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PACKAGING MATERIAL FLOW IN A CLOSED-LOOP CHAIN

PAKKEMATERJALI VOOG SULETUD AHELAS

MASTER'S THESIS

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Tallinn 2022

I declare I have written the master thesis independently.
All works and significant viewpoints of the other authors, data from different literature sources, and elsewhere used for writing this paper have been referenced.

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ABSTRACT

The title of this master thesis is Packaging Material Flow in a Closed-Loop Chain.

This thesis aimed to prove how beneficial closed-loop packaging material flow can be to a client and Nefab. From the customer's perspective, a closed-loop solution should add value by reducing the financial cost of packaging material usage and shortening the lead time. To Nefab, it is essential to add a success case into the supply chain service portfolio. The author did scenario analysis, total cost calculations, and reflection from the Nefab side to achieve the results. Also, Nefab carbon footprint analysis software was used to illustrate carbon footprint reduction.

As a result of the analysis and calculations, the author proved that a closed-loop solution where the studied packing material group gets transported back from the end customer to Nefab Estonia for cleaning, sorting, and reusing, reduces overall costs for the client. In addition, it shortens lead time and creates additional value by easing the client's daily workflow. The disappearance of the need to reproduce the packaging material also decreases the carbon footprint in the observed supply chain.

For Nefab to further improve the portfolio of successful service solutions, the author recommends mapping out similar supply chains in cooperation with other customers to build similar closed-loop solutions. Because based on data from this work, there are significant cost reduction possibilities available.

Overall, the author views the results as a mutual increase in competitive advantage. For the client, the reduction in costs improves profitability. In addition, shortened lead time improves flexibility and easing of daily work, allowing a client to focus on other aspects of procurement. Nefab enhanced its portfolio and acquired new knowledge and experience, resulting in a potential advantage ahead of the competition.

Keywords: Closed-loop Supply Chain, Reverse Logistics, Total Cost of Ownership, Cost Reduction, Competetive Advantage, Packaging Material, CO_2 footprint.

INTRODUCTION

The current volatile world influenced by war and pandemics has a significant impact on each company. All business areas will be affected by this. The price increases of energy, raw materials, and components push up the costs and availability. In addition, prolonged transportation times and unpredictable shortages create an overall insecure market situation. Therefore companies must find ways to decrease costs and improve their flexibility to unpredictability. Unfortunately, companies often overlook the costs of packaging material and its effect on their supply chain, missing the opportunity to save costs. Also due to the uncertainty, cooperation between companies is more important than ever, and trustworthy partners will emerge from the supplier network, creating a base for successful collaboration. Therefore, suppliers must be proactive and use their specialized knowledge of the specific field to create value for the client. More often than not, a mutual business advantage is created by doing this.

In today's supply chains, reusage of packaging materials by reverse logistics or a closed-loop systems is underused because it is usually cheaper to reproduce a new package than to transport it back and preparing it for reuse. Or the saving is too small and is labeled as not worth time and work for optimization. However, when the inputs are getting more expensive, a price increase is also imminent for packing materials. Therefore, a rise in interest in cost-saving from all areas, including packaging material, may change and companies look ways to reuse bought packaging materials rather than dispose them.

Another aspect that most companies have overlooked for decades is managing and measuring their business activity's effect on carbon footprint. Nowadays, we see a change because of the outside pressure created by international unions, governments, and customers. As a result, a sustainable business model is becoming more and more an ethical part of business relations, where without it, you can't enter into market or business relations. To illustrate this, the global company where the thesis author works has changed its mission and slogan to involve sustainability as a core value. Nefab Group states that "*we save resources in supply chains, for a better tomorrow*." Therefore sustainability aspect is added to this thesis to evaluate the effect on CO_2 footprint.

Based on previous points, the author of this thesis identifies the problem as following. Companies often lack the motivation and experience to optimize supply chains in low cost areas of their businesses. One of those low cost areas is usually packaging material flow. Due to this, closed-loop packaging material flows with material reusage are less used in business-to-business world. In today's world the one-way flow is dominant in this segment. Author thinks that the omission is unjustified and with this thesis, the objective is to design an alternative material flow to reduce the client's costs within the supply chain. The idea is to design a closed-loop packaging material flow scenario between Nefab and the customer. Proposed solution will be asserted through three main research questions: will closed-loop solution reduce TCO (total cost of ownership) for a client, how it affects customer lead-time and what are the consequences in regards of CO_2 footprint.

The author expects that the result of this thesis give better insight to a previously stated prerequisite, that packaging material flows get often overlooked as they don't offer enough cost saving potential. Author hopes to refute this assumption and offer viable assertion in favor of closed-loop solution usage through calculations and comparison. By doing this, value will be created to a customer by mainly reducing the cost which will improve their bottom line, also the reduction of lead-time is targeted. As a value to Nefab, the thesis will give valuable insight and experience into the supply chain service area. Nefab's current portfolio in this area of expertise is not very strong, and the data gathered from this work is valuable for improvement. Furthermore, in case of a successful solution proposal that fulfills all prerequisites raised, Nefab will directly use this as a business case and offer closed-loop solution to a client.

The thesis is divided into four chapters. First chapter gives theoretical overview regards the essence of supply chain management and how to improve the sustainability of it, reverse logistics and closed-loop supply chains. Also how these theories and brought out examples conform with thesis. In the second chapter author explains the Nefab business strategy and evaluates if the supply chain chosen for work is viable for research. Third chapter is devoted to the metholodgy of the thesis, where design of research is presented and the steps of scenario analysis covered. Final chapter is dedicated for the scenario TCO models with calculations, comparison between created scenarios and the final verdict for proposed solution. Author adds in the recommendations how to use the data gathered with this thesis.

Regards the knowledge and experience in packaging materials and supply-chain solutions - the author of this thesis has 3-year work experience with Nefab Packaging OÜ (from now on stated as Nefab) as a key account manager and sales manager. Having a good overview of Nefab clients and their supply chains, he believes there is vast potential for closed-loop packaging solutions. Furthermore, as a sales manager, he has prioritized work on supply chain-related services within the sales team. Depending on the thesis results, the data gathered with this work will be used in future sales strategies.

1 SUSTAINABLE SUPPLY CHAINS

1.1 Supply Chain Management

Over the years, the definition and theory of supply chain (SC) have altered due to globalization, changes in business relations, production, and sourcing activities worldwide. To illustrate the previous point, the author gives a few examples regarding the evolutions of supply chain definitions. First, Beamon B. (1998) stated that a supply chain is a "structured manufacturing process wherein raw materials are transformed into finished goods and delivered to end customers. " This can be regarded as a core definition of the supply chain. Next, chow D. And Heaver T. (1999) add more complexity. They describe the supply chain as an association of different manufacturers, distributors, suppliers, logistic service providers (including transportation), and information providers who cooperate in providing goods to clients. Finally, Carter, Rogers, Choi (2015) describe the supply chain as follows (Carter et al., 2015, 5-13):

1. The supply chain is a network consisting of nodes and links,
2. The supply chain as a network operates as a complex adaptive system, where every agent grapples with the tensions between control and emergence,
3. The supply chain is relative to a particular product and agent,
4. The supply chain consists of both a physical supply chain and a support supply chain,
5. The visible horizon of the focal agent bounds the supply chain,
6. The visual horizon of the focal agent is subject to attenuation, where distance is based on factors including physical space, cultural distance, and closeness centrality.

It is challenging to give a supply chain one concrete definition to fit all purposes. Therefore the most suited definition needs to be chosen regards the content of the subject. For this thesis, the author will use the supply chain definition by Ayers J.B (2001). She described the supply chain as a cycle of processes between connected suppliers involving physical goods, information, and financial assets to satisfy the end customer.

Supply chains need active management to make them efficient and competitive. Therefore, supply chain and supply chain management (SCM) are inter-related concepts – supply chain management is the management of supply chains (Du Toit & Vlok 2014).

Supply chain management's activity aims to examine and manage supply chain networks. This concept aims to save costs, improve customer service, and enhance a company's competitiveness in the global market (Langley et al. 2008).

For this thesis, Mentzer, DeWitt, Keebler, Min, Nix, Smith, and Zacharia (2001) give the best description of supply chain management as they define supply chain management as "*systemic, strategic coordination of the traditional business functions and the tactics across these business functions within a particular company and across businesses within the supply chain, to improve the long-term performance of the individual companies and the supply chain as a whole*. "According to this definition, the supply chain can be visualized as a pipeline. Furthermore, the importance of customer satisfaction in creating competitive advantage and overall profitability for individual companies and the supply chain has also been highlighted in Figure 1. Based on that assumption, supply chain management cannot reach its full potential (Mentzer et al. 2001).

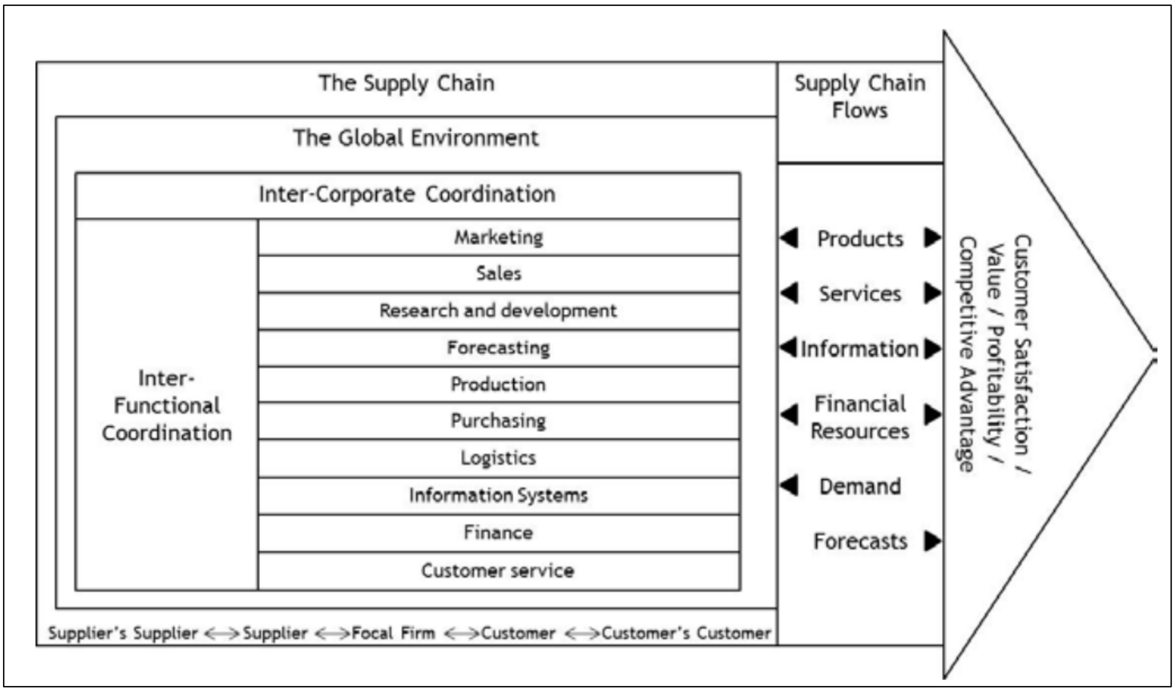

Figure 1. A model of supply chain management
Source: (Mentzer et al. 2001, 1-25)

Also, it is worth reminding that competition is the core of success or failure for an enterprise. Fundamentally competitive advantage grows out from a value the enterprise can create for its clients as it exceeds the cost of producing it for the company itself. Value is what clients are willing to pay (Porter, 1985).

1.2 Sustainable Supply Chain Management

Sustainable supply chain management (SSCM) is a development of traditional supply chain management, including social and environmental objectives and economics. However, social dimensions have mainly been overlooked as sustainability has been misinterpreted as environmental practice (Varsey, 2016).

As the world has been changing around us, so are businesses and their supply chains. There is no denying that change is needed to secure a sustainable tomorrow for us and our offspring. Alternating global business activity with sustainable supply chains is a cornerstone for that. In recent years, sustainable supply chain management has increasingly found its way to thinking of sustainable business activities. It can play a crucial role in sustainable business processes (Nieuwenhuis et al., 2019).

Sustainable supply chain management will come into the picture as many companies are looking over their economic ambitions and turning their attention to a broader range of goals like reducing CO_2 emissions in their production and supply chains. Therefore, carbon reduction needs to be supported by sustainable supply chains to provide a viable background system for companies.

Seuring, Aman, Hettiarachchi, Lima, Schilling, and Sudusinghe (2022) describe the central conceptual elements of a sustainable supply chain by nine characteristics (Figure 2). These abstract elements show the primary and most common links between focal companies and related sustainable supply chain elements—numbers one and two from the illustration link the focal company with its stakeholders and their ambitions. Numbers three to six from the illustration view the relationships between supplier and focal company, focusing on performance. Finally, numbers seven to nine view the outcomes as a risk, performance, and products and services.

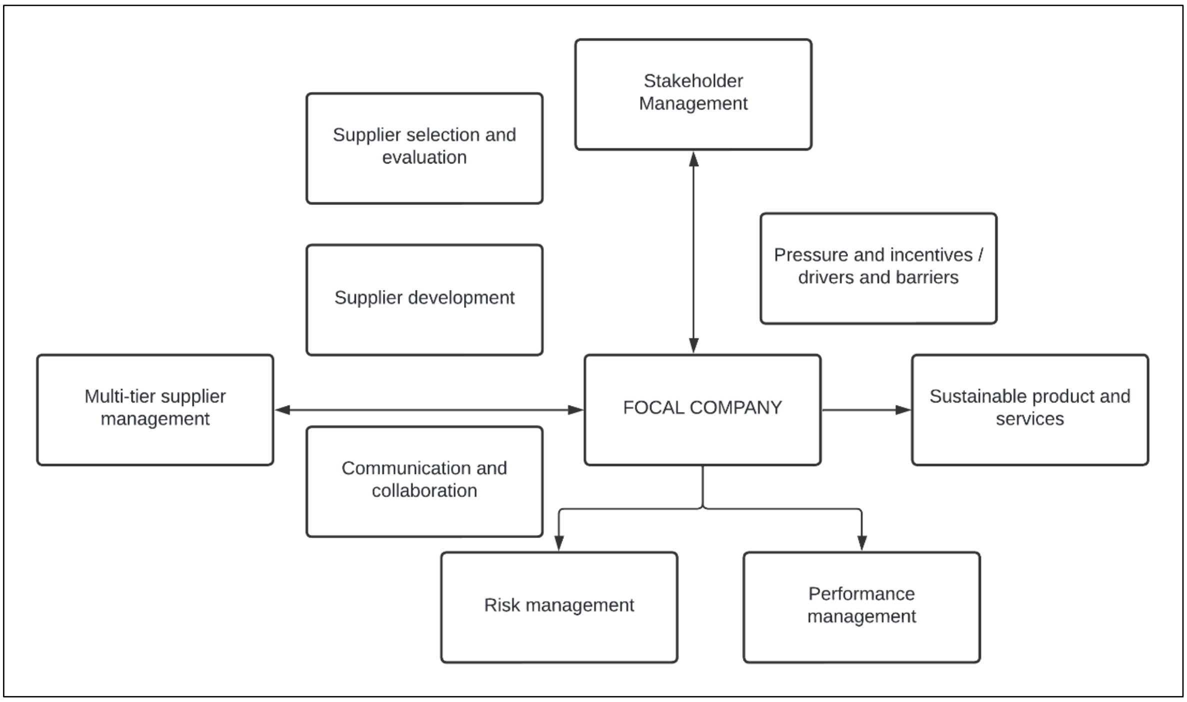

Figure 2. Core conceptual elements of Sustainable Supply Chain Management
Source: Author, based on Seuring et al. 2022, 2

The relations of sustainable dimensions within the supply chain are explained and summarised (Figure 3) by Ching and Moreira (2014). They have added additional elements to link economic and environmental dimensions with social dimensions. Eco Design presents egological gains by designing products where the company has to consider environmental concerns. The product's design needs to simplify the process of recovery and reusage. It also finds leaner production regards materials spent for production. Green purchasing introduces environmental concerns in the sourcing process of a product or service. Lean practices aim to improve operational performance by eliminating waste, resulting in improved environmental performance. Traceability reduces losses in production and in tracking efficiently. The social aspect is improving the working conditions of workers by pressuring the suppliers. Two practices are linked to all three dimensions: improving cooperation with suppliers and standardization by supplier certification - ISO 9000, 14000, 2600, and SA 8000 - which are connected to three dimensions of sustainability. Life cycle analysis (LCA) monitors impact only on the environment (Ching & Moreira, 2014).

