and the end client is assumed to be insignificant and is therefore out of scope. Regarding air transport via Carrier 3, the same calculation has been done for Carrier 2, but using another hub and selecting Cologne, Germany, as an airport instead of Leipzig, Germany.

Small truck transportation has been calculated to be picked up at the warehouse with a 3.5-ton truck and further transported to a hub, depending on the carrier. For countries other than the Netherlands, for the calculation, a 40-ton truck has been used to calculate the CO_2 eq. emissions for the travel between the hub and the net central hub in the destination's country. As Carrier 2 and Carrier 3 have multiple hubs in, for example, Germany, a central hub is chosen to take an average transport distance. The calculation of the CO_2 eq. emissions of the large truck category, with Carrier 1, entail the use of 40-ton trucks which do the transport from the warehouse to the hub and the next hub and so on. All transport via Carrier 1 is done with pallets, however, calculations are done per product or in total.

	Airplane	**Small truck**	**Large truck**	**Total**
CO_2 eq. emissions in KG	2149.18	234.34	459.54	2,843.06
% CO_2 of total	76%	8%	16%	
Total weight	1,995.50	3,730.30	11,210.00	16,935.80
% Weight of total	12%	22%	66%	
CO_2 eq./KG	1.08	0.06	0.04	
Number of products	2,253	5,314	4,299	11,866
% products of total	19%	45%	36%	
CO_2 eq./product	0.95	0.04	0.11	
Total B2B transport costs 2023	€13,121.28	€11,336.71	€13,194.97	€ 37,652.96
% costs of total	35%	30%	35%	
Costs/product	€5.82	€2.13	€3.07	

Table 7: Total emissions per transport mode.

From Table 7, it can be concluded that the total CO_2 eq. emissions in 2023 from the warehouse to the business partners worldwide were 2843,06 KG. The average of all Product X types, the total transport CO_2 eq. emissions are 0.39 KG CO_2 eq. per KG material. 76% of the total amount of CO_2 eq. emissions resulted from transportation via air, even though that only accounted for 19% of all products transported in 2023.

From this data, the Pareto principle can be applied. The Pareto 80/20 principle states that a small number of causes (20%) is responsible for a large percentage (80%) of the effect (Lipovetsky, 2009). In this case, 11% of the weight of the total products transported in 2023 accounts for 76% of all CO_2 eq. emissions. The transport mode responsible is the airplane. To visualise, this effect is shown in Figure 7.

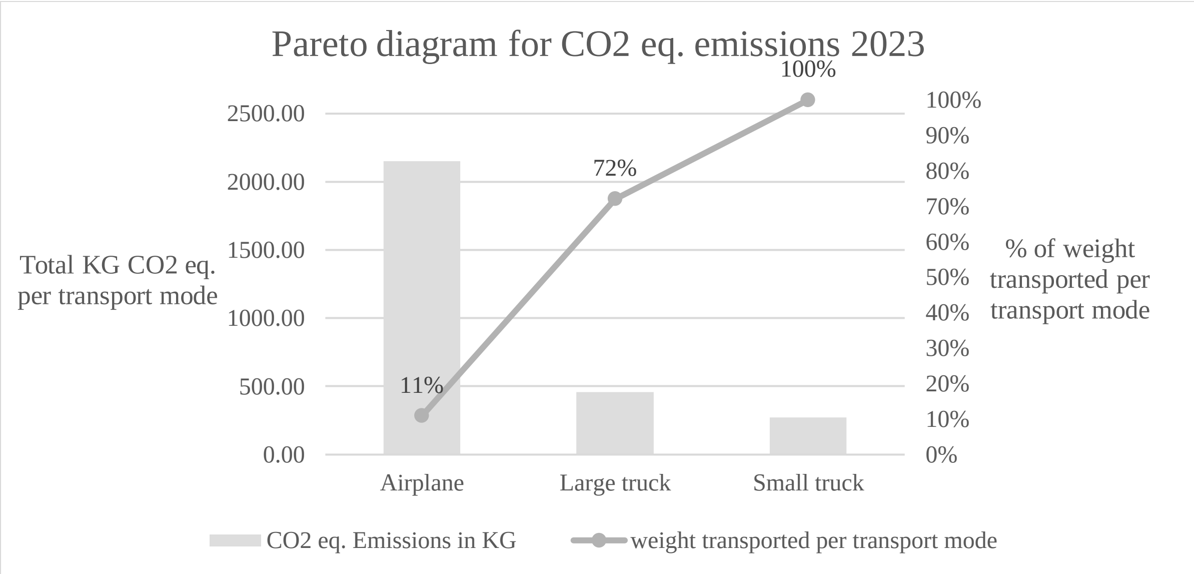

Figure 7: Pareto distribution of KG CO_2 eq. and transported weight for warehouse to business partner transport.

To compare the previous calculations done in recent years, the carbon emissions eq. per product are shown in Table 8. For every transport mode, the first column is the KG CO_2 eq. that is calculated over 2023 per product (type) and the second column is the percentage of the total amount of products ordered that are shipped with that transport mode.

	Total products	**Airplane**		**Small truck**		**Large truck**		**Total KG CO_2 eq. per product**
Product X type 1	5,625	1.17	16%	0.06	36%	0.09	49%	0.25
Product X type 2	5,258	0.78	23%	0.05	51%	0.14	26%	0.22

Table 8: 2023 Transport to business partner CO_2 eq.

3.3 Carbon Emissions eq. for RMA Transportation

For 2023, a total of approximately 4300 products were sent back from the business partner, from which 95% were repaired or refurbished and sent back to the business partner (Repair Employee Company X, 2024). As data on RMA transport of Product X is not complete or easily accessible, this data is calculated from all RMA transportation of two departments narrowed down to the orders to the receiving countries of Product X. This way, the emissions can be calculated per KG of RMA transported.

Of the RMAs that were repaired or refurbished, approximately 28% were transported back by airplane instead of truck, which made up for 93% of the emissions emitted by RMA transport to the business partner, as is shown in Figure 8.

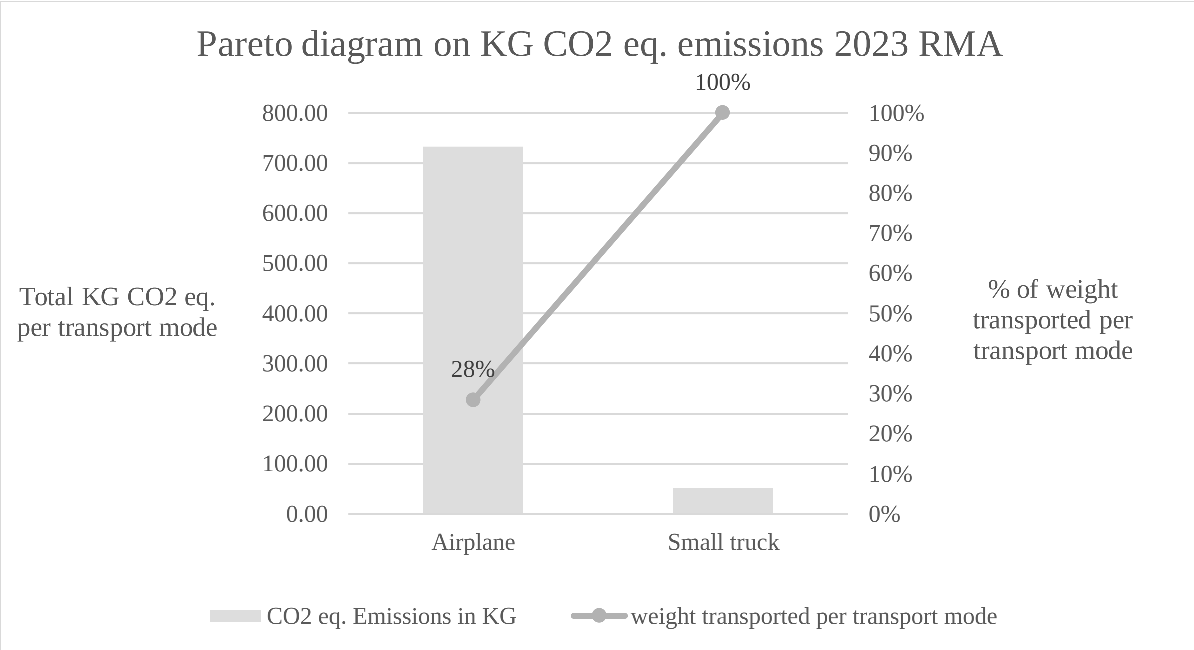

Figure 8: Pareto distribution of KG CO_2 eq. emissions in 2023 of RMA transportation per transport mode.

In 2023, 7.6% of Product X was sent back. According to the Repair Employee of Company X (2023), 95% of RMA are fixed and sent back. Therefore, only 7.2% of all sold products are returned. Dividing the transport emissions by the number of products sold results in the average KG CO_2 eq. per KG of 2023 increasing by 0.015 KG.

3.4 Conclusion on Carbon Emissions eq. of Transportation of Product X

Table 9 shows the results if all transport emissions from the different transport stages of Product X are summed up.

	KG CO_2 eq. per product
Product X type 1	0.655
Product X type 2	0.283

Table 9: Total KG CO_2 eq. emissions.

Transport via airplane accounts for 21% of all emissions of transport of Product X. The biggest stage contributor to the CO_2 eq. emission is transportation between the manufacturer and the warehouse. This accounts for approximately 60% of the total CO_2 eq. emissions. The RMAs account for 4% of the total emissions.

Comparing this to the previous calculations, incorrect assumptions made in the LCA of Company X, and the consultancy are discovered in this research as well as a more in-depth calculation of the carbon emissions eq. on the account of transportation between the manufacturers and the warehouse, between the warehouse and the business partners and the RMA transportation. The consultancy firm that calculated the emissions of Product X, stated that transportation is done with a truck of lorry size 16-32 tonnes and that the RMAs are likely to be insignificant (Consultancy Report, 2021). As explained in Section 2.1, the truck size varies quite a lot as well as the transport mode. The previous calculations done by Company X lacked the consideration of transportation via airplane and made assumptions regarding business partner location and therefore, transport distance. These assumptions are false if compared to the data of 2023.

Concentrating on the individual stages, transportation between Manufacturer A and the warehouse is in this calculation assumed to be done for 50% with a 7.5-ton truck and 50% with a 3.5-ton truck. It is likely to have a different distribution as a Warehouse Employee (2023) stated that more 3.5-ton trucks are arriving from Manufacturer A than 7.5-ton trucks are arriving. However, noting that Company X and Manufacturer A are working on increasing the 7.5-ton deliveries and decreasing the 3.5-ton deliveries, for this calculation a 50/50 distribution is chosen.

Transportation via airplane accounts for 76% of the total CO_2 eq. emissions of the second stage even though that only accounts for 11% of the total weight. In the third stage, RMA transportation, 93% of the emissions account for 28% of products transported.

4 Related Literature

In this chapter, multiple knowledge questions are answered to get more insights into the theory and possible strategies in reducing the carbon emissions eq. of freight transportation, that already exist and could be interesting for Company X to implement. This chapter will answer the following research question;

What strategies are stated in literature regarding the reduction of the carbon emissions eq. of a freight transportation process?

Applicable knowledge questions are set up to guide the literature study.

- Knowledge question 1: What information is requested for the CSRD to be reported regarding the transportation of Product X?
- Knowledge question 2: How can carbon emissions eq. of freight transportation be decreased, according to literature?

To state the importance of research into the emission of transportation, in 2010, Mckinnon and Piecyk already found that climate change is expected to wield a significant influence on freight transport operations in more than 80% of businesses by 2020 (Jevinger & Persson, 2016). Reducing the greenhouse gasses of the production industry starts by analysing the greenhouse gas (GHG) emissions. "*As the old business mantra states, 'if you can't measure it you can't manage it' and so the logical place to start is with detailed measurement of GHG emissions.*" (Mckinnon & Piecyk, 2010). It is forecasted that transportation will be responsible for 30–50% of CO_2 emissions by 2050 (Salehi et al., 2017). Therefore, in 2022, the European Union introduced the CSRD (Nilsson, 2023).

4.1 Measuring Scope 3 of the Corporate Sustainability Reporting Directive (CSRD)

The newly initiated CSRD has a specific focus on scope 3 of a company's organisation compared to other directives introduced by the UN in the past (Callahan et al., n.d.). Scope 3 accounts for the GHG emissions that occur indirectly in the value chain of the organization, which includes activities both upstream and downstream. Examples of these indirect emissions are emissions from purchased goods and services, transportation, waste disposal, and employee commuting (Nilsson, 2023). To highlight the significance of the company's supply chain and scope 3 emissions, Nilsson (2023) stated that the supply chain and scope 3 emissions usually make up about 90% of the company's GHG emissions. Transportation contributed to approximately 21% of the total global CO_2 emissions in 2020, which emphasizes the need for research on this part of the supply chain (Nilsson, 2023). The CSRD of 2022 focuses on the third scope specifically as this is the largest contributor to GHG emissions of companies worldwide (Nilsson, 2023). This thesis focuses on the transportation and distribution of scope 3 which are shown in Figure 9 with the red circles.

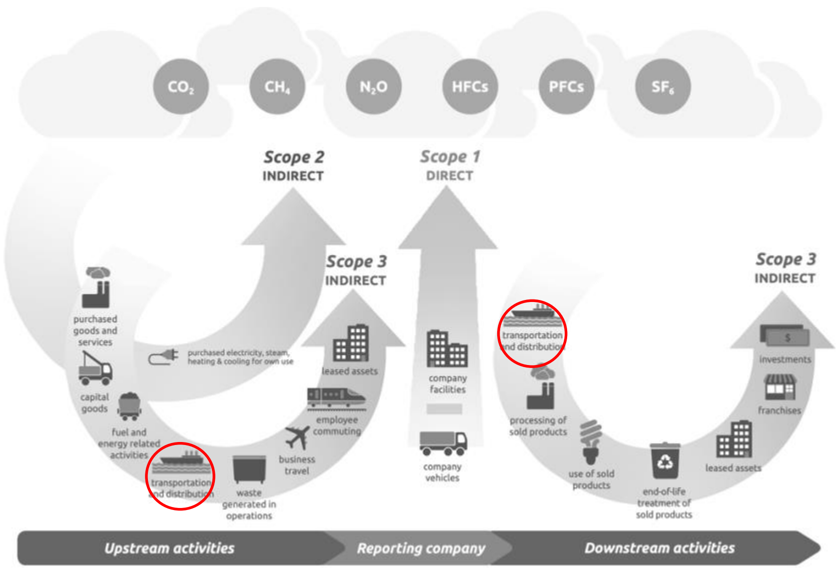

Figure 9: Overview of GHG Protocol scopes and emissions across the value chain.

Source: (Callahan et al., n.d.)