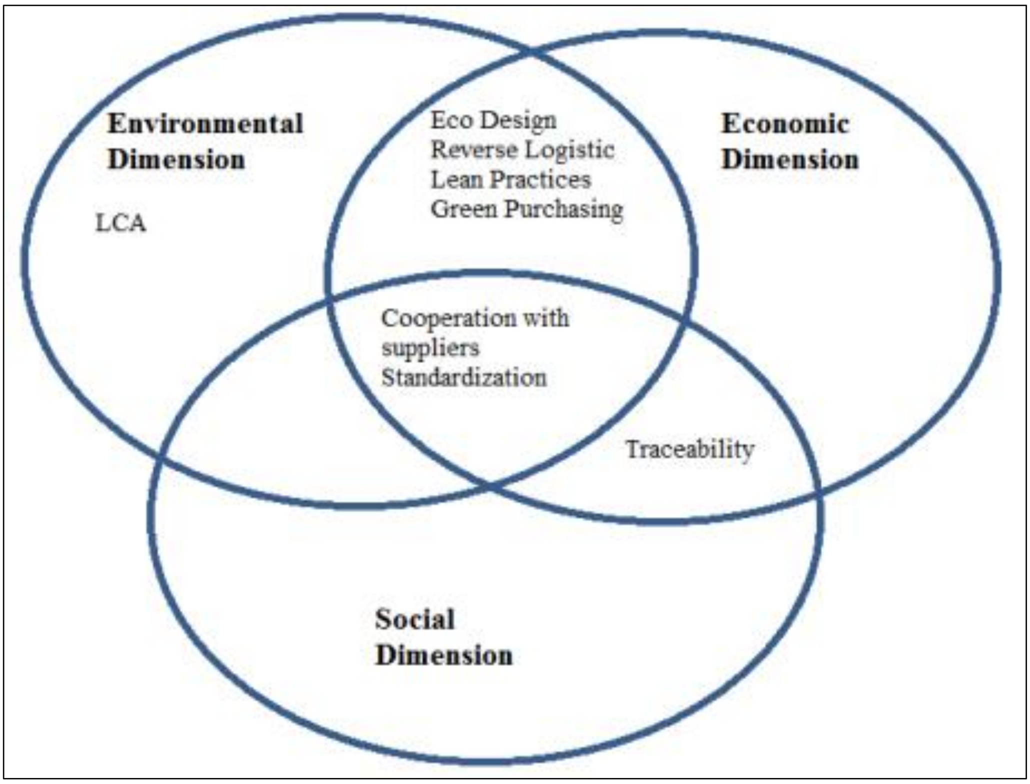

Figure 3. Relation of practices to the sustainability dimensions
Source: (Hong & Moreira 2014, 43)

In a survey conducted by Economist Intelligence Unit in 2008 involving 1200 executives and sustainability experts, 53% of enterprises worldwide claim to have coherent, sustainable policies. Still, less than 29% of executives say that their enterprise has a strategy covering the whole supply chain. There is undoubtedly a dilemma and uncertainty about whether sustainability is an opportunity and possible competitive advantage or just a mere negative effect on a company's bottom line (Ching & Moreira, 2014).

1.3 Reverse Logistics

One of the well-known definitions of reverse logistics is as follows: "*the process of planning, implementing, and controlling the efficient flow of materials, in-process inventory, finished goods, and related information from the point of consumption to the end of origin for the purpose of recapturing value or proper disposal* "(Rogers & Tibben-Lembke, 2001). Reverse logistics differ from forwarding logistics, covering various logistic aspects described in Table 1 (Tibben-Lembke & Rogers, 2002).

Table 1. Differences between forwarding and reverse logistics

Cost	Comparison with forwarding logistics
Forecasting relatively straightforward	Forecasting more difficult
One to many transportations	Many to one transportation
Product quality uniform	Product quality is not uniform
Product packaging uniform	Product packaging is often damaged
Destination/routing clear	Destination/routing unclear
Standardized channel	Exception driven
Disposition options clear	Disposition not clear
Pricing relatively uniform	Pricing dependent on many factors
Importance of speed recognized	Speed is often not considered a priority
Accounting systems closely monitor forward distribution costs	Reverse costs are less directly visible
Inventory management consistent	Inventory management is not consistent
Product life-cycle manageable	Product life-cycle issues are more complex
Negotiation between parties straightforward	Negotiation complicated by additional considerations
Marketing methods well-known	Marketing is complicated by several factors
Real-time information readily available to track product	Real-time information readily available to track product

Source: (Tibben-Lembke & Rogers 2002, 276)

Reverse logistics and its information and product flow are very different from the standard one-way forward flow. For example, in retail, the information flow for forwarding logistics can be seen in Figure 4, where future sales forecasts are used to project future needs. At every step of the chain, advanced shipping notices (ASNs) are used to clarify the flow.

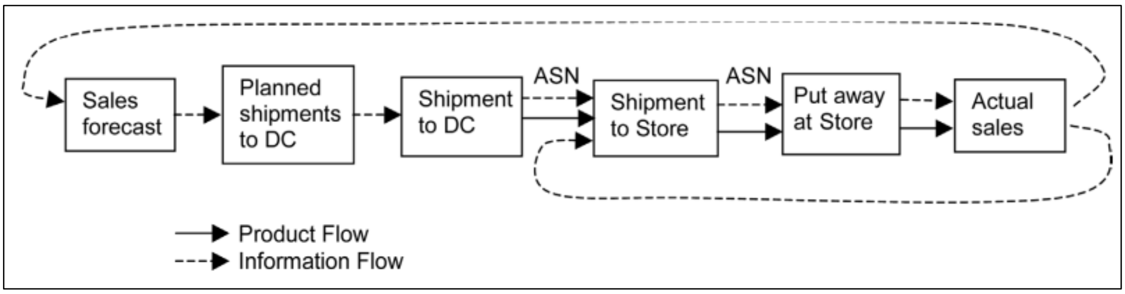

Figure 4. Forward logistics information flow for retail
Source: (Tibben-Lembke & Rogers 2002, 273)

In contrast, reverse logistics flow (Figure 5) is very reactive because enterprises usually do not control the beginning of the discharge as it is most often than not triggered by the customer. (Tibben-Lembke & Rogers, 2002)

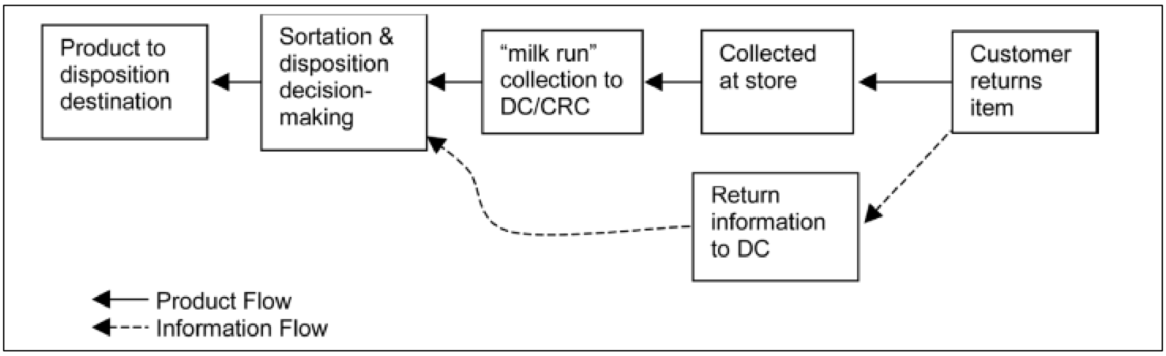

Figure 5. Forward logistics information flow for retail
Source: (Tibben-Lembke & Rogers 2002, 273)

The return flow of products was once considered of secondary importance to most companies worldwide, but now the trend is changing. (Jayaraman & Luo, 2007). The secondary importance may be explained through Porter's value chain (Figure 6) – according to that, the reverse flow is not the company's main activity. Therefore, it has never been in strong focus and has been in the shadow of so-called primary activities.

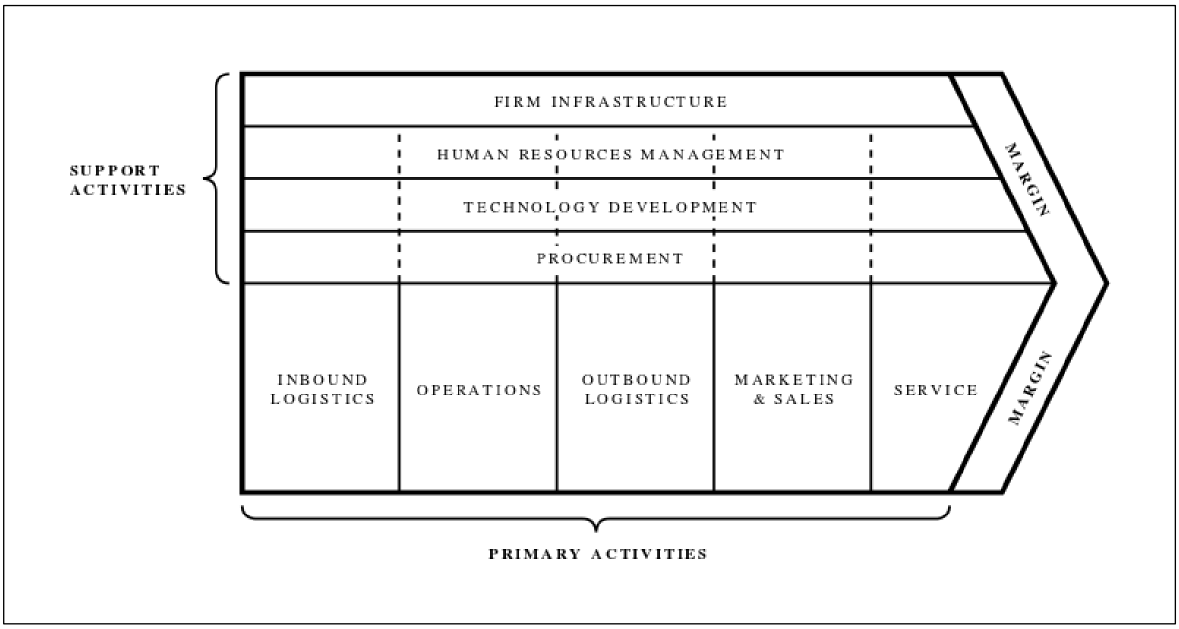

Figure 6. Porter value chain
Source: (Porter 1985, 37)

There is no denying that reverse logistics is a challenge for most companies because of its complexity. Also, reverse logistics has a long-term effect on the company's bottom line. As seen in Figure 7, the physical product flow has separate backward channels to all primary activities described by Porter and has a reductive effect on profit margin level (Jayaraman & Luo, 2007).

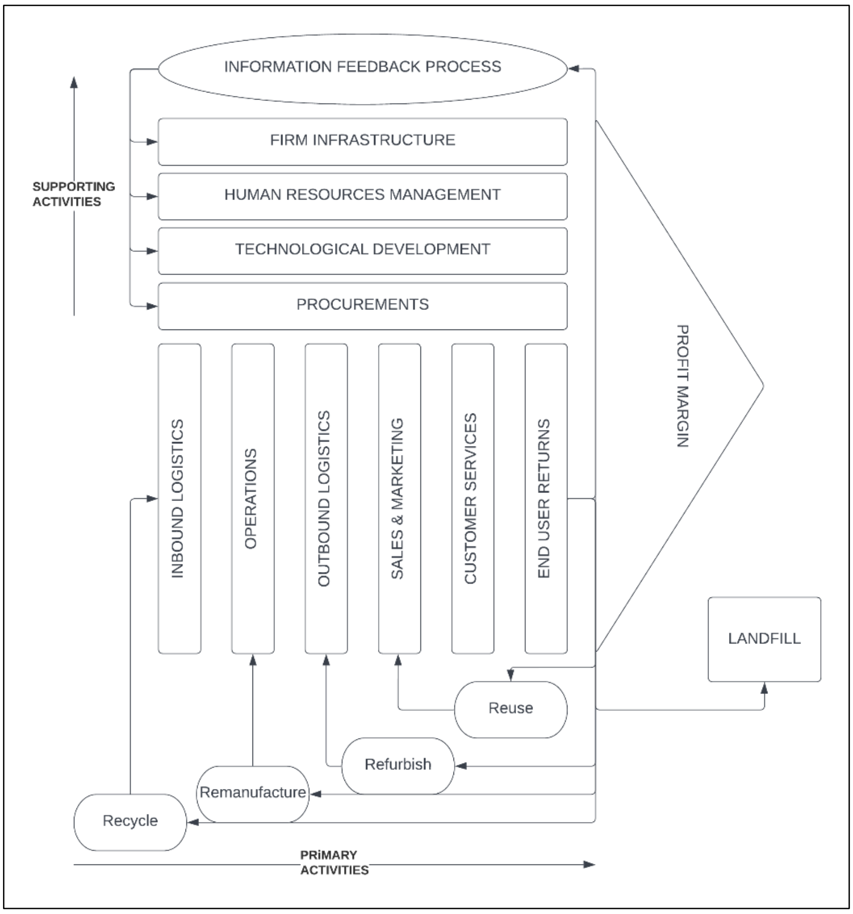

Figure 7. A Process of the reverse value chain
Source: (Jayaraman & Luo, 2007, 62)

To further explain how reverse logistics affects profit margin, we have to look at Table 2, which lists some aspects where the costs of reverse logistics differ from forwarding logistics (Tibben-Lembke & Rogers, 2002).

Table 2. Reverse logistics costs

Cost	**Comparison with forwarding logistics**
Transportation	Greater
Inventory holding cost	Lower
Shrinkage (theft)	Much lower
Obsolescence	May be higher
Collection	Much higher – less standardized
Sorting, quality diagnosis	Much greater
Handling	Much higher
Refurbishment / repacking	Significant for RL, non-existent for forwarding
Change from book value	Significant for RL, non-existent for forwarding

Source: (Tibben-Lembke & Rogers 2002, 276)

Many standard inventory management models do not work well in reverse flow as you have more inconsistencies in product flow than in forwarding flow. (Tibben-Lembke & Rogers, 2002). Reverse logistic flow results in a more complex system than forwarding logistics and requires improved ways of work. Mastering these logistical challenges may give companies a significant competitive advantage.

1.4 Closed-Loop Supply Chain

A closed-loop supply chain (CLSC) incorporates the forward and reverse supply chain activities into a particular system to improve economic and environmental performance (Krikke et al., 2004). Therefore closed-loop supply chains include the elements of the forwarding supply chain. But add in the aspects of reverse logistics like obtaining the products from the end-user, moving products from the points of use to the point of disposition, testing, and sorting to determine the product's condition and choose the most economically reasonable action (Guide et al., 2003).

Guide & Wassenhove (2006) describe CLSC as "*the design, control, and operation of a system to maximize value creation over the entire life-cycle of a product with the dynamic recovery of value from different types and volumes of returns over time*. "

The best way to get supply chain managers interested in CLSCs is to display that there are profits to earn for companies who are willing to improve their competencies in reverse logistics and CLSCs (Guide & Wassenhove, 2006). In addition, closed-loop supply chains can create additional cash flow (generate profit) by returning goods from the customer and recovering available value (Atasu et al., 2008).

For example, Xerox started its closed-loop chain already in 1991. Customers return their empty cartridges to the manufacturer, where they are cleaned and inspected. Cartridges will then be reused or recycled depending on the condition. A simplified model of this loop chain can be seen in Figure 8 (Daniel et al., 2002)

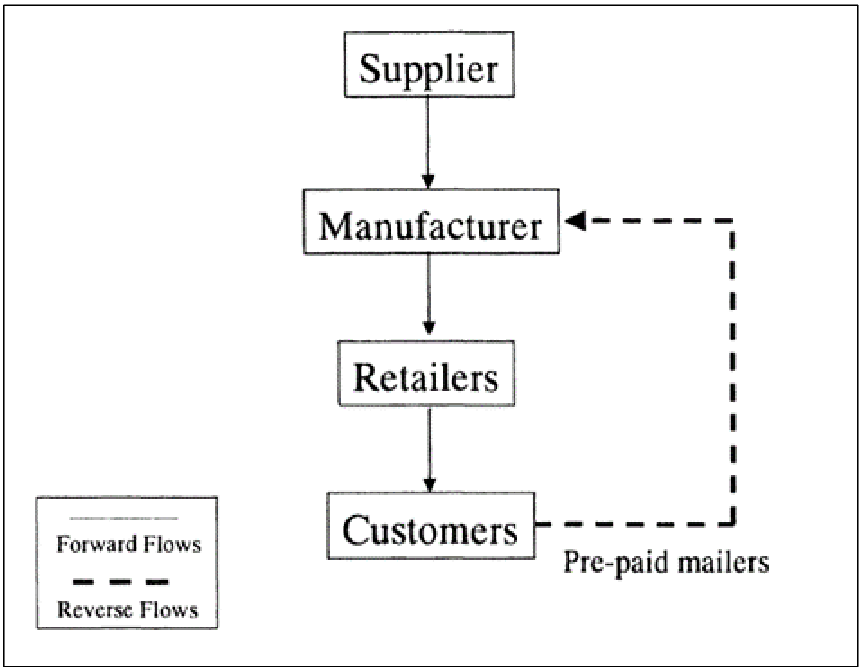

Figure 8. A closed-loop supply chain for cartridge reuse
Source: (Daniel et al. 2002, 48)

An important factor why the Xerox system was successful was that reverse flow was made easy for the end customer. Also, it was free of cost for the client as Xerox pre-paid it. The inclusion of ecological aspects increases the complexity of the chain processes, as shown in Figure 9 (Krikke et al., 2001).