According to the GHG protocol, the CSRD requires two types of transportation emissions measures; (1) upstream and (2) downstream. The upstream transportation and distribution emissions are calculated based on the transportation and distribution of products that the reporting company purchased in the given year. This includes transportation and distribution between a company's tier 1 suppliers and its operations, inbound logistics, outbound logistics (of sold products), and transportation and distribution between a company's facilities (Callahan et al., n.d.). To elaborate, Company X needs to report the upstream emissions from transportation between Manufacturers A and B, and the warehouse. The downstream transportation and distribution for the CSRD is the "*transportation and distribution of products sold by the reporting company in the reporting year between the reporting company's operations and the end consumer (if not paid for by the reporting company), including retail and storage (in vehicles and facilities not owned or controlled by the reporting company)*" (Callahan et al., n.d.). To clarify, in this case, Company X needs to report the emissions from transport between the warehouse, the business partner and the transport of the RMAs. The GHG protocol considers air, rail, marine and road transportation.

The first step for Company X is to measure the current carbon emissions eq. The lack of supply chain visibility is a challenge in measuring the emissions of a product (Royo, 2020). For the CSRD, companies first need to focus on reporting their carbon footprint therefore, measuring their emissions is step one. Inadequate data collection and reporting systems hinder the ability to measure emissions effectively. Investing in research and development of innovative measurement technologies can provide more accurate and precise emissions data. When the carbon emissions eq. are measured and visible, the next step is to look for parts of the supply chain where these emissions can be reduced.

4.2 Solutions to Reduce CO_2 eq. in Transportation

Past research states ideas for reducing the emissions of freight transportation. Ideas such as collaboration, transport mode selection, giving the customer emission reduction incentives and offsetting emissions are discussed in this section.

Collaboration

Promoting education and awareness among companies and employees about measuring emissions and providing them with tools and resources to do so effectively can help overcome measurement challenges (Royo, 2020). Educating other companies can be interpreted by communicating the requirements to suppliers, manufacturers and logistic partners. To report their emissions, companies need to collaborate and validate accurate data together. Companies that outsource logistic activities often face difficulties in measuring reliable and accurate emissions figures. Shared responsibility, transparency and collaboration are important to measure accurate emissions data (Royo, 2020).

Transportation mode selection

Wong et al. (2022) focus on three approaches to reducing GHG emissions for transport. The first is to shift transportation modes to more emission-efficient modes like railways or marine ships. A study on rail transport versus truck transport and their emissions encouraged the shift from road to rail transport. Song (2022) and Vasiev (2023) both state that rail transport is the most emission-efficient mode of transport that can be selected. Calculations show that a complete railway route is preferable to transportation by road, as the volume of emissions is almost 500 times less (1.87 tonnes compared to road transport) (Vasiev, 2023). The most favourable modes for the transport of freight are railway and maritime transportation, especially for the movement of large cargo loads (Witaszek & Witaszek, 2015).

According to a report on the accessibility of rail transport in Europe, truck transportation continues to dominate freight transport, despite the increasing demand for a more integrated approach to different modes of transport, including rail and water transportation (Jahn et al., 2022). However, direct access of companies to the railway network or waterways declined fast within the last two decades (Bühler & Jochem, 2008). Thus direct train or ship services are rare. The European Union has set a target of shifting 30% of road freight over 300 km to other modes of transport like rail or waterborne transport by the year 2030 (Knapcikova & Konings, 2018). By 2050, this target is expected to increase to over 50% of all freight transportation.

Moreover, preferences for faster, more energy-intensive transport modes (i.e., truck and air vs. ship and rail) cause freight emissions to increase (Corbett et al., 2007). Air transportation should be limited to cases that require short delivery times for low-weight goods (Witaszek & Witaszek, 2015). Limiting air transportation to cases requiring short delivery times for low-weight goods can help reduce overall CO_2 emissions in the transport sector. Witaszek & WItaszek (2015) argue that distance travelled should be considered since most emissions occur during take-off.

Collect transport

In the case of road transport, routes can be optimized to shorten the delivery routes. Using collected transport (making rounds along multiple destinations) instead of having empty return trips reduces emissions (Wong et al., 2022). Collect transport improves the cost-effectiveness and efficiency of transport operations and also reduces energy consumption and the carbon footprint (W. Zhang et al., 2022). In the case of Company X, this insists that the manufacturer would visit multiple clients instead of going to the warehouse with a small order and back empty. Freight consolidation can help reduce CO_2 emissions by up to 14% (W. Zhang et al., 2022). This reduction can go up to 52% if rail transport is also considered.

Increasing load factor

Another solution next to decreasing the amount of empty return trips is to increase the load factor of the truck (Liimatainen et al., 2015). An increase in load factor reduces the number of trips to transport air. This denotes space in the truck that is not used to transport products. If collect transport is not used, combining orders in one shipment can decrease the total CO_2 eq. emitted.

For air transport, increasing the load factor and therefore reducing the operational gross weight of the airplane is the best way to improve energy and carbon efficiency (Rizet et al., 2012). For rail transport, grams of CO_2 per kilometre decrease exponentially when the load factor is increased (Rizet et al., 2012).

Outsourcing logistics

Outsourcing logistics for less-than-a-truckload shipments can be done with third-party logistic service providers (Tang et al., 2014). It is more cost-effective to bundle products for shipment instead of hiring a truck to send a small order. Additionally, this method reduces emissions as the logistic carriers collect and consolidate freight from clients and therefore no empty trips are necessary. Outsourcing logistics also creates a bigger opportunity to use other fuels. For example, trucks that drive on hydrogen or electricity (Wong et al., 2022). Some large carriers like DHL are now piloting with trucks that are hydrogen-driven (Hartman, 2021).

Reduction incentives at the customer

In a Norwegian study on consumer preferences, it was found that female consumers are likely to accept increased delivery time if it implies reduced emissions, indicating a preference for environmentally sustainable last-mile delivery options (Caspersen & Navrud, 2021). A case study conducted in Mexico found that consumers are willing to wait longer for their home deliveries when given environmental impact reduction incentives, such as CO_2 equivalent, electricity, trash, and trees saved (Fu & Saito, 2018). Fu and Saito (2018) evaluated that consumer preferences for home delivery options can be influenced by environmental incentives, which include CO_2 equivalent, electricity, trash, and trees. They stated that informing customers about the consequences or possible changes and their effects, causes customers to consider choosing to request a late delivery. This includes letting customers choose their delivery methods to encourage customers to select options that consume less electricity or fuel (Fu & Saito, 2018).

Optimizing reverse logistics

To optimize reverse logistics, Mukherjee et al. (2023) introduce the same improvements as for the rest of the transportation flow, namely, optimizing delivery routes, consolidating shipments, and using eco-friendly transportation methods (Mukherjee et al., 2023). Other research suggests establishing recycling centres to improve resource utilization, increase efficiency and decrease emissions from transportation (Aljuneidi & Bulgak, 2020; Zhou & Zhao, 2022).

Offsetting emissions

Another solution to reduce the carbon footprint of the product is to offset the emissions. This means compensating for the emissions by investing in projects that reduce or remove emissions elsewhere (Baras, 2023). Baras questions if offsetting is morally correct. In his conclusion, he states that emitting and offsetting is always morally inferior to not emitting. However, emitting and offsetting could cause a zero carbon footprint (Baras, 2023). There are guidelines for offsetting if a company decides to use this method to decrease emissions (Helppi et al., 2023). For example, the number of emissions offset should be transparent to the public. Moreover, the projects that receive contributions should be able to effectively reduce emissions. The purchased carbon credits should come from projects which achieve real and measurable reductions in carbon emissions eq. or removals of carbon from the atmosphere (Helppi et al., 2023).

4.3 Summary

To conclude, this chapter answered the sub-research question; *What strategies are stated in literature regarding the reduction of the carbon emissions eq. of a freight transportation process*?