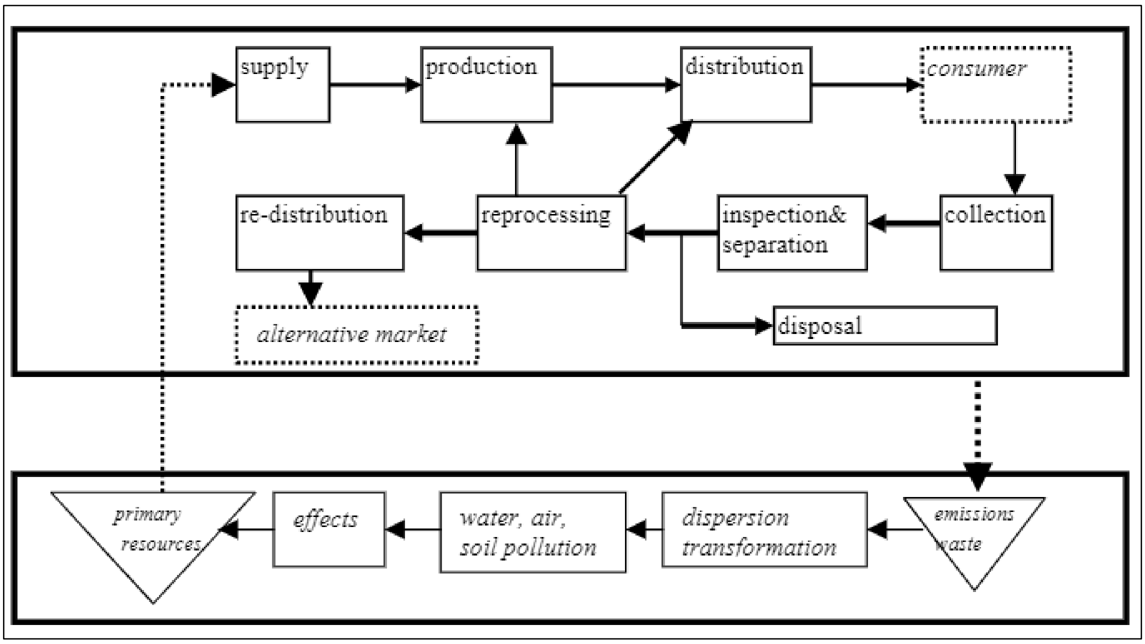

Figure 9. Closed loop-supply chain and environmental chain-linked, analogous to (Bloemhof-Ruwaard, 1995)
Source: (Krikke et al. 2001, 3)

During the closed-loop system design, economic and environmental impacts must be considered and calculated together as one may ineffectively affect another. For example, transporting goods back over a long distance may be economically reasonable, but the effect will be more CO_2 released into the atmosphere – or vice versa.

Another positive effect of a well-designed closed-loop system is its effect on lead time. In today's world, where product life cycles are short, demand is volatile, and pressure from competition is immense, logistics lead time reduction merits a focal point to business success (Christopher, 2016). For example, figure 10 highlights the common scenario where customers' desired order cycle time is shorter than the logistics lead time supplier can offer, resulting in a negative lead time gap.

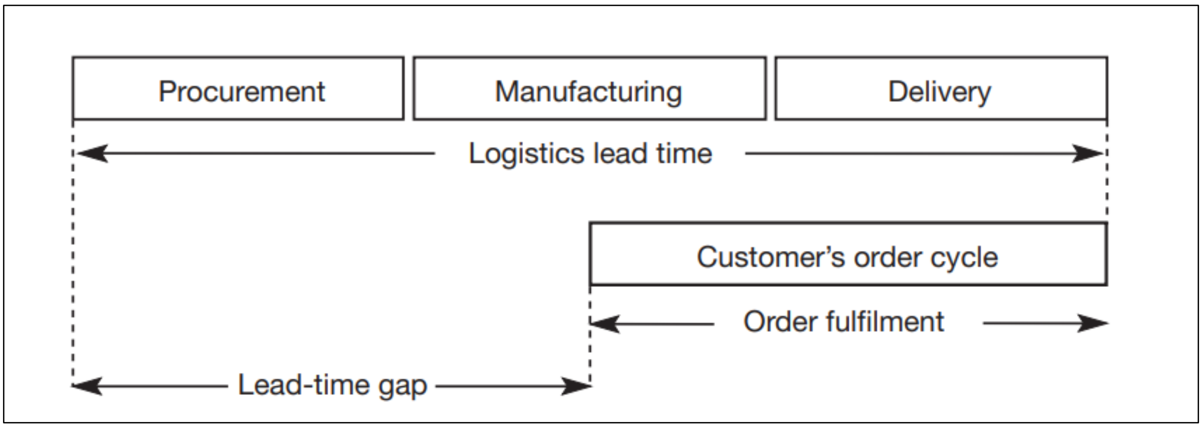

Figure 10. The lead-time gap
Source: (Christopher 2016, 160)

There are two solutions to reduce the lead-time gap. The first is to increase clients' willingness to wait longer – usually, it decreases supplier competitiveness in the market. A second and better view of increasing the competitive advantage of suppliers is to shorten logistics lead time and get closer to the client's desired level. A well-designed closed-loop solution with buffer stock may provide this as the need to produce new goods is reduced.

Managers are starting to recognize the vast potential of reverse supply chains and closed-loop systems but struggle to control and efficiently organize these flows, which may offset small profit margins in forwarding supply chains (Guide & Wassenhove, 2006). Logistic service providers should use their vast experience, knowledge, and motivation to create these systems for their partners. For example, Xerox found that empty cartridges do not need disposal. Instead, these can be collected, cleaned, and made ready for reuse – creating a simple yet effective closed-loop system. For this thesis, the author will use Nefab's expertise in packaging material and the logistic area to provide a similar closed-loop solution with plastic tray packaging material for its client.

2 TERMS OF REFERENCE

2.1 Nefab Business Strategy

The roots of Nefab Group are in Sweden, a city called Runemo, where it started as a small carpentry shop in 1949. Developing from a one-person shop to a leading packaging solution provider has been remarkable. Over six decades, Nefab has widened its reach to 32 countries worldwide, creating revenue of 760 million USD per year and offering job for more than 4000 people (Nefab Group 2021).

Nefab Group has positioned itself as a leading packaging and logistic solution provider for companies active in the following segments: energy, automotive, telecom, healthcare, aerospace, and Lithium batteries. These companies are in Nefab's focus because they produce high-value products that are pretty delicate to dangers of transportation like vibration, humidity, shocks, careless handling, etc. To minimize those risks, customers need custom engineered packaging solutions to ensure their products reach their destination intact. In recent years, Nefab has widened its business concept to logistic solutions to have a more substantial impact on clients' supply chain and save valuable resources, time, and money to clients (Nefab Group 2021).

Nefab Group started its activity in Estonia in 2001 when Nefab group decided to set up a factory to produce plywood-based products for the Scandinavian market. By 2004 local sales unit was created to enter the local market. By 2021 Nefab Estonia (from now on, Nefab) has expanded its factory in Lagedi to 10 000m^2, offering work for 240 people (both blue and white collars), and opened an external warehouse in Lehmja with a 3000m^2 floor space to provide logistic services for its clients (Nefab Estonia 2021). In 2020 company revenue was 19,7 million EUR with a profit of 1,4 million EUR (Majandusaasta Aruanne, 2020).

The local Nefab Group unit shares the same core values with the group. Although they can choose their strategies, it is still very similar to group one – reducing costs in the client supply chain through engineered packaging material and logistic solutions (Nefab Estonia 2021). Estonian sales unit has the same intense focus on key customers and finding solutions to optimize costs and take responsibility through their supply chain. The Estonian sales unit is also responsible for the Latvian and Lithuanian markets.

Nefab Group core business strategy is to be a valuable partner for its clients by helping them reduce costs in supply chains. Its highlighted by Nefab slogan, "*we save resources in supply chains*." Promised cost reduction is achieved by main four main activities (Nefab Group 2021):

- Multi-material engineering,
- The total cost approach,
- Global supply and services,
- Custom packaging solution.

Nefab Group has built strong engineering competence and can offer packaging solutions made from various materials. Nefab R&D *(*Research and Development*)* focuses on finding and developing new materials. The main focus is to protect the client's product, and it's achieved by combining materials like plywood, corrugated, steel, plastic, etc. Recent success stories have been implementing strawboard material made of agricultural straw waste. Most of the packaging materials are created by Nefab, maintaining the high-quality promise for its clients. All this results in a unique package solution that Nefab clients value.

Nefab Group aims to offer global supply and services, but its international presence does not transfer directly into a competitive advantage (Gupta, Govindarajan, Roche 2001). Therefore Nefab has set its aim to offer a total cost approach for its clients by combining the competence of packaging materials and logistic solutions. As a result, Nefab has the credentials to have a more significant impact on clients' supply chains than the competition. Furthermore, most logistic solution providers on the market have the competence in service but none in the material segment. Nefab strategy combines these two and takes care of most of the functions within the client supply chain: inbound, outbound, packing, warehousing, stock management, etc. (Nefab Group 2021).

Nefab has targeted clients with a global presence to maximize its capabilities and the vision to be their global partner for packaging solutions. This chosen client segment is GKA-s (Global Key Accounts*)* within the Nefab group. Nefab can build complex logistical chains between countries and continents, resulting in the circulation of used packaging materials. In recent years, the Estonian unit's focus has also shifted to offering logistic services for Baltic customers. For example, in 2018 first logistic center was opened in Lehmja to offer simple warehousing services for customers. Today they offer a wide variety of solutions like VMI (Vendor Managed Inventory), packing service, warehousing (both for packing materials and client products), buffer stock, *VAS* (Value-adding services), and outbound logistics (mainly container loading), etc.

2.2 Overview of Supply Chain

It is essential to understand if the supply chain under analysis is worth the assessment in the first place. Meaning does it have enough annual material flow to perform reliable calculations. Also, is the distance between the chain links too far from each other to even consider a reverse logistic solution as it's visible that the cost of transportation would be too high considering the piece price tray. Also, to determine if the plastic trays we are trying to reuse are reusable.

First, let's evaluate the reusability of packing material in this supply chain - plastic trays. The trays used in this flow are polystyrene plastic, in short, PS plastic – a polymer made from the monomer styrene. The product design makes these trays ideal for reusage as they are nestable, meaning it is possible to partially place one product into another, resulting in a significant space-saving (ca 42%) during transport and storage. Regards the durability of PS plastic and overall suitability for reusage author bases its assumption on an interview with a Nefab engineer and rates the material worthy at least 50 to 100 times of reuse. Unfortunately, Nefab has not conducted any reusage durability tests. Therefore, this number remains estimated, but in the frame of this work, the trays will be regarded as fully reusable.

For the volume assessment, the author will use the company's sales statistics from 2018 to 2021, and the client submitted a forecast for 2022 quantities. The average consumption per year is 131 551 pieces (including a forecast for 2022). Figure 11 illustrates the previous year's consumption and forecast.

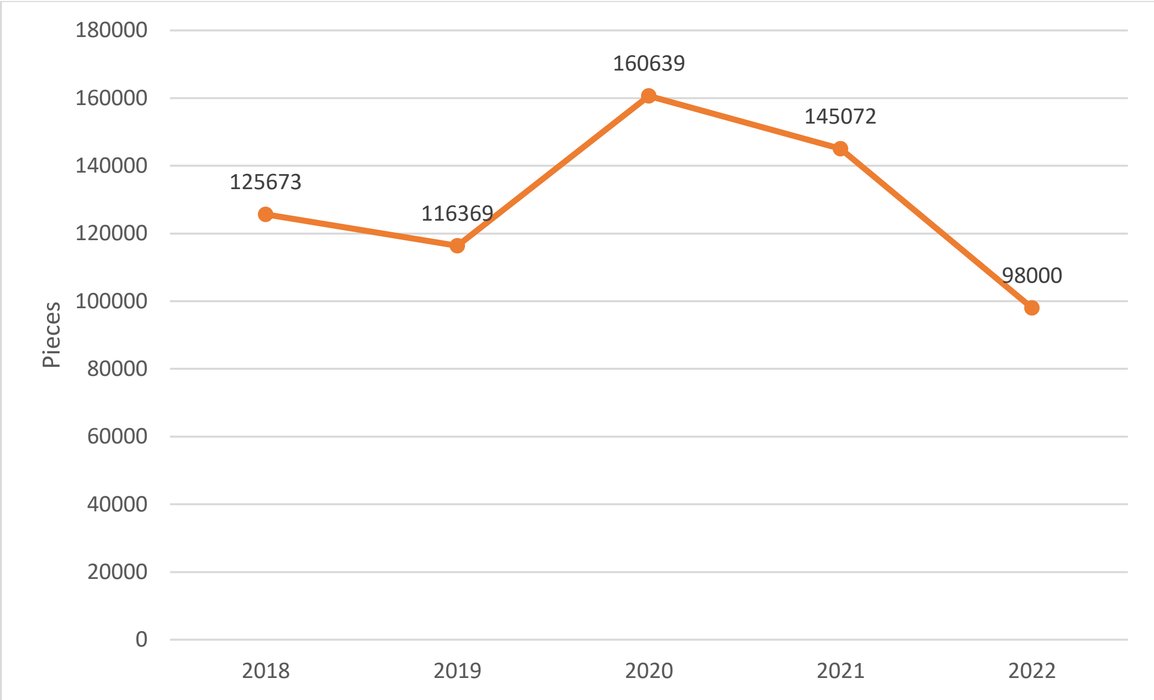

Figure 11. Delivered trays in pieces per year (also included forecast for 2022).
Source: Author

Another vital factor to examine is the volatility of consumption from month to month to see if there are patterns for peaks and lows to take into account. Therefore, the author analyzed the average quantities sold from 2018 to 2021 per month. Figure 12 shows the results of this.

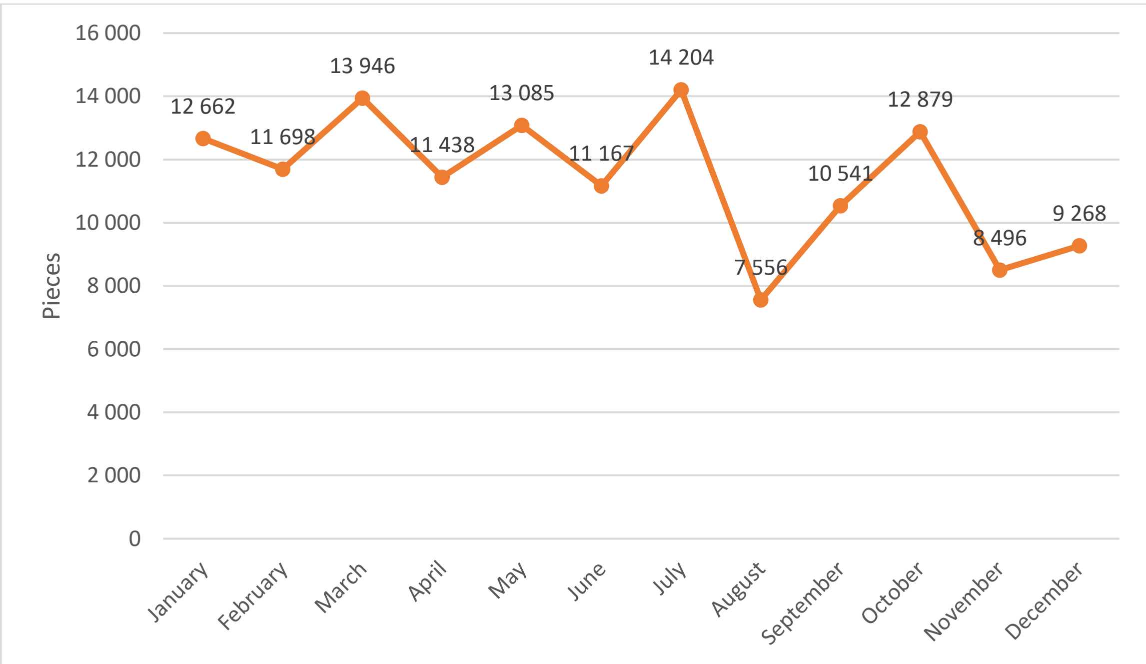

Figure 12. Average delivered tray quantities per month (2018-2021)
Source: Author

There is usually a small peak in July and a decline in August. The reason is probably related to the summer holidays – the client fills the stock with packed products in July to have availability to ship in August when most of the production is on collective vacation. Nevertheless, it is a valuable insight because when creating a buffer stock of plastic trays, it needs to be taken into account that the consumption in July is 24% higher than the annual average per month. Figure 13 highlights the deviation from the annual standard.