This chapter discussed the literature behind the research question and answered the applicable knowledge questions. The first knowledge question aimed at requiring information regarding the CSRD and the specification of the scope of this research. The CSRD has a bigger focus on scope 3 which focuses on the indirect emissions in a company’s value chain. This thesis concentrates on scope 3's transportation and distribution, specifically on upstream and downstream transportation.

The second knowledge question focused on finding reduction methods for the current emissions of freight transportation. The optimization of this process starts with measuring the current emissions of the transport. Company X also has this challenge. Researchers suggest increasing the visibility of the supply chain and collaborating with logistic partners to make the current emissions more measurable. A subject that has been widely investigated in literature is transport mode selection. The overall conclusion is that road transportation should shift to rail transportation to decrease the emissions emitted. As rail accessibility for companies in Europe is not optimal, the UN developed a plan to increase rail freight transport by 30% before 2030. Researchers also stated that air transportation should be limited to small express deliveries. Collect transportation and increasing load factors in air travel and road transportation decrease the number of empty returns. Using other technologies as hydrogen-driven trucks are suggested solutions from literature to reduce the emissions of transportation. A questionable other option to reduce the carbon footprint is to offset the emissions. This discussion has two sides as even though it may not be morally correct and does not fix the problem in the long run, it does technically make the product carbon neutral. In addition, looking at morality, letting customers decide could decrease the carbon emissions eq. According to studies done in Mexico and Norway, most customers would be willing to wait longer for an order if it would be transportation more environmentally friendly. Lastly, to optimize reverse logistics, establishing recycling centres, optimizing delivery routes, consolidating shipments, and using eco-friendly transportation methods are solutions to decrease carbon emissions eq.

5 Strategy Design

In this chapter, strategies that evolved from Chapters 3 and 4, are put into the problem context perspective at Company X. Implementation of the strategies and their possible results are stated in Section 5.1. Together with the decision-makers at Company X, KPIs are generated in Section 5.2 to score the different strategies in the scorecard of Section 5.3. This chapter answers the following two sub-research questions:

What KPIs regarding the transportation of Product X, are important for Company X?

What are possible strategies that Company X can implement to reduce the CO2 eq. emissions of transportation of Product X?

5.1 Strategies and Implementation

As stated in Chapter 4, the first step is to measure the current carbon emissions eq. For the CSRD, Company X needs to report the emissions from transport between the EMS, the warehouse, the business partner and the transport of the RMAs. The carbon emissions eq. data at Company X is not existent for most products. If Company X were to apply this theory to all products, step one would be to get the data of the current carbon emissions eq. which would require, but is not limited to, specific product details like weight, insight into the transport flows, and recent order data which states the transport mode used, the weight of the packages and the destinations.

Collaboration with stakeholders

A strategy suggested by researchers and stated in Section 4.2.1, is to collaborate with partners, suppliers, and carriers to gain a good insight into the current emissions (Royo, 2020). Collaborating with stakeholders also has the potential to improve the carbon emissions eq. of the product as the shared responsibility might make the stakeholders more aware of their emissions. A method to implement this strategy is to discuss the importance of reducing carbon emissions eq. with the applicable stakeholders. With the CSRD of the UN, companies all over the world will be forced to report their emissions, and therefore, also the suppliers of Product X, the business partners and the carriers. To turn this strategy into practice, Company X can discuss the carrier options with the company behind the online tool (Transsmart) used to select carriers for each package and find alternatives to the current routes and transport modes. According to the Manager of Outbound Logistics at Company X (2023), Company X can adjust the filters in Transsmart to for example only show the options excluding air travel. Collaborating with stakeholders will open the discussion on how to reduce carbon emissions eq. and could start conversations about the transportation modes selection and the use of collected transport.

Spreading production

Another point of improvement could be to change the distribution of products produced at Manufacturer A versus B. This strategy is not stated by literature but is generated during the data analysis of the 2023 data. As can be seen in Table 5 of Section 3.1, the emissions emitted from transport between Manufacturer B and the warehouse per product is more than 78 times lower per Product X than transport from Manufacturer A to the warehouse (considering 50% 3.5-ton trucks and 50% 7.5-ton trucks for delivery). Therefore, to decrease the transport emissions, it is advisable to increase the orders at Manufacturer B and decrease the orders at Manufacturer A. However, according to the Manager of Outbound Logistics at Company X (2024), the biggest drawback is the price difference. If this strategy was accepted and Manufacturer B would be equipped with, for example, 30% of all orders instead of 17%, the total carbon emissions eq. per a Product X type would decrease by approximately 15%. This is calculated by multiplying the transport emissions from Manufacturer A to the warehouse and from Manufacturer B to the warehouse per product with their respective weights (0.7 for 70% at Manufacturer A and 0.3 for 30% at Manufacturer B) and adding the results. Then the percentage change is calculated.

Transport mode selection: manufacturer A to the warehouse

In the first stage of the transportation process of Product X, transportation is partly managed by Manufacturer A. Currently, Manufacturer A uses 7.5-ton trucks with collect transport, and 3.5-ton trucks with empty returns, to deliver Product X. As per the Data Analysis of Chapter 3, it is calculated that the increase in the use of 3.5-ton trucks solely for the delivery to Company X increases the transport carbon footprint more than increasing the use of 7.5-ton trucks with collect transport. Therefore, it is concluded that 7.5-ton trucks produce less emissions, and the use of 3.5-ton trucks should decrease. Discussing this issue with Manufacturer A and setting rules, for example, allowing only transportation with 7.5-ton trucks once or twice a week, has a high potential of making an impact on the emitted emissions of transport of Product X. The decrease from 50% of 3.5-ton trucks with empty returns to 0% of the orders shipped with 3.5-ton trucks, could decrease the total transportation emissions of Product X type 1 by 36%, and Product X type 2 with 6%. This is calculated by calculating the emissions for both cases and resulting in the difference in emissions per product which could then be used in a percent change formula. To find the total reduction, these reductions are weighted against their respective order quantity percentage of the total and result in a weighted total decrease of the emissions of 26%. A small reduction of the use of 3.5-ton trucks to, for example, 20% use of 3.5-ton trucks instead of 50%, would decrease the total carbon emissions eq. by 16%.

Transport mode selection: decreasing air travel to business partner

In the second stage of the transportation process, transport via airplane is a recurring subject. Figure 6 of Section 3.2 shows the destinations for Product X transport via air in 2023. Some countries have been reached via multiple transport modes. For example, Switzerland has been reached with a large truck, as well as with an airplane. Belgium was reached with all three transport modes in 2023. This shows that the choice for transport via airplane is not always done only out of necessity. Two main factors that also contribute to the selection of air travel are the speed of delivery and the price. Table 7 of Section 3.2 shows, however, that the transport costs per product shipped via airplane in 2023 are double that via a small truck. If countries that can be reached with a small or large truck instead of an airplane (for example Belgium and Switzerland) are reached by truck, the total carbon emissions eq. of Product X would decrease by 11%. The calculation in the data analysis of the transport emissions between the warehouse and the business partner is based on the order data of 2023 which includes the destination, the weight of the package sent, and the transportation mode selected. From this data, the emissions per country are calculated per transportation mode with the online tool (CarbonCare.org, n.d.). To apply this strategy, we altered the 2023 data to look as if the orders from the warehouse to Belgium and Switzerland were not delivered by airplane but by truck. This resulted in a new emission result from which the percent change is calculated.

Transport mode selection: increasing large truck delivery to business partner

According to the order data of 2023, larger orders in terms of weight, above 45 KG, are mostly done by Carrier 1, so with large trucks. Table 7 of Section 3.2 shows that transport via a large truck has the lowest emissions per KG shipped but has a larger emission factor when calculating the emissions per product. Therefore, if heavier orders (over 45 KG) are shipped with large trucks instead of smaller trucks or airplanes, the emissions would also decrease. For now, 45 KG is taken by Company X as it is the lowest accepted weight per order in 2023 which was chosen based on costs. If every shipment in 2023 with an order weight above 45 KG was shipped with large trucks instead of with an airplane or small truck, except for orders that cannot be shipped by truck, the total emissions of transport would decrease by approximately 5%. This is calculated by finding the percent change between the total emissions from 2023, and the total emissions from 2023 minus the emissions from orders transported between the warehouse and the business partner that exceeded 45 KG and were delivered by airplane or small trucks plus the emissions from these orders but if they were delivered by Carrier 1 (large trucks).

Transport mode selection: RMA from the warehouse to the business partner

Even though RMA transportation only makes up 4% of the total emissions of transport of Product X, it should be considered to rule out the option to transport the RMAs back by airplane, with an exception for countries that are hard to reach by truck (such as the US or Qatar). As 93% of the emissions from the transport of RMAs originate from air travel, even though only 28% of products are returned by airplane, reducing air travel could significantly decrease emissions for this stage in the transportation process. However, this strategy cannot decrease the total transportation emissions of Product X by more than 4%. The reasons for air travel of the RMAs are the costs and delivery time. According to the Operations Manager of Company X (2024), business partners would not mind having an increased delivery time as they almost always have a small stock on hand.

Educating the decision-maker

When decisions regarding transportation towards the business partner are made, the decision maker should consider the CO_2 eq. emissions if Company X requires the emissions to decrease. Sending a package to Belgium from the warehouse with an airplane, for example, should be avoided.

On a larger scale, to decrease the emissions of transportation of Product X, decision-makers at Company X should keep the environment in mind when making big decisions, such as changing carriers or suppliers.

Reduction incentives for customer

As noted in Section 4.2.7., research found that consumers are willing to wait longer for their home deliveries when given environmental impact reduction incentives, such as CO_2 equivalent, electricity, trash, and trees saved (Fu & Saito, 2018). Providing customers with the option to reduce carbon emissions eq. by selecting a longer delivery time or opting for pricier yet environmentally friendly transportation modes can prove to be an effective strategy for emission reduction (Caspersen & Navrud, 2021). In addition, informing the customers about the amount of carbon emissions eq. they could save with these strategies could increase the strategy's effectiveness (Fu & Saito, 2018).

Decreasing product weight and packaging volume

An alternative strategy to reduce emissions is to decrease the product weight and packaging volume. As emissions in transportation directly correlate with product weight, using lighter materials for packaging and the product itself can decrease the emissions for transportation. In addition, reducing the volume of packaging not only frees up additional space for other products but also optimizes the load factor of a vehicle (Liimatainen et al., 2015).

Offsetting

Another strategy that could be implemented at Company X is offsetting, which comes with a moral dilemma. Company X has the option to make Product X carbon neutral through carbon offsetting. Nevertheless, while this compensates for the emitted CO_2 eq. on one hand, it does not result in an actual decrease in emissions on the other. In Company X's case, a strategy to implement could be to only offset the emissions that are not able to be reduced at the time. We recommend reducing the carbon emissions eq. as much as possible and keep improving the carbon footprint, in addition, Company X can offset the rest of the emissions to become carbon neutral. Moreover, it should be noted that offsetting emissions should not be the only strategy to be implemented if Company X is willing to reduce the carbon emissions eq. of Product X.

If Company X decides to offset emissions, it is advisable to give the customer the same option. Giving customers the option to offset their emissions when purchasing Product X, not only raises awareness about Company X's environmental responsibility but also empowers customers to do the same.

5.2 Key Performance Indicators

To score the different strategies generated from literature and the data analysis, KPIs are drafted from literature in collaboration with the sustainability team and the decision-maker at Company X (Outbound Logistics Manager at Company X, 2024). According to literature, KPIs should be specific, measurable, achievable and relevant (Kacprzyk, 2022). The KPIs shown in Table 10 are ranked from most important to least important by the sustainability team and the decision-maker at Company X. Every KPI received a weight from 1 to 3 in steps of 1, where 3 is highly prioritized and 1 is the least prioritized. Each strategy receives a score from 1 to 5 (1 = worst outcome, 5 = best outcome). For each strategy, the best and worst-case outcomes are stated in Table 10. The KPIs are relatively scored which considers the difference in the strategies. For example, the strategy with the highest costs receives a score of 1 and the least expensive is scored with a 5.

KPI	Weight (1 to 3)	Worst outcome (1)	Best outcome (5)
Costs	3	Relatively expensive	Free
Customer Satisfaction	3	Unsatisfied customers	Improved satisfaction
CO_2 eq. Emissions	2	No change	>10% reduction
Delivery Speed	2	Relatively decreased	No change, or improved
Risk and Safety	2	Relatively increased	No risk or safety issues
Return on Investment	1	More than 5 years	Immediately
Implementation Time	1	More than 2 months	0 hours

Table 10: Selected KPIs and weights.

Costs

The costs KPI is focussed on the change in costs. This could be additional costs for implementing the strategy, but it is also the indirect costs that the implemented strategy could cause (Gronalt et al., 2019). As this thesis is conducted at Company X from a procurement and logistics point of view, keeping the costs minimal is a high priority. The scoring of this category is done relative to the other strategies. This means that the costliest strategy gets a score of 1 and the cheapest strategy is scored with a 5.

Customer satisfaction

Customer satisfaction is very important at Company X as without customers, Company X would not exist. As also stated in literature: "*For a for-profit business, the most important KPI is the customer's satisfaction – without that, any product or service will remain unused, and the venture will eventually go out of business"*(Kacprzyk, 2022). Delivery time and sustainability are opposed subjects of interest when it comes to customer satisfaction. On the one hand, customers want their products as soon as possible, on the other hand, is sustainability for customers a rising interest.

CO_2 eq. emissions

As mentioned in Chapter 1, Company X has an increased interest in their carbon emissions eq. However, as Company X is still in the first phase of measuring and reporting, this KPI receives a weight of 3. A score of 1 would mean no change in the CO_2 eq. emissions and a score of 5 would state a more than 10% decrease.

Delivery speed

This KPI focuses on the change in delivery speed from the manufacturer to the warehouse, from the warehouse to the business partner or for the RMA transportation. This KPI is specifically selected from a logistics point of view, delivery speed affects customer satisfaction, therefore, this KPI is weighted with a 2 out of 3.

Risk and safety

This KPI focuses on the safety of the product and the risks associated with the process. Product safety depends on the transport process and handling of the product. A lot of transition points in the transport process could increase the probability of damage which decreases the safety of the product. Company X reduces risk by, for example, distributing production of Product X across two EMSs.

Return on investment (ROI)

Return on investment (ROI) is important to note when considering large costs for a strategy which is for example applicable to the spreading production strategy (Kacprzyk, 2022). As decreasing the emissions does not necessarily increase revenue, return on investment is not easily measured. Therefore, while scoring a strategy on this KPI, costs, implementation time and emissions are considered.

Implementation time

As Company X does not have strict targets yet on the Scope 3 emissions, this KPI does not have high priority. It is selected as a relevant performance indicator to ensure reality in the scorecard. If the implantation time is too long, the strategy loses its relevance as it does not portray any short-term solutions.

5.3 Scorecard

The elaborated strategies in Section 5.1 are scored based on the KPIs provided by the decision maker. The scorecard is visible in Table 11.