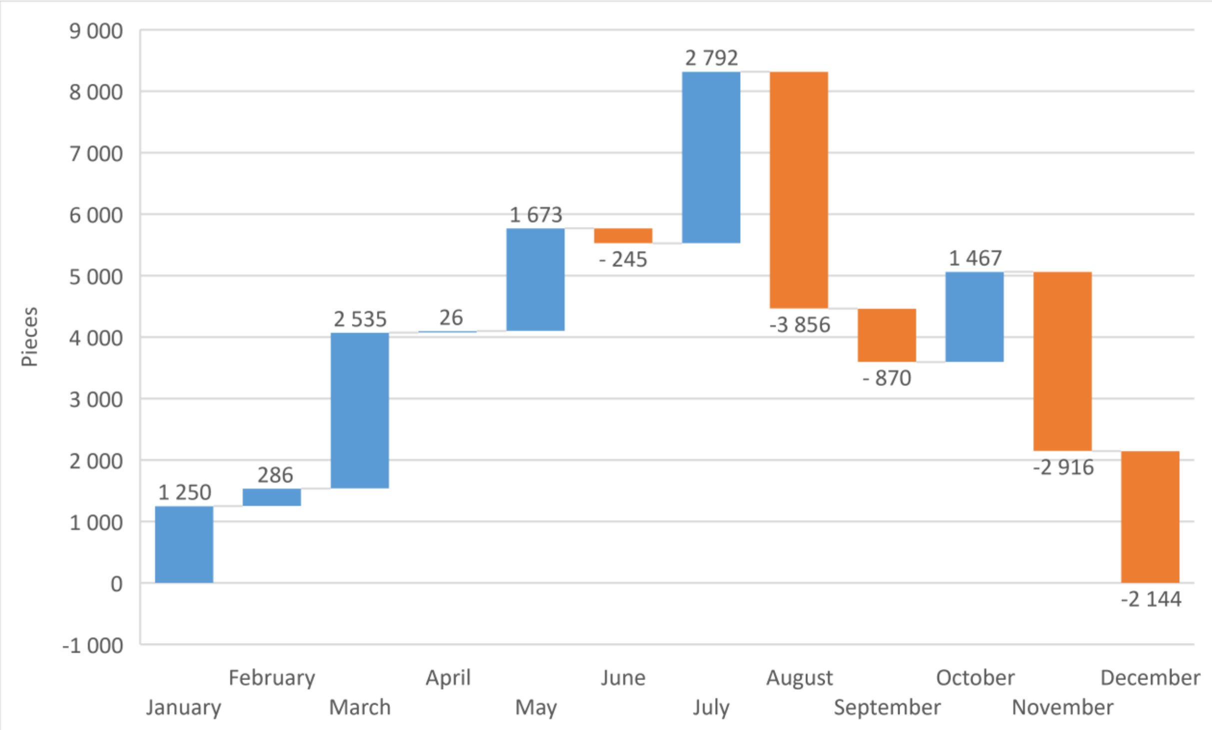

Figure 13. Monthly consumption deviation to an annual average
Source: Author

This model will be used in table 11 to estimate the monthly stock peak for pool sizing. Average monthly deviation in pieces will converted to deviation by percentage and used to project estimated usage for 2022, based on customer forecast.

The cumulative travel distance of packing material flow is ca 2600km, making it reasonable for reverse logistics. Furthermore, the return cost for one pallet is 72 EUR. (price agreement from 01.04.2022), and transportation time is a few days from the end customer.

The author values the annual material flow to be enough for reliable calculations. Based on Nefab engineer input, the viewed material is reusable and can be reused multiple times before it depreciates. The distance between the end customer and Nefab is reasonable for reverse logistics. All prerequisites raised by the author for creating a closed-loop solution have been filled.

2.3 Research Purpose and Expected Results

Companies underuse closed-loop supply chain solutions, especially regards packaging materials. The author thinks it is understandable because costs related to packaging material are usually low compared to production, labor, and logistic costs. This emphasizes Nefab role as a valuable partner and advisor in the packaging material area to take the initiative and proactively reduce expenses in the client's supply chain.

The case of low-cost staying under the radar can be said regards the one-way supply chain author views within this thesis. The piece cost of the plastic tray used by the client is low (especially compared to the products inserted into it). Therefore, the need to alter it has been non-existent. Nefab job is to highlight this, take the existing solution, and propose a new and better solution that reduces costs and adds additional value to the client by shortening the lead time, improving availability, easing day-to-day work, etc. Nefab's proposed scenarios will be designed considering: pooling, inventory management, transportation, and circulation of plastic trays.

The author will also visualize the carbon footprint comparison for all scenarios proposed. However, this illustration will be created using Nefab own software, which the author can not prove within this work. As for that, it will serve as a secondary purpose for this work. The calculations models used for carbon footprint results can be a subject to further research by the author.

Nefab's problem is the lack of experience and success cases in building closed-loop solutions for clients. Nefab has some previous business cases with pooling and circulating packing material. Project with local telecom company consisted of circulating complete export packaging set (pallet, collar, and lid) through several European units. With this thesis, the author hopes to make a small step in the right direction, improve Nefab competence in this field, and modify its service sales strategy accordingly.

The purpose of this thesis in one sentence is: research if a closed-loop packaging material flow will reduce TCO and lead-time for a client and minimize the overall CO_2 footprint within supply chain. With this thesis following results are expected:

1. Proposed closed-loop solution reduces the total cost of ownership,
2. New solution will shorten the lead time for a customer,
3. Carbon footprint of the proposed solution will be smaller than in existing one.

3 METHODOLOGY

3.1 Design of Research

This thesis is a case study of a closed-loop service offered by Nefab to reduce the total cost of ownership, improve logistics lead time and add a viable business case to Nefab portfolio. The author will use scenario analysis to understand how Nefab can reduce the total cost of ownership by reducing the need to buy new packaging material by reuse. The lead-time reduction will come through buffer stock and active stock management. Design research is visualized in Figure 14.

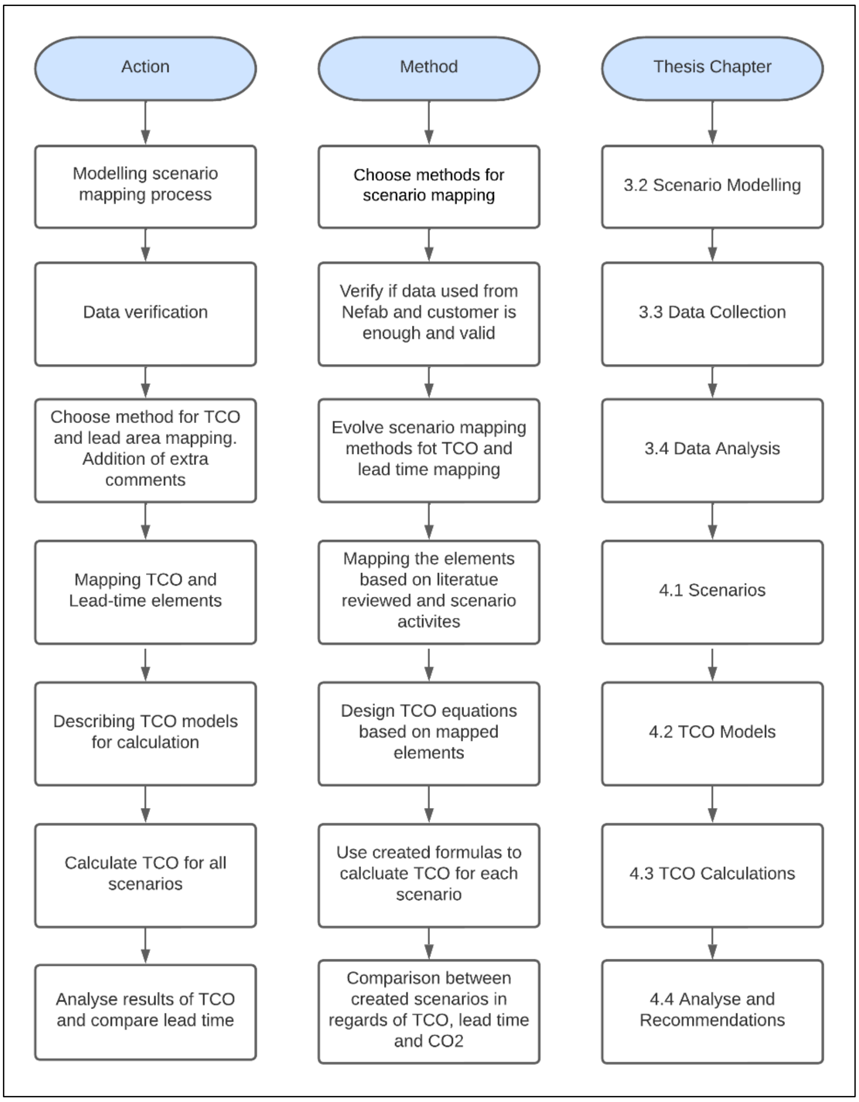

Figure 14. Design of research
Source: Author

The author uses scenario modeling and simulations to show scenario effects on costs and lead-time. In addition, a carbon footprint comparison will be made by the author using Nefab software called Greencalc.

3.2 Data Collection

Data used in the thesis is mainly from Nefab business and ERP (enterprise resource planning) software. Sales statistics relevant for calculations and analysis are pulled from the ERP system (invoiced sales) and then processed by BI (business intelligence) software, creating a user-friendly pivot table. Figure 15 highlights the view from Excel after the user used the suitable filters to clear the data.

Nefab Packaging OÜ SU
(Multiple Items)
All
All
All
All
(Multiple Items)

Column Labels												
January	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**	**October**	**November**	**December**	**Grand Total**
50 648	**46 790**	**55 785**	**45 751**	**52 340**	**44 668**	**56 814**	**30 222**	**42 165**	**51 516**	**33 983**	**37 071**	**547 753**
2 411	3 809	3 200	2 272	1 817	3 520	3 040	320	1 600	2 874	2 400	3 680	30 943
8 186	7 420	10 186	8 049	8 981	7 707	11 190	4 960	9 440	8 972	7 200	7 360	99 651
6 006	2 446	4 960	2 240	5 068	4 280	2 720	1 120	2 240	3 357	1 920	1 280	37 637
15 693	8 973	10 240	8 360	16 800	8 480	16 349	9 440	9 280	16 797	6 880	7 040	134 332
1 243	2 778	2 185	2 765	861	1 500	2 501	2 100	2 400	1 300	700	1 800	22 133
2 175	3 963	6 000	4 600	5 100	3 440	4 413	1 700	6 580	5 000	2 400	4 000	49 371
1 101	2 405	2 430	2 703	1 498	1 620	2 160	1 530	1 710	1 620	990	2 160	21 927
3 718	4 847	5 756	3 420	4 504	3 848	4 419	3 060	2 520	3 420	3 960	2 160	45 632
1 931	2 040	1 955	2 263	1 020	1 105	2 550	170	1 530	1 360	1 020	1 870	18 814
868	700	700	700	400	1 000	1 020	300	200	900	400	500	7 688
4 134	3 875	3 478	4 701	3 603	3 444	3 415	3 315	2 380	3 315	3 655	2 465	41 780
2 609	2 874	3 995	2 842	2 183	4 131	2 212	1 700	2 125	2 377	1 530	1 700	30 278
573	660	700	836	505	593	825	507	160	224	928	1 056	7 567
50 648	**46 790**	**55 785**	**45 751**	**52 340**	**44 668**	**56 814**	**30 222**	**42 165**	**51 516**	**33 983**	**37 071**	**547 753**

Figure 15. Pivot table with sales data (in pieces)
Source: Author

The author excluded additional artificial quantities created by credit notes and additional invoices made by accounting. A customer procurement specialist gives the forecast for 2022 packaging material consumption, used in further calculations. The accuracy of the given prediction is hard to estimate, but as it is in the previous year's usage region, the author will keep it unchanged.

Information regarding the packaging material dimensions, weight, packing instructions, etc., is from ERP. The amount of data possible to get from ERP is extensive and covers all aspects needed to proceed with this thesis. Figure 16 shows the view from ERP for packing instructions.

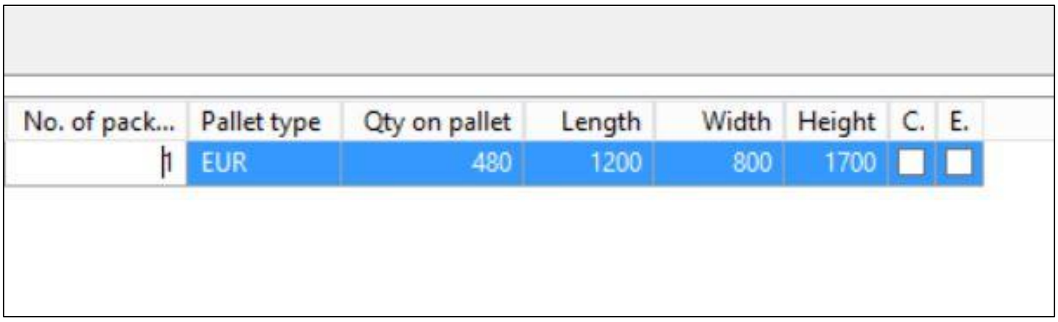

Figure 16. Packing instruction view from ERP
Source: Author

Data sources regarding the supply chain, material flow, and customer usage of an external warehouse are mostly business intelligence obtained by the author over a certain period. For example, the client declared the end customer's location years ago during the inquiry for a quote. The information regarding using an external warehouse was gained through a phone call with the customer purchasing specialist.

Data from the statistics Estonia web page will determine the company's work hour cost per worker. Furthermore, author estimations are used for plastic tray sorting, cleaning, and repacking. The space needed to perform the previously mentioned service is a projection by the author. Finally, Nefab's accounting data will be used for determining the m^2 cost of the warehouse. The same warehouse cost will assess customer expenses on external warehouse space.

3.3 Scenario Modelling

A scenario can be characterized as a description of a potential future outcome, counting in aspects that lead to that outcome. Scenarios draw attention to essential elements that drive the path to the possible future rather than giving a complete description of the result (Kosow & Gaßner, 2008). With this thesis, several future prerequisites for the scenario will be raised by the author:

1. Reduce the total cost of ownership for the customer;
2. Reduce lead-time for the customer;
3. Reduce carbon footprint within the supply chain (by data Nefab greencalc calculations).

Scenario 0 will be a description of the current situation. After that, new scenarios will

The author will use the normative scenario approach for this thesis, as a desirable future is defined before creating scenarios. The question is how to reach the desired scenario. Ways to reach the goal will be highlighted in scenario elements. Figure 17 illustrates the critical aspects of the normative method analysis.

	Explorative	**Normative**
Procedure	Explores possible future developments with the present as point of departure	Identifies desirable futures or investigates how to arrive at future conditions
Function	Explorative and/or knowledge function	Target-building function and/or strategy development function
Implementation	Study of factors and unpredictabilities, test of possible actions to be taken and/or decision-making processes	Definition and concretization of goals and/or, if appropriate, identification of possible ways to reach a goal
Central question	What? – What if?	How? – How is it to come about? – How do we get there?
Inclusion of probabilities	Possible	Indirect, part of plausible shaping and planning

Figure 17: Schematic comparison of explorative and normative scenarios
Source: Kosow & Gaßner, 32 with elements borrowed from Henrichs (2003); Greeuw et al. (2000); Steinmüller (1997).

Material flow paths are required to identify cost components for scenarios. Most probably, the costs are related to management, production (price viewed product), transportation and warehousing areas. It's also important to mark the assumption of how critical one cost aspect is to overall costs, which means that the high importance cost factor needs to be accurately measured. Conversely, the low importance factor is acceptable to be with moderate accuracy.

The author will examine the current solution's information and material flow and map the critical activities of scenario 0. Table 3 shows the visualization of the mapping result example. For cost importance, exact numbers are not necessary, and estimation of cost importance is enough. Lead time for the customer is relatively close to reality and can be used later for direct comparison between scenarios.