KPI→ Strategy ↓	Costs	Cust. Satis.	CO_2 eq.	Delivery Time	Risk & safety	ROI	Impl. time	Total
Collaboration	5	5	2	5	5	5	4	31
Supplier agreements	5	5	5	4	5	5	4	33
Spreading production	1	5	5	5	5	1	1	23
Decreasing air transport	4	3	5	2	5	3	4	26
Choosing Carrier 1	4	3	3	3	5	4	4	26
RMA with truck	4	4	3	3	5	4	4	27
Educating decision makers	5	4	4	4	5	5	4	31
Customer incentives	4	5	3	5	5	4	4	30
Packaging	4	5	2	5	4	3	3	26
Offsetting emissions	3	4	4	5	5	3	5	29

Table 11: Scorecard.

To get the final score per strategy, the weights distributed by the decision-makers are integrated into the adjusted scorecard in Table 12. To elaborate, the collaboration strategy receives a cost score of 15 by multiplying the score (5) with the weight of the KPI (Costs = 3). A cost score of 15 is given as the strategy is free to implement, no implementation costs are necessary. The only costs that could be associated with the collaboration strategy are the employee costs for conducting the meeting with the partners. Customer satisfaction, delivery speed, risk and safety and the ROI are not affected by this strategy. The strategy has the potential to decrease emissions and implementation time is minimal. The maximum score attainable is 70 points.

KPI→ Strategy ↓	Costs	Cust. Satis.	CO_2 eq.	Delivery Time	Impl. time	Risk & safety	ROI	Total
MAX points attainable	*15*	*15*	*10*	*10*	*5*	*10*	*5*	*70*
Collaboration	15	15	4	10	4	10	5	**63**
Supplier agreements	15	15	10	8	4	10	5	**67**
Spreading production	3	15	10	10	1	10	1	50
Decreasing air transport	12	9	10	4	4	10	3	52
Choosing Carrier 1	12	9	6	6	4	10	4	51
RMA with truck	12	12	6	6	4	10	4	54
Educating decision makers	15	12	8	8	4	10	5	**62**
Customer incentives	12	15	6	10	4	10	4	**61**
Packaging	12	15	4	10	3	8	3	55
Offsetting emissions	9	12	8	10	5	10	3	**57**

Table 12: Adjusted scorecard with weights.

As can be seen in Table 12, the strategies that have the highest scores (marked bold) are also the cheapest to implement, which can be traced to the KPIs with priority.

5.4 Summary

This chapter answers the fourth sub-research question: "*What are possible strategies that Company X can implement to reduce the CO2 eq. emissions of transportation of Product X?*".

Possible strategies for Company X to implement to decrease the emissions of transport of Product X include the following:

- Collaborating with current partners like Transsmart and the carriers to open the discussion on how to reduce carbon emissions eq. and increase measurability.
- Spreading production to increase transportation between Manufacturer B and the warehouse and decrease transport from Manufacturer A to the warehouse.
- Looking at the supplier agreements and adjusting the transportation rules to only use 7.5-ton trucks.
- Decreasing air travel from the warehouse to the business partner by choosing Carrier 1 more often as carrier for orders above 45KG.
- Decreasing air travel of the RMAs from the warehouse back to the business partner.
- Educating decision-makers to make more sustainable choices when selecting transportation methods.
- Introducing customer incentives to choose sustainable options for delivery.
- Offsetting emissions.

To get the top strategies, KPIs are selected from literature in collaboration with the decision-maker. These KPIs are, from most important to least important, costs, customer satisfaction, emissions, delivery speed, risk and safety, return on investment, and implementation time. These KPIs answer the third sub-research question: "*What KPIs regarding the transportation of Product X, are important for Company X?*". The KPIs are drafted from literature and together with the decision maker at Company X, they received a weight on the priority and importance from 1 (least important) to 3. With these weights, a scorecard is created to rank the strategies on effectiveness and degree of importance. The scorecard concluded with the following top 5:

1. Adjusting supplier agreements
2. Collaboration with stakeholders
3. Educating decision-makers
4. Reduction incentives at the customer
5. Offsetting emissions

6 Conclusion

This research aims to analyse existing inbound and outbound data of Product X of 2023 and find strategies to decrease the CO_2 eq. emissions of the transport of Product X. To guide this research and give insight into the deliverables and methods used, sub-research questions were constructed and answered in their respective chapters. The sub-research questions are answered as follows.

1. *What is the current transportation process and its carbon emissions eq., of Product X?*

In Chapter 2, it becomes clear that the transportation process of Product X can be divided into three stages: (1) transport from the manufacturer in Eastern Europe and Western Europe, to the warehouse, (2) transport from the warehouse to the business partner, and (3) transport of the RMAs back to the business partner after the products are repaired or replaced. Concluded from Chapter 3 is that the first stage of the transportation flow of Product X, transport between the manufacturer and the warehouse, accounted for approximately 60% of all transport emissions. The emissions of the second stage of the transportation process, between the warehouse and the business partner, are for 80% caused by air transportation which is used for less than 20% of the orders. The last stage is the RMA transportation between the warehouse where the products are fixed, to the business partner. Even though this stage only contributes to 4% of the total emission, 93% of the 4% of the total emissions are caused by air transportation. Moreover, 28% of the RMAs are sent back by plane. The total emissions for transportation of Product X type 1 are 0.605 KG CO_2 eq. per product and 0.281 KG CO_2 eq. per product for Product X type 2. This distinction is created as Product X can be bought in two types with a difference in weight.

2. *What strategies are stated in literature regarding the reduction of the carbon emissions eq. of a freight transportation process?*

Two knowledge questions led the literature search. The first knowledge question stated: "*What information is requested for the CSRD to be reported regarding the transportation of Product X?"*. To answer this knowledge question; the CSRD has a bigger focus on scope 3 which focuses on the indirect emissions in a company's value chain. This thesis concentrates on scope 3's transportation and distribution, specifically on upstream and downstream transportation.

The second knowledge question was: "*How can carbon emissions eq. of freight transportation be decreased?"*. The second knowledge question focussed on finding alternative reduction methods to the current emissions of freight transportation. The first step for Company X is to measure its current emissions. Researchers suggest increasing the visibility of the supply chain and collaborating with logistic partners to make the current carbon emissions eq. more measurable.

A subject that has been widely investigated in literature is transport mode selection. The overall conclusion is that road transportation should shift to rail transportation to decrease the emissions emitted. Researchers also stated that air transportation should be limited to small express deliveries.

Using collect transportation and increasing load factors in air travel and road transportation decrease the number of empty returns. Using other technologies as hydrogen-driven trucks are suggested solutions from literature to reduce the carbon emissions eq. of transportation.

A questionable other option to reduce the carbon footprint is to offset the emissions. This discussion has two sides as even though it may not be morally correct and does not fix the problem in the long run, it does technically make the product carbon neutral.

Looking at morality, letting customers decide could decrease the carbon emissions eq. According to studies in Mexico and Norway, most customers would be able to wait longer for an order if it would be transportation more environmentally friendly.

Lastly, to optimize reverse logistics, establishing recycling centres, optimizing delivery routes, consolidating shipments, and using eco-friendly transportation methods are solutions to decrease carbon emissions eq.

3. *What KPIs regarding the transportation of Product X, are important for Company X?*

Together with the decision-makers at Company X, several KPIs were generated to assess the strategies with a scorecard. As elaborated in Section 5.2, the KPIs are ranked from highest to lowest priority in the following order: costs, customer satisfaction, CO_2 eq. emissions, delivery speed, risk and safety, return on investment and implementation time. The KPIs received a weight based on which had the highest priority and was the most important in the decision-making process, which is stated in Table 10.