Table 3. Method sample for Scenario 0 mapping

Activity	**Responsible**	**Description of activity**	**Cost importance**	**Time consumption (days)**
1.	Customer	Stock monitoring and order management	Low	0,25 (close estimation)
2.	Supplier	Order management	Low	0,25 (exact)
...	...	...	...	...

Source: Author

Time consumption mapping serves two purposes. Firstly we can track the lead time, and secondly, we can evaluate how quickly the material moves through the chain. Comment regards the level of accuracy is added. Column "TCO importance" only considers the costs related to purchasing and using the plastic tray in inbound flow from the client's perspective.

As highlighted in table 4 as an example, a new parameter will be added for the following scenario mappings – cost change compared to scenario 0, which gives the first cost comparison against scenario 0.

Table 4. Method sample for following scenario mappings

Activity	Responsible	Description of activity	Cost change	Cost importance	Time consumption (days)
1.	Supplier	Pooling and buffer stock	Increase (new activity)	High	0 (exact)
2.	Customer	Order management	Lowered (no stock monitoring)	Low	0,10 (close estimation)
...	...	...	...	...	...

Source: Author

After every scenario mapping, the author will analyze if the presented prerequisites are fulfilled. If they are, no new scenario will be created and vice-versa. The author will continue with calculations to verify the assumption regards requirements.

3.4 Data Analysis

3.4.1 Total Cost of Ownership

The total cost of ownership (TCO) is a concept where all the expenses related to an acquisition are accounted for, creating an overview of the actual price for the organization (Ellram, 1999). In addition, to ensure that all the possible expenses related to the purchase decision are included, it is necessary to look at all activities that may be affected (Tibben-Lembke 1998). Figure 18 illustrates the several elements of TCO in more detail.

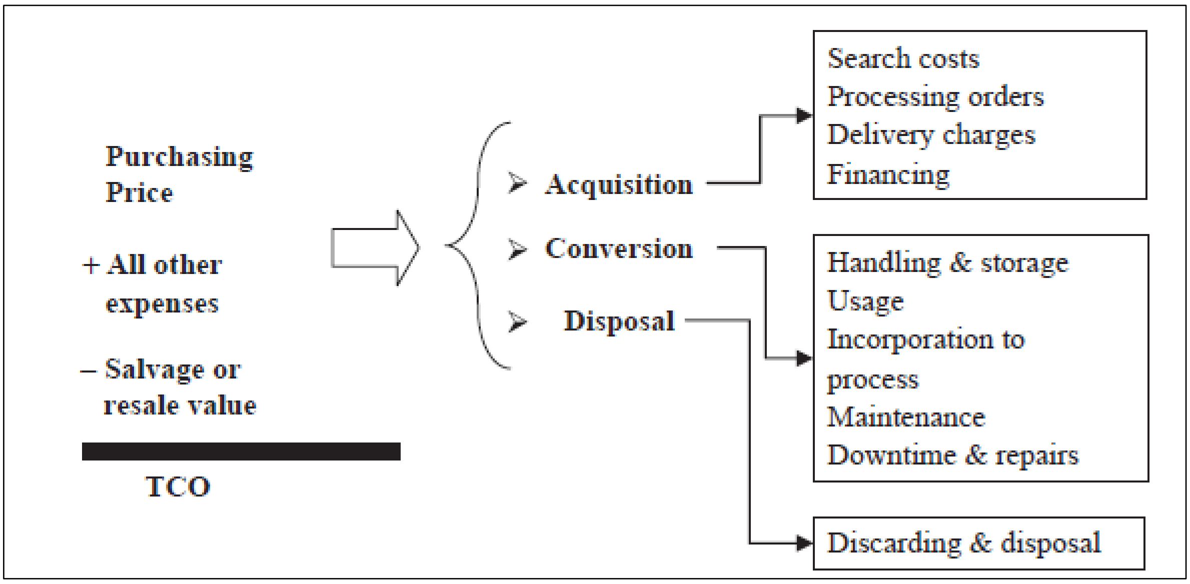

Figure 18. Elements of the total cost of ownership.
Source: (Piscopo et al. 2008, 208)

Creating and analyzing TCO models give suppliers better knowledge about their customer business and supply chain. This wisdom provides a better view of customer needs and what they value. This results in the ability to create additional value for the client (Figure 12) – customers need to acknowledge the value suppliers can make for them (Piscopo et al. 2008). The importance of TCO models as either a cost-saving tool for the companies or as a sales tool for suppliers to create a competitive advantage is inevitable.

3.4.2 TCO and Lead Time Models

All author-created scenarios will further be mapped regarding cost areas and lead time to the customer. For simplicity, tables will be used for data collection and formulas for TCO calculations.

For TCO universal calculation model will not be used, as the cost parameters will appear after the scenario mapping process. Therefore separate cost model for each scenario in chapter 4.2 will be created. The purpose of the TCO model for each method will be to get the total cost price per piece. Before making the formula model, all cost areas of the scenario will be highlighted, as shown in table 5 as a reference.

Table 5. Method sample for cost area mapping

Respon sible	Description of cost area	Cost elements
Supplier	Creating plastic tray pool	*POOLING COST = POOL SIZE X PRODUCT PRICE*
Client	Monitoring stock and issuing a purchase order	*LABOR COST = COST OF WORKFORCE TIME X TIME USED FOR ACTIVITIES*
...	...	...

Source: Author

A TCO model formula using abbreviations will be created after determining cost areas and cost formulas for scenarios. Finally, the calculation results will be given in piece price for the customer considering all the costs related.

A different mapping process will be done to assess the lead time. The evaluation starts with the customer issuing the order and ends with goods arriving at the customer's premises. Table 6 shows an example of lead time evaluation method.

Table 6. Method for lead time evaluation

Activity no	Activity for scenario 0	Time (workdays)	Activity for scenario 1	Time (workdays)
1.	Customer monitors stock and issues purchase order	0,20	Customer issues purchase order	0,15
2.	The supplier handles purchase order	0,10	The supplier handles purchase order	0,10
...	...	...	...	...

Source: Author

After the lead time mapping, all scenarios will be compared against each other. One of the prerequisites was that the created method needs to improve lead time against scenario 0. The data regards time consumption will be taken from the scenario mapping table. This table will be later used in chapter 4.4.

The author believes that this step-by-step mapping process is the best work method in this scenario analysis as it keeps a clear structure and avoids missing critical aspects of TCO elements. The comparison between created scenarios will be made in chapter 4.4. However, as mentioned before, there are no formulas regards carbon footprint assessment between scenarios as the author can't verify the origin and structure of the formulas.

Disclaimer: There are slight alternations to the sales price, production price, and Nefab sales mark-up to protect the Nefab trade secret. The alternations done are not high enough to jeopardize the trustworthiness of the calculations.

4 ANALYSIS

4.1 Scenarios

4.1.1 Modelling Scenario 0

The current scenario between Nefab and a client is a classic one-way material flow regards the packing material. The client dictates the flow and triggers the process by issuing a purchase order. Nefab's reaction to that is order management, production, and delivery. After receiving the plastic tray, the client packs their product into it and ships them to the end customer in Europe. Finally, the end customer repacks the product and disposes of the packing material marking the end of the flow. Figure 19 illustrates the overall picture of the flow.

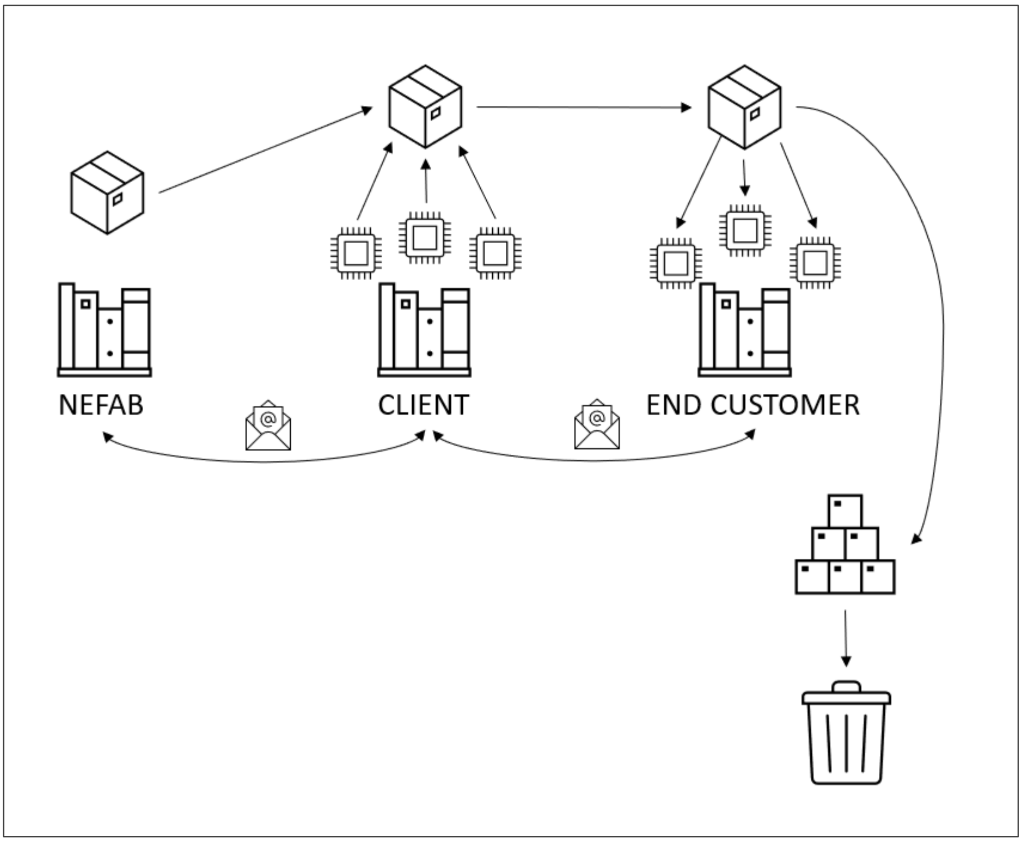

Figure 19. Visualization of scenario 0 material and information flow.
Source: Author

The activity mapping was done to have a more detailed and precise understanding of the chain's material flow and different elements. Table 7 shows the results of the mapping. The data gathered by the author was done by following the flows of information and material and mapping the critical activities through the chain. The area of action was taken by the client's point (inbound, client, outbound, and end customer).

Table 7. Scenario 0 mapping

Activity no	Responsible	Description of activity	Cost importance	Time consumption (workdays)
1.	Customer	Stock level monitoring and order management	Low	0,20 (close estimation)
2.	Nefab	Order management	Low	0,15 (exact)
3.	Nefab	Production	Very High	20 (exact)
4.	Nefab	Packing and delivery	Medium	1,5 (exact)
5.	Customer	Receiving and storage	Medium	3 (estimation)
6.	Customer	Usage of packing material	None	1 (close estimation)
7.	Customer	Delivery to end customer	None	2 (close estimation)
8	End customer	Receiving and usage	None	5 (estimation)
9.	End customer	Disposal of packing material	None	0,5 (estimation)

Source: Author

Based on a phone call with the client purchaser, it takes ca 0,5H to process the stock level, prepare a purchase order and send it out via e-mail. Due to Nefab response time, it takes one-fifth of an 8-hour workday to Nefab receive the e-mail. Finally, Nefab inserts the order and plans the ordered quantities into the production plan. The most time-consuming phase is production and delivery. Promised lead time to the client is 22 days. The author gives customer outbound and end-customer usage of goods a rating of close estimation for time consumption. This is again based on a phone call with the customer purchaser.

The author estimates that the production of packing material has the highest effect on TCO, as this directly transfers to the plastic tray piece price that customer has to pay to acquire the packing material. Production cost includes the raw material to produce, direct labor, work center costs, etc.

4.1.2 Modelling Scenario 1

For creating scenario 1, a closed-loop method is used. Nefab will integrate the closed-loop practice with the VMI service, where Nefab takes the responsibility of stock monitoring from a client to themselves. The scheme for scenario 1 can be seen in figure 20. Nefab will do all the stock handling by pooling the plastic trays and renting them to the customer. The client's only action is to order the material when needed in their production. The second criterion for a new solution is to reduce lead time for a client. The effect of buffer stock is that customers won't need to wait for the production as there is available material in the stock, and only time consumption is related to order management and transport.

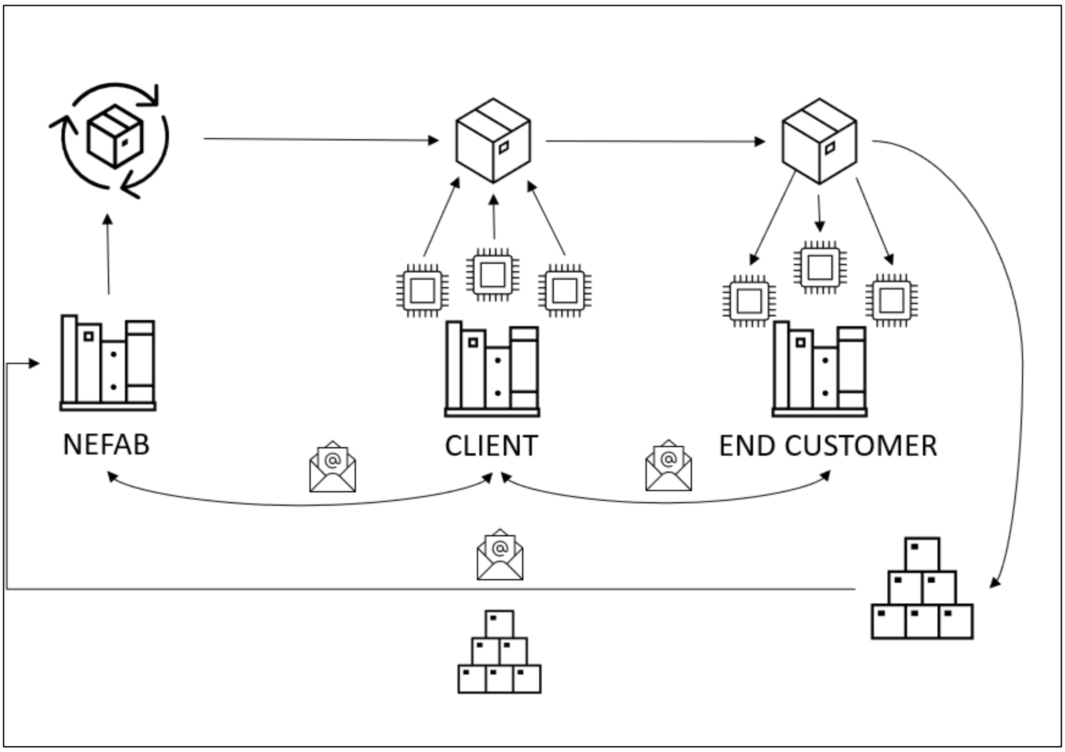

Figure 20. Visualization of scenario 1 material and information flow.
Source: Author

VMI service removes the stock monitoring need for the client. Therefore, the structure of activities has changed from the previous solution. As table 8 describes, the client's only responsibility is to issue an order when they see a need for packing material in their factory. The author estimates that the order management time for the client reduces to 0,10 days. Time consumption of order management for both parties could be further reduced by EDI (electronic data interchange). Still, as it is not part of this thesis, this improvement will not be further examined. Furthermore, the reverse transport of used trays from the end customer will be done every two weeks. This leaves a time buffer for sorting and also cleaning.

Table 8. Scenario 1 mapping

Activity no	Responsible	Description of activity	Cost change	Cost importance	Time consumption (days)
1.	Customer	Order management	Decrease	Low	0,1 (close estimation)
2.	Nefab	Order management	Same	Low	0,15 (close estimation)
3.	Nefab	Delivery	Same	Medium	1,5 (exact)
4.	Customer	Receiving and storage	Decrease	Low	5 (estimation)
5.	Customer	Usage of packing material	-	None	1 (estimation)
6.	Customer	Delivery to end customer	-	None	2 (close estimation)
7.	End customer	Receiving and usage of goods	-	None	3 (estimation)
8.	End customer	Gathering used trays	-	None	1 (estimation)
9.	Nefab	Loading and transporting used trays from end customer to Nefab Estonia	Increase (new cost)	High	2,5 (close estimation)
10.	Nefab	Cleaning, sorting and stock managing of trays (resulting in service cost). Pooling packing material.	Increase (new cost)	High	2 (close estimation)

Source: Author

For a customer, the delivery lead time is significantly reduced to three workdays than the 22 workdays offered with the existing solution. The material circulation time through the chain is 20,2 workdays.

For scenario 1, the highest cost factor is the servicing and pooling cost for Nefab, which will be transferred to the client by service price. The hypothesis by the author is that the service price is lower than the usual purchase price per piece to the client. Also, the lead time for the customer is improved as they can call in material from Nefab directly to their factory.

Finally, the author estimates that the closed-loop system and logistics have a smaller carbon footprint than producing new plastic trays for customers' new orders, with high raw material and energy costs related to the production process.

Based on this author confirms that, at first glance, scenario 1 fills the prerequisites raised. The validity of this will be confirmed with TCO calculations through TCO models and direct lead time comparison. Nefab greencalc will be used to assess the CO_2 reduction.

4.2 TCO Models

Regarding confirming the assumption regarding scenario 1 cost savings compared to scenario 0, TCO models and calculations for both methods will be done. As mentioned in the methodology, lower priority cost areas will be assessed with lower accuracy. Still, all high-cost aspects are in focus, and the author tries to evaluate them as precisely as possible. All created TCO formulas are done by the author based on the theory of TCO.

The product's price is given with incoterm FCA (*Free Carrier*), meaning that the outbound loading cost is accounted into the price, also the price includes sales mark-up. For estimated annual consumption (*EAC*) client forecasted consumption of 98 000 pieces will be used. The author deliberately did not include financial inventory costs as the client demand of return on capital employed (*ROCE*) is unknown to the author. Also, the cost from the end customer perspective was not included because the difference between disposal cost versus storage and loading cost of used material is probably close and would not significantly affect the result calculation.

4.2.1 TCO Model for Scenario 0

The first step in creating a TCO model is to map all main cost areas and their elements, done in table 9. Later these mapped cost elements are used in formula creation.

Table 9. Cost area mapping for Scenario 0

Responsible	**Description of cost area**	**Cost elements**
Customer	Stock monitoring and order management	*ORDERING COST = TIME X COST OF TIME*
Customer	The landing cost of a plastic tray	*LANDING COST = PRICE OF PRODUCT + TRANSPORT COST*
Customer	Storage cost at an external warehouse	*STORAGE COST = STOCK LEVEL X WAREHOUSE COST X TIME*

Source: Author

For scenario 0, there are three main areas of TCO. The costs related to stock monitoring and order handling. Fees for stock-keeping at external premises and finally, the most important – price of landing the plastic trays.

The TCO formula is based on cost element mapping and combines all main cost areas into one formula. For order handling and stock-keeping, the estimated annual consumption is used, and costs are taken by yearly rate and then divided by the consumption to get the customer's total cost per piece. The result of the formula will be the customer's total cost per piece.

$$\mathrm{TCOs0} \;= p + tc + \frac{\dfrac{oc \;\times\; EAC}{MOQ} + \dfrac{ASL \;\times\; wc \;\times\; d}{pq}}{EAC} \qquad (1)$$

Where

TCO_{s0} – Total cost per piece for scenario 0,

P – price per unit (*FCA*),

tc – transport cost per unit,

EAC – estimated annual consumption,

oc – ordering cost per unit,

MOQ – minimum order quantity,

ASL – average storage level,

wc – warehouse cost per pallet per day,

d – number of days in a period,

pq – number of products per pallet.

There are many ways to calculate the average stock level. Therefore author describes the logic behind it a little further. The standard MIN / MAX approach is used not to overcomplicate it. An estimated consumption per workday, lead-time of production, and average deviation from month-to-month consumption (based on sales statistics for 2018-2021) define the MIN level. The maximum level is calculated by adding the minimum manufacturing quantity from the production to the MIN level.

$$ASL = \frac{MIN + MAX}{2} = \frac{2 \times MIN + MMQ}{2} = \frac{2 \times (\frac{EAC \times LT + dq}{d}) + MMQ}{2} \quad (2)$$

Where

MIN – Minimum stock quantity,

MAX – maximum stock quantity,

MMQ – minimum manufacturing quantity,

d – days in a period,

dq – average deviation in monthly usage quantity in pieces.

Other elements of the TCO cost model are self-explanatory and do not require further insight.

4.2.2 TCO Model for Scenario 1

Similar to scenario 0, cost area mapping was simulated by the author. Results are in table 10. The main difference between cost areas is removing the product's purchase price as the service cost replaces it. Also, the customer warehousing cost was deducted as with service Nefab can provide MOQ as small as 480pc (one pallet), meaning this can be stored and client factory and usage of an external warehouse is not necessary.

Table 10. Cost area mapping for Scenario 1

Responsible	**Description of cost area**	**Cost elements**
Customer	Order management	*ORDERING COST = TIME X COST OF TIME*
Customer	The landing cost of the tray	*LANDING COST = SERVICE PRICE X TRANSPORT COST*
Nefab	Creating material pool	*POOL COST = POOL SIZE X PRODUCTION COST*
Nefab	Costs related to the service offering	*SERVICE COST = REVERSE TRANSPORT + WAREHOUSING + DIRECT LABOUR + WORK AREA COST*

Source: Author

The cost model for the closed-loop system is similar to the previous one, but the price per unit (p) is replaced by the service price per unit (SP). As stated before, with this value offer client does not need to worry about replacing broken or damaged packing materials. Instead, Nefab will do it themselves as a part of the service offer.

$$\mathrm{TCOs1} = SP + tc + \frac{\frac{oc \times EAC}{MOQ}}{EAC} \quad (3)$$

Where

TCO_{s1} – Total cost per piece for scenario 1,

SP – Service price per unit.

The most important aspect of this TCO formula is to accurately calculate the service price that comes from the cost pricing by Nefab service by taking into account the cost of reverse logistics and additional service activities like transport from the end customer, cleaning, sorting, and stock keeping. Also, Nefab estimated sales mark-up will is included in the service price as it was in price per piece.

$$SP = \left(\frac{rtc}{pq} + \frac{wc \times ps \times d}{pq \times EAC} + slc + sac + pc\right) \times MU \quad (4)$$

Where

rtc – reverse transport cost per pallet,

slc – service labor cost per piece,

sac – service area cost,

ps – pool size in pieces,

pc – pool cost adjusted with three-year depreciation per piece,

MU – sales mark-up.

For calculating the pool cost author expects that the trays will be used at least for three years, meaning that the cost will be divided by 33% per year (basically an amortization of the tray). Also, Nefab can get improved production costs for creating the pool stock through higher manufacturing quantity.

The client's yearly forecast and monthly peak usage define plastic tray pool size. Based on scenario 1, mapping the circulation time of one patch is 21,25 workdays, which is a month. Therefore to evaluate proper pool size, the consumption per month is considerable. Also, the high service level for the client is more important than optimizing costs. Therefore, maximum monthly usage will be taken as the pooling level. Table 11 highlights the logic behind assigning pool level.

Table 11. Projection of 2022 consumption based on client forecast and previous consumption.

Month	Deviation from average monthly usage	Estimated monthly usage for 2022
January	11%	9 062 pc
February	3%	8 371 pc
March	22%	9 981 pc
April	0%	8 185 pc
May	15%	9 364 pc
June	-2%	7 992 pc
July	24%	10 165 pc
August	-34%	5 407 pc
September	-8%	7 544 pc
October	13%	9 217 pc
November	-26%	6 080 pc
December	-19%	6 632 pc

Source: Author

The estimated consumption for 2022 is 98 000pc, the monthly average usage is 8166 pc, and the peak usage is projected to be 10 165pc. For extra safety, an additional 20% will be added to avoid shortages due to logistics, replacing broken trays, or providing material when clients have sudden increased needs. This gives us a pool size of 12 000pc (rounded to full pallets). Average monthly usage deviation is 1196pc, later used in average stock level calculation.

Reverse transport cost is calculated by three weeks' average usage (the reverse transport will be done every two weeks), and the cost of transportation will be taken from the current price list given by the forwarder. Therefore, a combination of reverse transport every three weeks and a pool size of 12 000pc is enough to keep customers' active stock and avoid shortages.

Service labor cost will be calculated by the estimated time endurance of unpacking the pallet of trays, cleaning and sorting them multiplied by the average price of worker hour for the company. This calculation is not entirely accurate as it needs to be tested. However, the author simulated the closest possible circumstances. One full pallet (480 pc of packing material) takes approximately 1 hour to process for two workers (including the forklift movements). The area needed for service work is small as the sorting needs only one table. Therefore, area usage is estimated to be 8m^2. Warehouse m^2 will be calculated based on the direct costs (rent, utilities, security, insurance, depreciation of warehouse installations, etc.).

4.3 TCO Calculations

TCO calculations will be made based on previously created models by the author. The inputs used in formulas are described in more detail in appendices. Some essential cost and product parameters are recapitulated below, giving a more transparent view for the following calculations:

- The optimized quantity of packaging material on a standard EUR sized (1200 x 800mm) is 480 pieces. The outer dimensions of SKU (stock keeping unit) is 1200 x 800 x 1700 mm. Therefore, SKU is non-stackable in a trailer.
- All the labor cost calculations will be conducted using the current average monthly gross wage of 1548 EUR (Average monthly gross wages and salaries). They result in a total cost for a company to be 2071 EUR (tax-free income marked as 306 EUR). Worker active work hours are estimated to be 168 H/month. Therefore hour cost for the company is 12,32 EUR/h,
- The client forecasted an annual need of 98 000 pieces would is used as a yearly consumption,
- All prices and costs for transportation, packing material, Nefab warehouse, etc. are by the day of 01.04.2022,
- Both customer and Nefab warehouse costs will be 0,27 EUR/m^2 per day, including the rental fee, utilities, and amortization of machinery.

Some cost elements are described below the calculations to ease the understanding of calculations and remove the need to scroll between appendices.

4.3.1 TCO for Scenario 0

The minimum manufacturing quantity is 2400 pieces for calculating the average storage level. The lead time for a client is 22 workdays. It is resulting in an ASL of 7110 details for the client.

$$ASL = \frac{2 \times (\frac{98\,000 \times\ 22 + 1196}{365}) +\ 2400}{2} = 7110$$

The current price level of one packaging material is 1,45 EUR, incoterms FCA (free carrier), Nefab sales mark-up is included in the price. The transportation cost per unit is according to the current Nefab domestic freight agreement - the average cost of one pallet transportation to the client is 38 EUR, and the quantity on a pallet is 480pc, making the cost per piece 0,14 EUR. Order handling cost is calculated by how many purchase orders there are annualy. The amount of purchase orders is multiplied by the workhour consumption and cost. More detailed overview of aspects of TCO calculation for scenario 0 can be seen in appendix 1.

$$\mathrm{TCOs0} = 1{,}45 + 0{,}14 + \frac{\frac{0{,}20\ \times 12{,}32\ \times\ \ 98\,000}{2400} + \frac{7110\ \times\ 0{,}27\ \times\ 365}{480}}{98\,000} =$$

$$1{,}45 + 0{,}14 + \frac{1006 +\ 1459}{98\,000} = 1{,}45 + 0{,}14 + 0{,}03 = 1{,}56$$

The TCO for scenario 0 is 1,56 EUR/pc based on the calculation. Figure 21 highlights the distribution of main costs. Order handling and storage costs for the client per piece are almost obsolete as the additional extra cost is 0,03 EUR/pc. It also means that the order handling and warehouse costs accuracy don't need to be improved, and they do not affect the TCO result to a great degree.

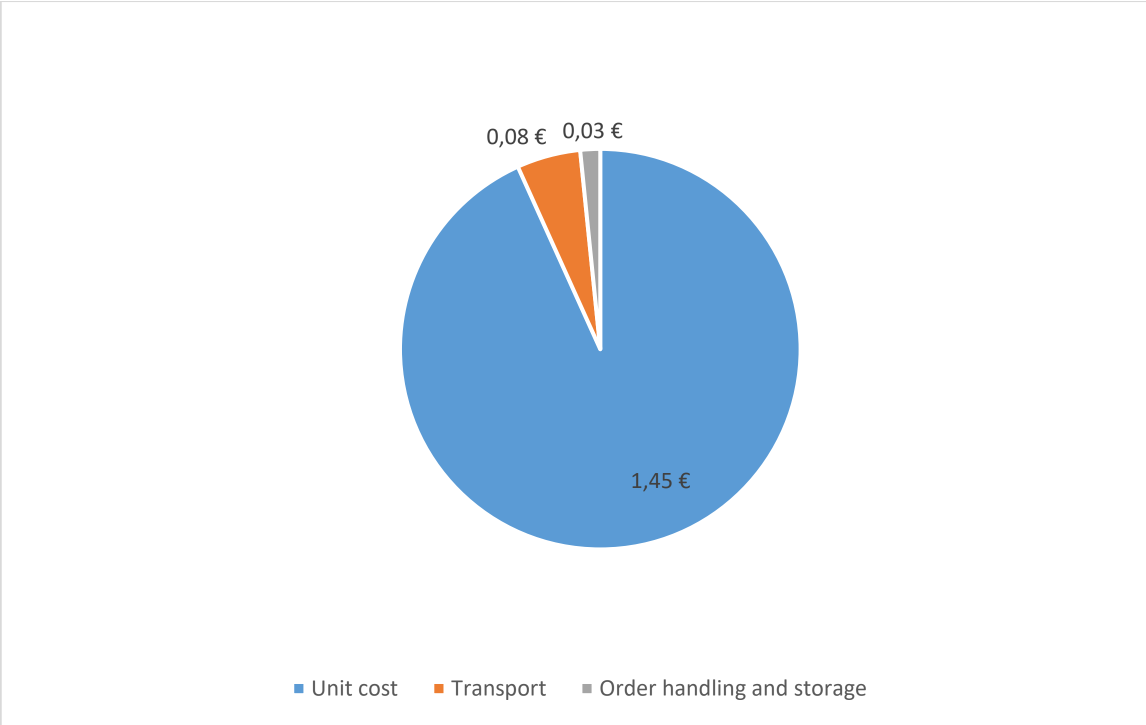

Figure 21. TCO distribution for scenario 0.
Source: Author

The author believes that the TCO for the scenario is accurate for comparison, and no alternations are needed. The most important aspect is the unit cost, and reducing that with the following methods is the key.

4.3.2 TCO for Scenario 1

The most critical aspect of closed-loop total cost evaluation is to accurately calculate the cost for Nefab to provide the service as it needs to be commercially sustainable for them.

The reverse transport cost of one SKU from the end customer is 72 EUR/pallet. Service labor cost is 0,05 EUR/pc as one worker can effectively sort and clean 480 pieces in one hour (including movements with a forklift). For the service area, the cost for 8m^2 is 0,27 EUR/m^2 per day, resulting in 0,01 EUR/pc. For calculating the pooling cost, its base is the pool size of 12 000pc. It is estimated by the author that ca. 20% of the pool needs to be replaced by Nefab during the year due to damages. It is resulting in a real production demand of 14 400pc per year. The production price of one plastic tray is 0,92EUR. This sum related to creating a pooling buffer is divided by the annual consumption of 98 000pc, resulting in a cost of 0,13EUR/pc. For Nefab sales mark-up, it is estimated to be around 30%. More detailed overview of aspects of TCO calculation for scenario 1 can be seen in appendix 2

$$SP = \left(\frac{72}{480} + \frac{0{,}27\ \times 12\,000 \times 365}{480 \times 98\,000} + 0{,}05 + 0{,}01 + 0{,}135\right) \times 1{,}3 =$$
$$(0{,}15 + 0{,}03 + 0{,}05 + 0{,}01 + 0{,}135) \times 1{,}3 = 0{,}38 \times 1{,}3 = 0{,}49$$

Based on the calculation, the service cost is 0,49 EUR/pc. The cost breakdown of the service can be seen in Figure 22.