4. *What are possible strategies that Company X can implement to reduce the CO_2 eq. emissions of transportation of Product X?*

Combining the data analysis and the related literature gave a list of possible strategies that Company X can implement. These include, in no particular order;

- collaborating with stakeholders to improve measurability,
- changing supplier agreements to only receive 7.5-ton trucks instead of 3.5-ton trucks,
- increasing production at Manufacturer B instead of Manufacturer A,
- decreasing air travel between the warehouse and the business partner,
- choosing Carrier 1 more often as carrier for orders above 45 KG,
- decreasing RMA transportation with an airplane,
- educating decision makers when choosing a transport mode and carrier,
- increasing customer incentives to choose sustainable delivery options,
- looking at packaging to decrease the packaging volume and weight,
- and lastly, offsetting unavoidable emissions that cannot be decreased at the time.

With the scorecard stated in Section 5.3, the following research question can be answered.

"*What strategies should Company X implement to reduce their carbon emissions eq. of the transportation of Product X by 10%?*".

According to the scorecard in Table 12, the main strategies that should be considered are collaboration with stakeholders, adjusting supplier agreements to decrease the frequency of delivery by 3.5-ton trucks, educating decision-makers to make more sustainable decisions in carrier selection, and looking at customer incentives. However, when the focus is on the 10% improvement in combination with the scorecard, changing supplier agreements and carbon offsetting are the best strategies to implement. Collaboration with stakeholders may start the conversation on being more environmentally friendly but will not decrease emissions by 10%, which also applies to the education of decision-makers strategy. Offsetting would be effective in combination with other strategies to reduce the emissions and offset the rest.

6.1 Recommendations

Out of the strategies with the best scores in the scorecard, the strategy regarding supplier agreements would have the most impact on carbon emissions eq. It is recommended to implement this strategy as it would have the benefit of collaboration with the supplier and the benefit of a possible change in the transportation mode selection and its scheduling.

Secondly, a strategy that would be interesting to include in the plan to reduce emissions, which is not costly but could take some effort to implement, is looking at customer incentives. In addition to Company X's sustainability strategies, customers could also be offered the option to make their delivery more sustainable. When the customer creates an order, it should state how much CO_2 eq. emissions are caused by the transport of their order, which can be compared to Y trees in the Amazon rainforest for example. Next, the client can choose to offset the emissions, pay more for a more sustainable delivery or choose to do nothing.

Even though the increase in choice for Carrier 1 and less RMA transportation by air could not make a large difference, these strategies are easy to implement. Collaborating with the tool that facilitates the decision for carrier and transport mode selection, can give the decision maker more sustainable options to choose from while also keeping the costs in mind. Therefore, the recommendation is to combine multiple strategies to be able to reach the 10% reduction. Collaborating with the carrier selection platform, adjusting the filters, educating the decision makers and choosing more often Carrier 1 and small trucks than airplanes as transport mode, could have a significant influence on the CO_2 eq. emissions.

It is recommended to use carbon offsetting but not on its own. Carbon offsetting is effective when it is combined with other reduction incentives. It is recommended to offset the emissions that are not able to be reduced at the time.

6.2 Further studies

Further studies could include the following.

For the CSRD, multiple emission types should be reported separately, including CH_4, N_2O, HFCs, PFCs and SF_6 (Nilsson, 2023). In this thesis, these emission types are calculated in total under the CO_2 equivalent. Because of the scope of this research, these elements are disregarded.

To measure the emissions for Product X, other stages of the supply chain should be measured too, including production, warehousing, and end-of-life of the product.

Stages that are not included in this research because of the lack of time and resources are the transport of raw materials and components to the manufacturers, and the transportation between the business partner and the end client. Scope 3 of the CSRD requests information on the emissions of transportation of tier 1 suppliers, therefore, it does not yet request information on the transport of the raw materials or product transport between the business partner and the end client, but this information could be necessary in the future.

To implement the customer incentives strategy, it would be advisable to research the flexibility of the clients of Product X. To elaborate, would the clients of Company X accept a longer delivery time if they were aware that it would decrease transport emissions? In addition, market research on the ways of offering these incentives and what competitors do could be added to the research.

A further study could be done on the packaging of Product X. Research can be done on making the packaging more environmentally friendly and focussing on making the packaging as precise in measurements and light as possible.

Another research could be on transportation via train or boat. It is advisable to check if the current carriers offer this solution, or if new carriers should be selected. Additionally, the return on investment for this solution should be calculated and assessed if it would significantly impact emissions without increasing costs.

7 Discussion

This chapter discusses the limitations and validity and the impact of this research.

This thesis focuses on CO_2 eq. emissions. However, for the CSRD, CO_2, CH_4, N_2O, HFCs, PFCs and SF_6 must be reported separately (Nilsson, 2023). This thesis contributes to reporting the emissions by improving the visibility of the supply chain, but the emissions data of Product X is not complete for CSRD reporting. However, this was not the objective of this research. This research aimed at offering multiple strategies to decrease the CO_2 eq. emissions, not to focus on the CSRD.

Moreover, this thesis focussed on the emissions of transportation of Product X, which accounts, according to the calculation of the consultancy report (2021), only for less than 1% of all emissions of Product X. However, this research can be applied to other departments and products of Company X which would increase the overall effectiveness. Moreover, as Company X wants to reduce its carbon emissions eq., it should look at all sections of the supply chain of Product X.

This research used the data of 2023 as a basis. However, as COVID-19 affected Company X and these effects were still noticeable in 2023, a larger database would have been more accurate to base data on. In 2021, Company X changed data storage software therefore data from before 2021 is hard to find. As data from 2023 would be the closest to normal and there was no other data available, 2023 data was the chosen dataset for this research.

In addition, at Company X, data is stored on a few different databases which makes the complete data difficult to acquire. Therefore, for the sales data of 2023, two databases had to be combined to create the 2023 sales data of Product X out of the sales data of two different departments. In this process, the incomplete data of one of the two databases resulted in an incomplete data list. Therefore, the results of transport between the warehouse and the business partner are based on 20% of all sales data of 2023. Because of the scope of this research, this was accepted as a valid representation of the data.

In the case of transportation between the EMS and the warehouse, the weight of the product is used to calculate the transport emissions excluding the packaging. This is because there is no data available on the weight of the packages that are received and because orders are packaged differently depending on the number of products ordered. Therefore, the emissions of transport between the EMS and the warehouse are probably higher as the transported weight is higher than just the product weight.

The RMA calculation considers the package weight when calculating the emissions but cannot consider the product type. Therefore, while calculating the emissions for RMA transport, we couldn't obtain two different emission results as there is no distinction in the data of the RMAs for the product type. It is possible that the emissions for Product X type 2 are now too high, as portrayed in the answer, and the emissions for Product X type 1 could be too low, as the products differ in weight.