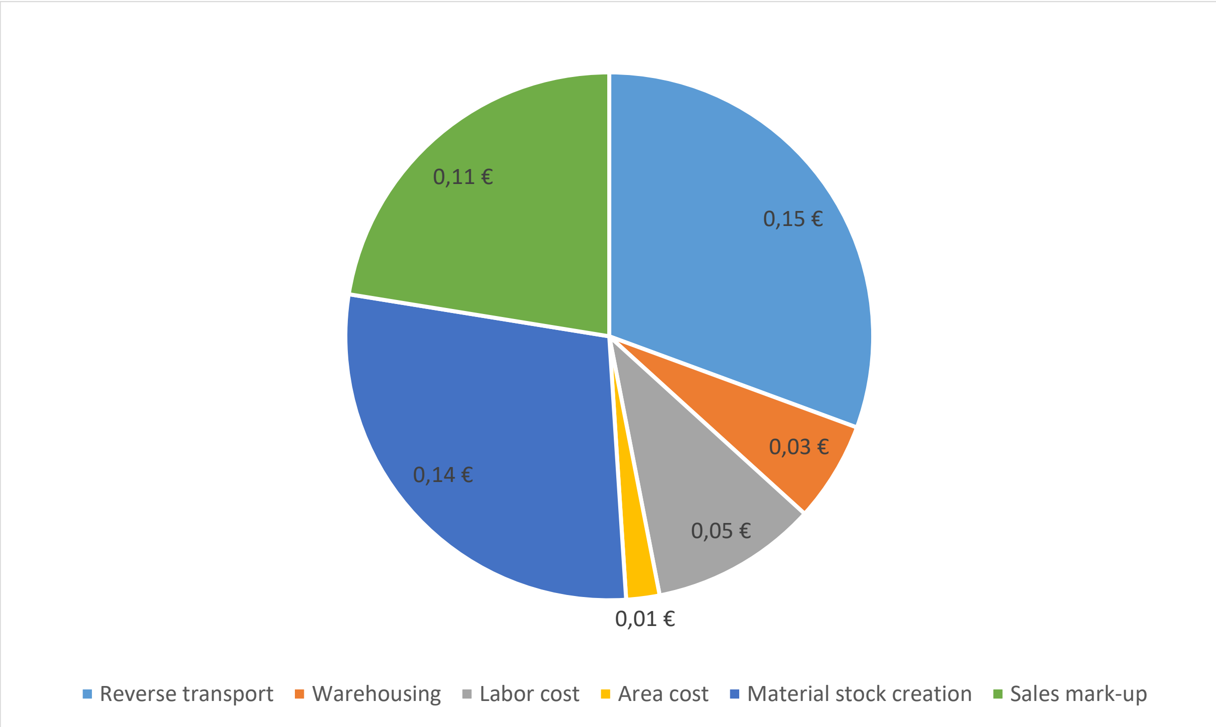

Figure 22. Service cost breakdown
Source: Author

Again, the most significant contribution comes from the investment in manufacturing plastic trays, reverse transport costs from end customer premises, and sales margin. The evaluation of these costs is pretty accurate. The author acknowledges that he may have underestimated the time cost of tray sorting, but it won't significantly affect the overall cost.

For scenario 1 TCO, the most significant change from a cost perspective is replacing the purchase with a service price. Also, as Nefab can provide smaller SKUs, customer don't need to keep stock at the external premise and consume packaging material directly at their factory.

$$TCOs1 = 0{,}49 + 0{,}08 + \frac{\frac{0{,}10 \times 12{,}32 \times 98\,000}{480}}{98\,000} =$$

$$0{,}49 + 0{,}08 + 0{,}01 = 0{,}57$$

Based on the calculation, the TCO for scenario 1 is 0,57 EUR/pc. The distribution of TCO in scenario 1 is highlighted in Figure 23.

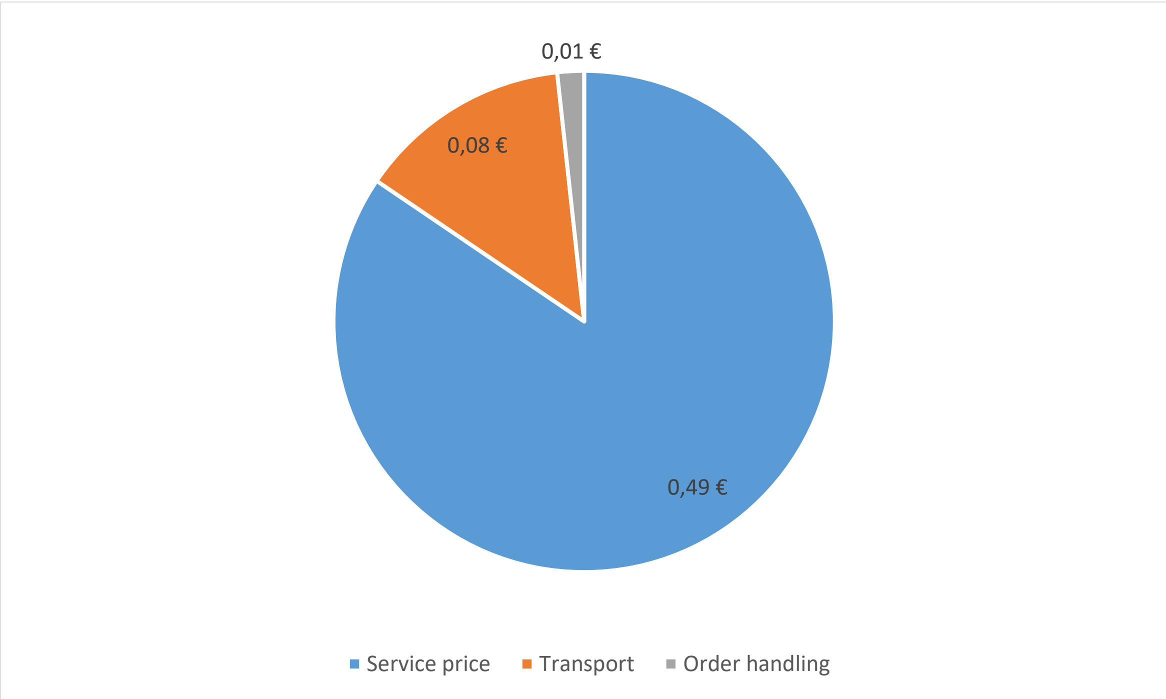

Figure 23. Cost distribution of TCO for scenario 1
Source: Author

The main cost area for scenario 1 is the service price. It's understandable as all the costs related to offering the service are concentrated there.

4.4 Analyse and Recommendations

4.4.1 Analyse

In this chapter, the author compares created scenarios to conclude if the prerequisites raised at the beginning of the thesis are completed. With developed methods, it was aimed to lower TCO, shorten lead time, and reduce carbon footprint within supply chain.

TCO for the scenario 0 is 1,56 EUR/pc and for scenario 1 is 0,57 EUR/pc. Resulting in a significant cost reduction of 63%. Figure 24 highlights the cost-saving in 2022 for forecasted consumption and the consumption done in 2018-2021.

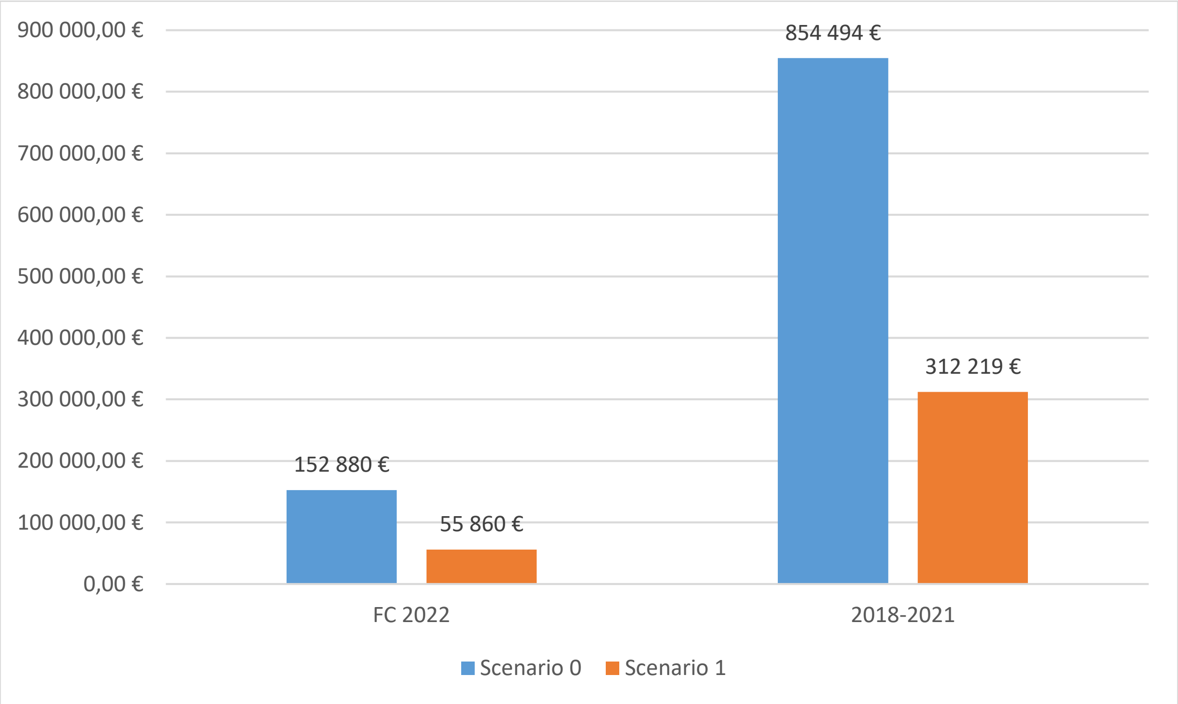

Figure 24. Cost comparison between scenarios
Source: Author

Based on the 2022 forecasted consumption of 98 000pc, the annual saving with scenario 1 is 97 020 EUR. Additionally, the theoretical saving using consumption history from 2018 to 2021 would be 542 275 EUR. Therefore, it is confirmed that scenario 1 reduces TCO for a client.

For lead-time evaluation, both scenarios are compared in table 12, from when the client triggers the need by issuing a purchase order to receiving packaging material. Again, lead time is taken only from the customer's perspective (the end customer is irrelevant).

Table 12. Lead time to customer comparison

Activity no	Activity for scenario 0	Time (workdays)	Activity for scenario 1	Time (workdays)
1.	Customer monitors stock issues purchase order	0,20	Customer issues purchase order	0,10
2.	Order management by Nefab	0,15	Order management by Nefab	0,15
3.	Nefab production	20	Delivery by Nefab	1,5
4.	Delivery by Nefab	2	-	
Total		22,35		1,75

Source: Author

The difference in Nefab delivery time for both the scenarios comes from the difference in flow – in scenario 0, the goods need to be transported from production to the logistic center. Still, in scenario 1, the goods are already kept in buffer stock. Overall the difference in lead time is 20,6 workdays in favor of scenario 1. The reduction is from 22,35 workdays to 1,75 workdays as seen from figure 25.

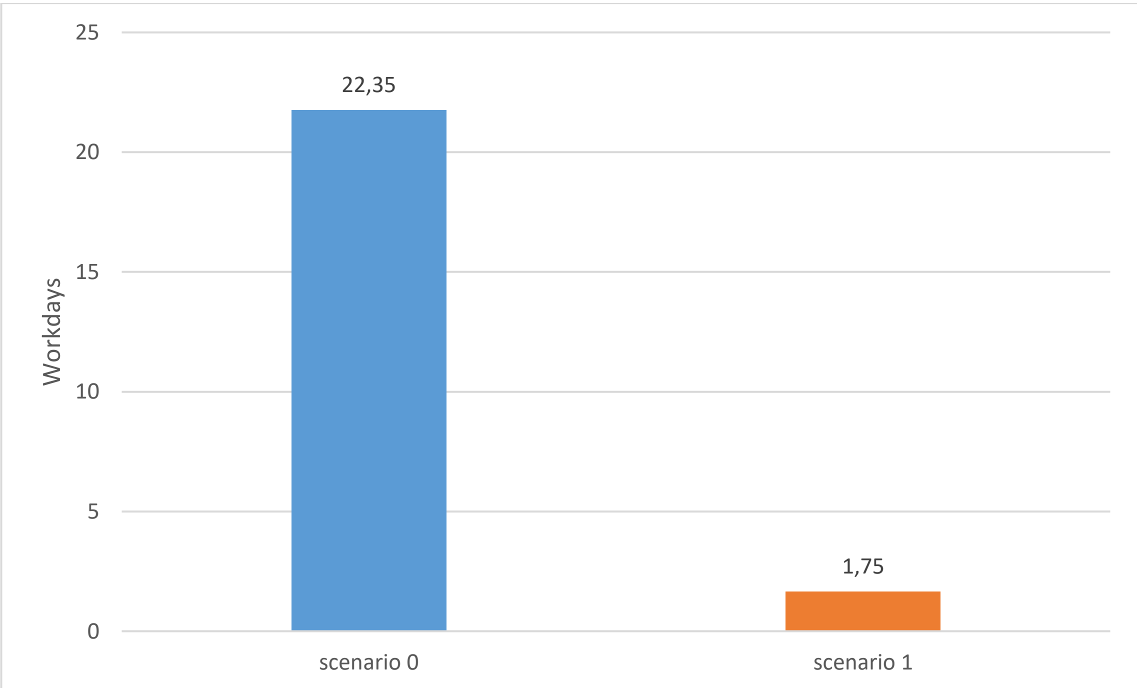

Figure 25. Lead time comparison between scenarios

Source: Author

For carbon footprint assessment, Nefab patented software Greencalc will be used. The overall logic of the software is to take into account all the aspects of the product life cycle. Figure 26 shows the input data used for automatic calculation. For comparing scenarios 0 and 1, the software uses the supply chain data, material, the weight of the product, and annual usage. In addition, for scenario 1, the reverse flow is included.

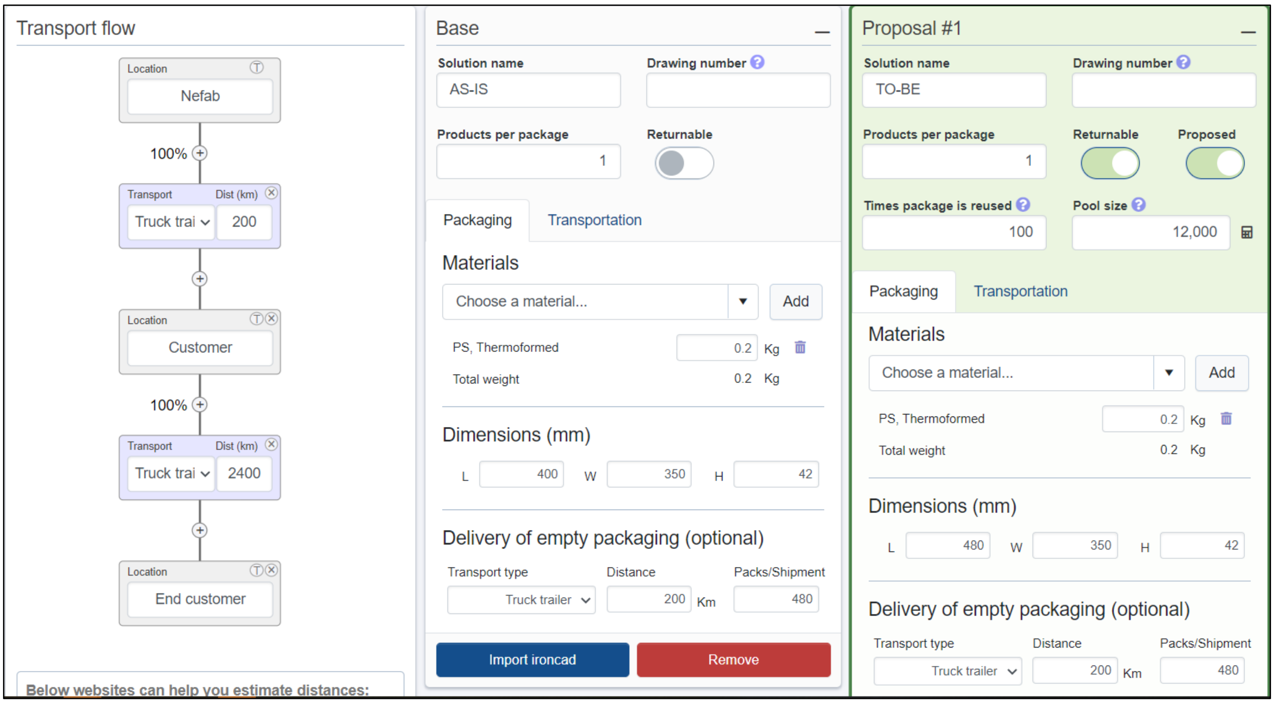

Figure 26. Greencalc input data

Source: Author

Based on inserted data by the author Greencalc gives a 14% annual saving on CO_2 footprint, better imaginable by deduction nine passenger cars from traffic for a year. Figure 27 highlights the aspects included in the calculation.