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Appendix

Appendix A: Problem-Solving Approach

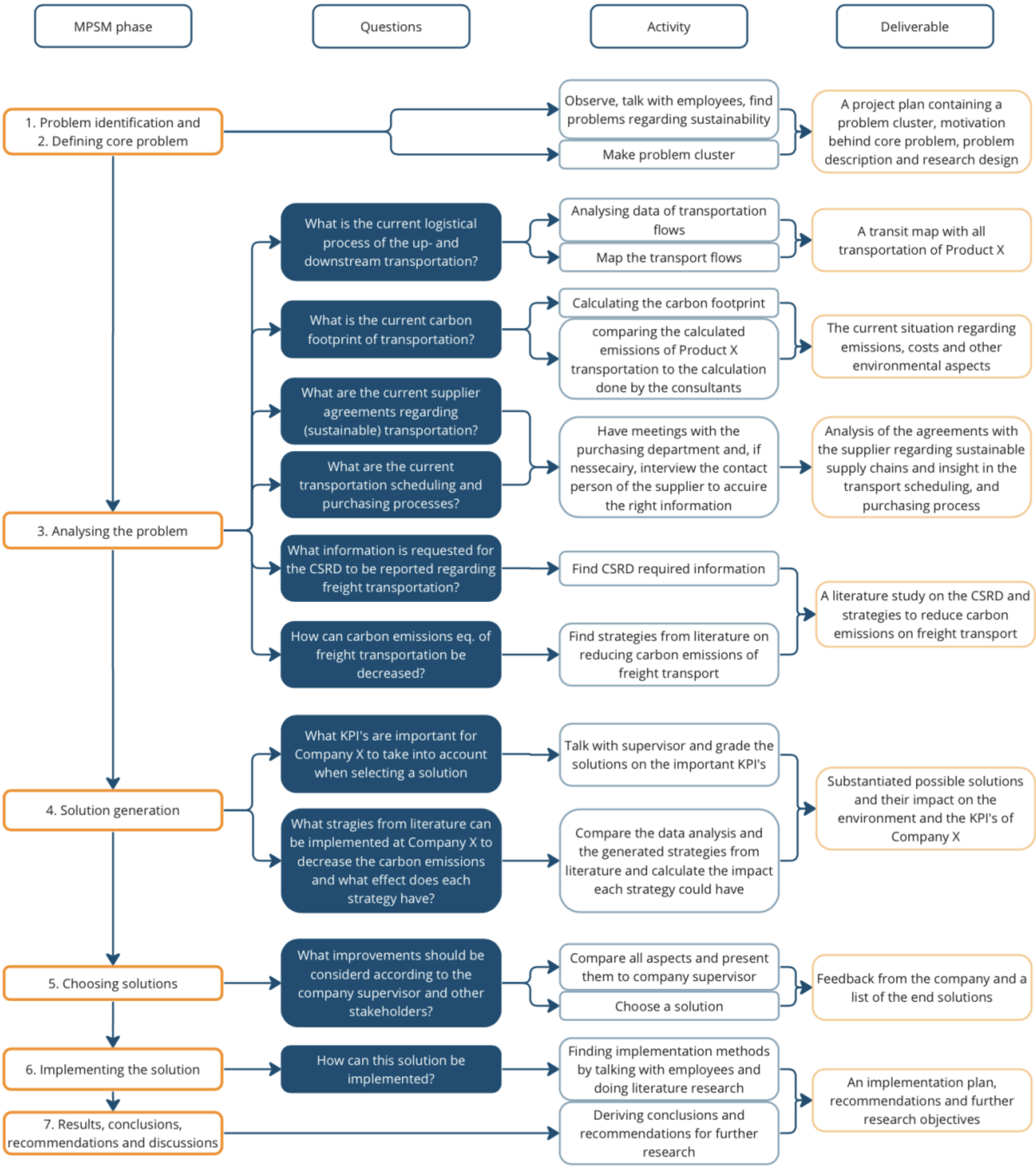

Figure 10: Problem-Solving Approach.

Appendix B: ISO clarification of the online tool used.

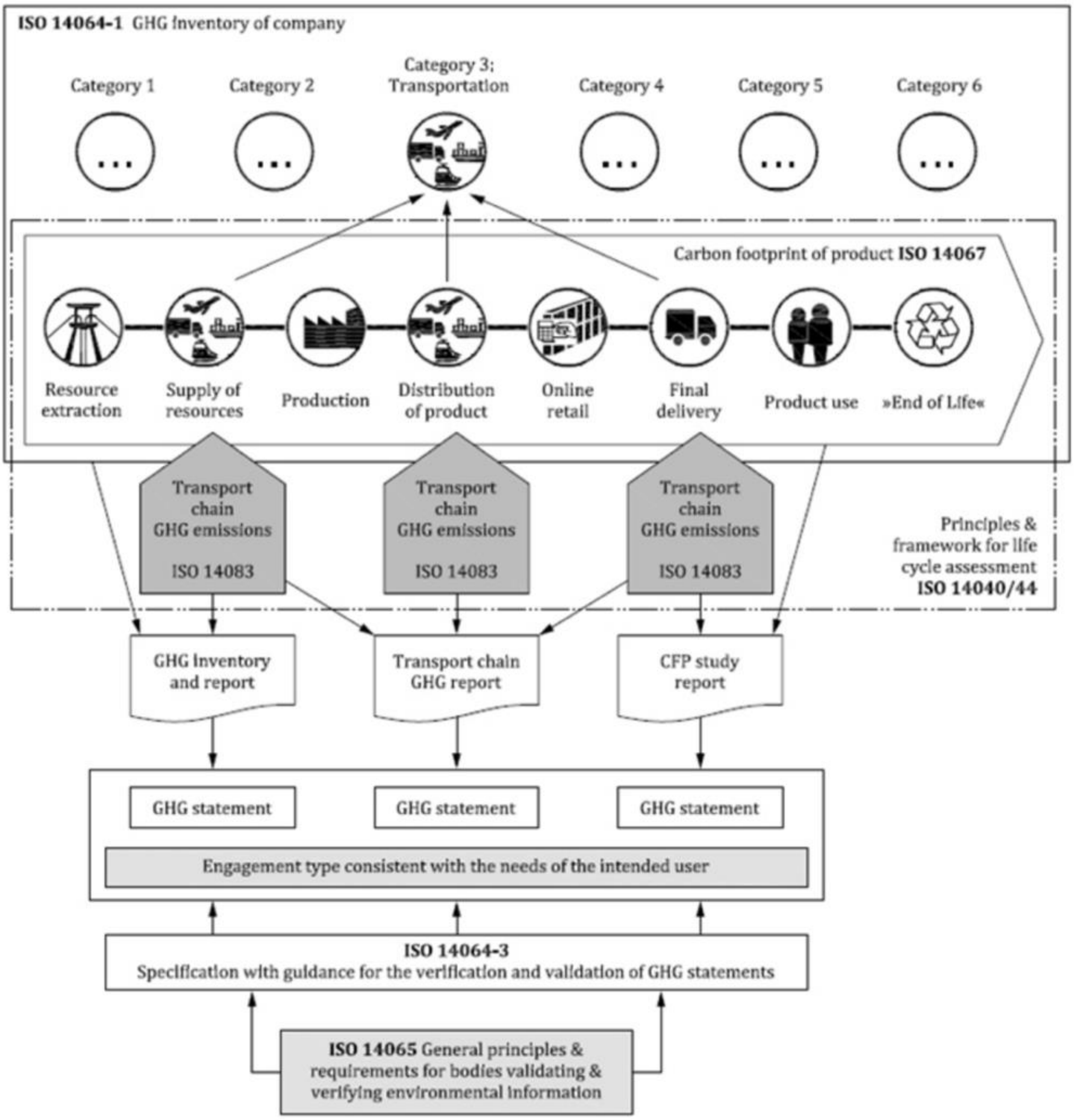

Figure 11: ISO clarification and tool methodology.

Source: (CarbonCare.org, n.d.)

Acknowledgements

I would like to express my deep gratitude to dr. P. Rogetzer and dr. C. Kolb, my research supervisors, for their patient guidance, enthusiastic encouragement and useful critiques of this research work. I would also like to thank the company supervisor for his guidance, and all the employees who assisted me with acquiring the right information and giving me overall support in this process. My special thanks to my university buddies, for proofreading this thesis and support during the past months.