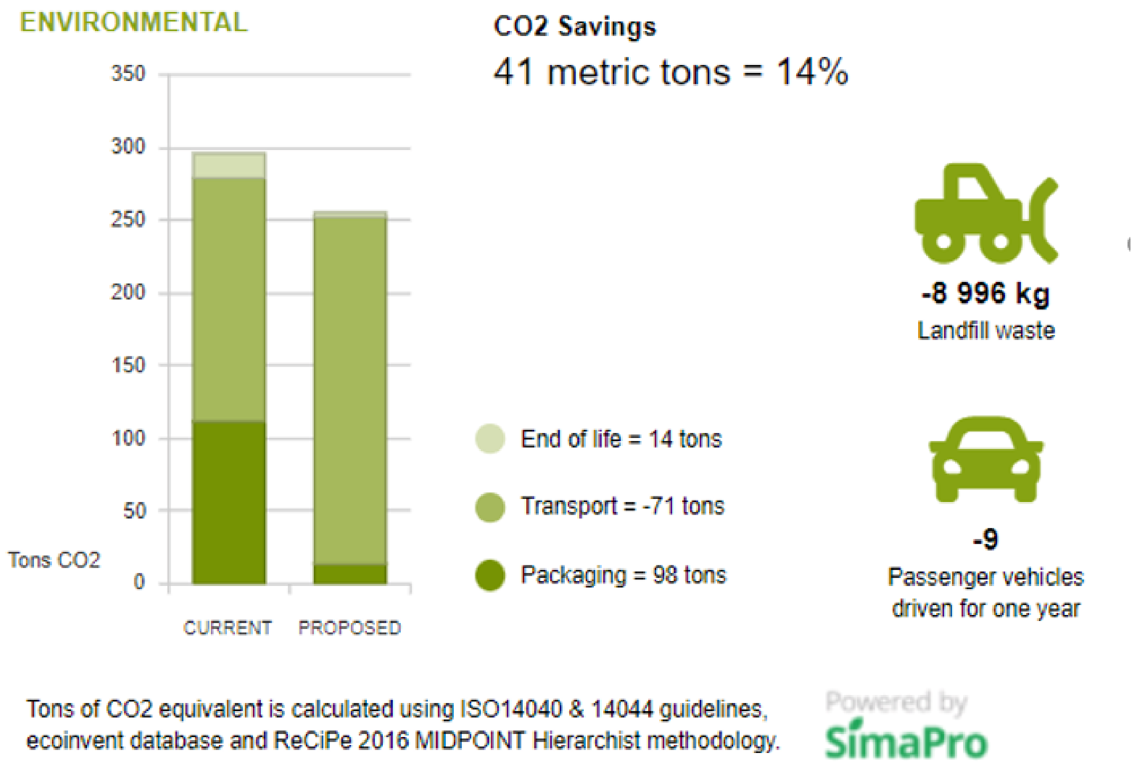

Figure 27. Greencalc calculation result (annual saving)
Source: Author

The main saving comes from the decreased amount of reproduction needed by using the same trays again. Of course, reverse freight from end-customers doubles the transport footprint, but scenario 1 still shows an annual reduction when all aspects are included.

With this knowledge, an author can confirm that scenario 1 completed all prerequisites, as highlighted in table 13.

Table 13. Scenario result comparison

Area	Scenario 0	Scenario 1	Difference
TCO of tray per piece	1,56 EUR	0,57 EUR	0,99 EUR
Annual TCO for trays	152 880 EUR	55 860 EUR	97 020 EUR
Lead time to customer	22,35 workdays	1,75 workdays	20,60 workdays
Carbon footprint	298 t CO_2	257 t CO_2	41 t CO_2

Source: Author

A system based on a closed-loop packaging material flow, combined with VMI service, will save overall cost and shorten the lead time. In the meantime, the CO_2 footprint is reduced within the supply chain. The annual saving for a customer is 97 020 EUR. Furthermore, lead time is decreased from 22,35 workdays to just 1,75 days. A closed-loop solution eases the customer's day-to-day work as an additional value. They don't have to worry about one packaging material group and can use their time and focus on other subjects. Buffer stock also minimizes the risk of packaging material shortage. It is also worth mentioning that none of the viewed areas had a counter effect on each other.

4.4.2 Recommendations

The results of TCO calculations prove that the low usage of closed-loop solutions in packaging material flow are unjustified. For example, in the frame of this thesis the change from one-way flow to closed-loop solutions saves customer ca 97 000 EUR annualy – a significant cost reduction which definitely has a impact on client bottom line. With this in mind, either the supply chain managers, factory managers or warehouse managers, whoever are responsible for packing materials should take the time and think about how they pack their products and where they send them to see if there is a potential for improved solution. Of course there are materials which cannot be reused, for example corrugated boxes, but then the thought should go in the direction of changing the material and use something reusable. Second most common obstacle is the the distance between arrival and shipping point, but again there are ways to consolidate the freights or use packing materials that use less space (like nestable trays). There are several ways to reduce costs on packing materials and the effect should not be underestimated in todays competitive business environment, where every advantage is used to increase competitiveness.

In a supplier perspective, who see themselves as an experts in packaging material or supply-chain service area should be more proactive to offer more complex solutions to its customers. They should be hungry to gather viable data that customers are willing to share regards their supply chains and build fact based business cases to reduce their TCO-s. In some cases it may lower supplier revenue (for example if sold materials get reused instead of selling news items again) but if done right the the porfitably should diminish. Overall this kind of proactiveness and desire to improve supply-chains create mutual value and trust which serves higher value in the future. Regards the value creation sustainability and CO_2 fooprint reduction should be a aim for both parties and in the opinion of the author should be prioritized over monetized values.

Nefab should emphasize the importance of gathering valuable data from their key customers regards their outbound supply chains, to see how they use the packaging material. In order to get the best possible insight Nefab sales team has to explain to clients that we are more than just packaging material provider and our ambition is to save costs for them. The results of this thesis should be used both internally and externally. Internally as a study material how the metholodgy of creating an improved solution should look like and to enhance self belief that we have the opportunity to make important alternations for our customers. Externally as a viable business case to present for a customer upon which this thesis was written. Also this solution can be added to our service portfolio reference case and showcased to other clients.

SUMMARY

A closed-loop supply chain with integrated VMI services can effectively reduce costs and improve customer lead time when designed correctly, and the background suits this kind of solution. As an additional value, VMI service enhances the ease of everyday work for the client as they can turn their focus on other subjects. Also, with a buffer stock, the risk of having a packaging material shortage is minimized. Unfortunately, these solutions are not widely used despite these possible advantages that can create a competitive advantage for the companies. Enterprise's low motivation to implement these solutions can be due to the estimation that the saving is too low, as the packaging material cost is minor related to the product itself. Or companies are not experienced enough to design these solutions. In the latter, they need the help of their logistical partners, who create these for themselves. Therefore partners need to have a proactive attitude regards this and see it as a way to enhance their competitiveness.

This thesis aimed to evaluate the effect of a closed-loop chain with a pooling system managed by Nefab, changing the current one-way flow of packaging material for a customer. The author raised three main targets to assess this. First, that new solution needs to reduce the total cost of ownership for a customer. Second, lead time needs to be reduced, and third overall CO_2 has to be lower than with the current solution. Cost and lead time objectives will be assessed through the calculations done by the author. For carbon footprint evaluation, Nefab software will be used. The CO_2 calculations may be a subject of future research for the author.

TCO models and formulas were created to compare the costs and lead time between the existing and proposed solutions. The author tried to involve all main cost areas essential to a customer. The CO_2 saving was measured by Greencalc software. Overall the results were the following:

- TCO per piece dropped from 1,56 EUR/pc to 0,57 EUR/pc. Creating an annual saving worth 97 020 EUR if implemented,
- The lead time will shorten by 20,6 workdays, from 22 workdays to 1,75,
- CO_2 was reduced from 298 t to 257 t, equivalent to removing nine passenger cars from the traffic for a year.

VMI service includes buffer stock kept on Nefab premises. Active buffer stock eliminates the time consumption of production, which had the most considerable effect on the current lead time. Furthermore, shortened lead time with reduced MOQ level

significantly enhances the flexibility of the supply chain, for example, the client won't need to keep additional stock and can order packaging material directly to their factory. In today's world, sustainability is becoming more critical – the reason why the author wanted to add the CO2 footprint comparison into the thesis. Since the packaging material is reused with a closed-loop system, the need to reproduce declines significantly and compensates for the reverse transport effect.

It is also worth mentioning that none of the viewed areas had a counter effect on each other. This made the overall assessment easy for the author. It would have been more difficult when the calculations would have shown a reduction in TCO but an increase in CO_2 footprint. The customer's vision and ethics would play a part in the decision in these circumstances, an intriguing subject for future research to determine how the scale tip.

From Nefab's point of view, the results of this thesis are encouraging as the author did not expect such a significant TCO reduction from a closed-loop solution as the calculations showed. Nefab will use the thesis results to further empathize with the importance of knowing your customer supply-chain and building more complex service solutions based on that. Account managers of the Nefab sales team need to acknowledge a better understanding of how the packaging material flows after it's delivered to their customer. This is the cornerstone for approaching clients proactively and proposing solutions that create shared value. The overall aim to grow in the logistic service market will continue in Nefab sales strategy.

The author highlights the following ideas for possible future research: the in-depth understanding of methodology, models, and formulas for CO2 calculations within the supply chain and how the solution would be assessed from the customer's point of view when indicators are opposite (for example TCO is reduced, but CO_2 footprint increases), as it creates a complicated dilemma, especially in today's market.

KOKKUVÕTE

PAKKEMATERJALI VOOG SULETUD AHELAS

Enri Leht

Me elame kiiresti muutuvas maailmas, mis on suuresti teadmatuses lähituleviku suhtes. Pandeemia, Euroopas aset leidev sõda ja sellega kaasnevad sanktsioonid, kliimamuutused ja teised tegurid loovad väga volatiilse keskkonna milles ettevõtted peavad kohanema. Selle tausal muutub aina olulisemaks kulude kokkuhoid ja selleks uute viiside leidmine. Üheks selliseks valdkonnaks on pakkematerjalidega seonduvad kulud. Selleks pole mitte ainult pakkematerjali nn. tüki hind, vaid vaadelda tuleks mõju tervele tarneahelale. Pakkematerjalil on oluline mõju terves ahelas, sest see kaitseb toodangut, mõjutab ruumi kasutust transpordivahendis ning ladudes. Töö autor saab oma olemasoleva töö kogemuse põhjal väita, et kahetsusväärselt paljud ettevõtted ei mõtle oma toote pakendamisele ja pakendi optimeerimisele piisavalt. Eelnev seisukoht seletab miks meil on vähe näited pakkematerjalide taaskasutamisest (mitte taaskäitlemine), sest selle mõju alahinnatakse ja/või ei osata pakendiringluslahendusi edukalt projekteeida ning ellu viia.

Sellepärast on oluline tarnijate ja teenuspakkujate proaktiivne suhtumine ja oma klientidele leidlike lahenduste pakkumine. Keerulistes tingimustes nagu tänapäeval tõusevad tarnijate hulgast esile partnerid, keda saab usaldada ning kes aitavad kaasa sinu kasvule. Nagu eelnevalt mainitud, siis kliendid ei pruugi mõelda aspektidele mis pole tihedalt seotud nende põhitegevusega, enamasti on selleks ka pakendamine ja pakkematerjalid. Nefab, kes on ajalooliselt olnud pigem pakkelahenduste pakkuja on just seetõttu muutnud oma strateegiat ja proovib oma klientidele pakkuda tarneahela optimeerimist läbi oma pakkelahenduste ja tarneahelateenuste. Nefabi eesmärgiks on läbi oma lahenduste vähendada klientide kulusid tarneahelas, tõstes seeläbi nii oma klientide, kui endi konkurentsivõimet turul. Mudel millest võidavad mõlemad osapooled.

Antud töö eesmärk on hinnata kuidas suletud ahelas toimuv pakkematerjali ringlus säästab kliendile kogukulusid. Eesmärgi saavutamiseks kasutab autor stsenaariumianalüüsi. Selleks kaardistab autor hetkel toimivat lahendust ning pakub sellele alternatiivi, mis täidab autori poolt püstitatud eesmärgid: säästab kliendile kogukulusid, lühendab tarneaega ja vähendab tarneahela lõikes CO_2 jalajälge. Autor analüüsib tulemusi luues stsenaariumitele kogukulu arvutamiseks vastavad valemid ja leides läbi arvutuse kogukulu ühe ühiku kohta. Tarneaja võrdlemiseks kaardistab autor mõlema lahenduse puhul info- ja materjalivoo alates kliendi tellimusest kuni kauba saabumiseni kliendi lattu. Süsiniku jalajälje võrdlemiseks kasutab autor Nefabi tarkvara Greencalc. Nefab kasutab uurimuse käigus saadavat teavet ja kogemust, et edendada enda tegevusi logistikalahenduste pakkumisel. Olenevalt tulemusest võib sellel olla oluline roll müügistrateegia parendamisel.

Uuritavaks tarneahelaks on klassikaline ühesuunaline tarneahel kliendi ja tarnija vahel, millest klient tellib Nefabilt pakkimiseks vajaliku pakkematerjali. Pakkematerjal ise on vormitud vahtplast, mida kasutatakse peamiselt elektrooniliste seadmete pakendamiseks. Pakkematerjali on oma disaini tõttu säästlik transportida ja autori hinnangul on pakendit võimalik korrektselt käideldes taaskasutada kuni 100-korda. Tarneahela lõpus olev lõppklient, kes hetkel pakkematerjali peale kasutamist ära viskab, asub mõistlikus kauguses, et pakendi tagasitoomine poleks liialt kulukas. Autori hinnangul on vaadeldav tarneahel ja pakkematerjal sobilik ringeldamiseks ja analüüsi teostamine mõistlik.

Esmalt analüüsis autor hetke olukorda kaardistades stsenaarium 0 lülid, tegevused ja kuluallikad selles. Kuluallikad kaardistati selle eeldatava olulisuse järgi kogukulus, kõige kriitilisemaks hindas autor pakkematerjali ostuhinda. Sellest tuleneb alternatiivse lahenduse, stsenaarium 1, loogika asendada klassikaline pakkematerjali ostmine kliendi jaoks selle rentimisega Nefabilt. Selle käigus võtab Nefab kogu vastutuse pakkematerjali laomajanduse eest endile ja kliendile jääb ainult tellimuse esitamise vaev. Nefab ise alustab pakkematerjali tagasitoomist lõpptarnijalt, et seda taaskasutamiseks ettevalmistada. Sarnaselt eelnevale kaardistas autor pakutava lahenduse kuluallikad. Peale mõlema stsenaariumi kuluallikate kaardistamist loodi neile kogukulu arvutamiseks universaalsed valemid, mis proovisid endis kätkeda kõiki olulisemad kuluallikaid nagu materjali ostmine, transport, laokulud, tööjõukulud jne. Lisaks kaardistati mõlema lahenduse materjalivood, mille põhjal saab analüüsida tarneaegu.

Autor teostas peale arvutuste teostamist analüüsi, et näha kas pakkematerjali ringlusel põhinev tarneahel täidab eelnevalt püstitatud eesmärgid. Esmalt kogukulu kliendile – olemasoleva lahendusega on kliendile ühe vormitud vahtplast pehmenduse hind 1,56 eurot, mis teeb aastaseks tarbimiskuluks 152 880 eurot. Pakendi rentimise korral oleks kliendile kogukulu aga 0,57 eurot, mis tähendab rahalist säästu aastas 97 020 euro ulatuses. Teiseks oli vaatluse all kliendile pakutav tarneaeg, teenuslahendusega vähenes see 20,6 tööpäeva võrra - 22 päevalt 1,75 päevale. Süsiniku jalajälje võrdluse puhul usaldab autor Greencalc tarkvara poolt tehtud arvutusi, kuid kuna autoril puudub selle tõestamiseks teave, siis on see kirjeldatud kui lisainformatsioon. Ometigi näitasid

Greencalc arvutused, et materjali taaskäitlemisel väheneb aastane CO_2 jalagajälg 41 tonni võrra, mis on võrdne üheksa sõiduauto liiklusest kõrvaldamisega üheks aastaks. Kokkuvõttes täitis stsenaarium 1 kõik autori püstitatud eesmärgid. Autor usub, et tänu Nefabi pakutavale lahendusele paraneb mõlema ettevõtte konkurentsivõime – klient säästab kulusid ja tänu sellele parandab oma kasumlikust. Teenuslahendus pakub lisaks rahalisele säästule suuremat paindlikust läbi lühema tarneaja ja tänu puhverlaole on väiksem oht, et kliendi tarned jäävad hilinemisse pakkematerjali puudumise tõttu. Nefab saab aga antud uurimusest enda portfelli juurde eduka eduloo teenuste valdkonnas. See tõstab esile, kui oluline on omada teadmist kliendi tarneahela kohta, sest see tagab võimaluse näha viise selle parendamiseks.

Autor sai töö käigus kaks teemat, millele võib tuleviku uurimuste käigus tähelepanu pöörata. Esiteks millisel loogikal põhineb CO_2 arvutuste ja võrdluste tegemine, näiteks milliste teguritega Nefabi enda Greencalc tarkvara arvestab tulemuste saamisel. Teiseks, juhul kui antud stsenaariumianalüüsi käigus oleks ülesse kerkinud vastandlikud tulemused. Näiteks, kui loodud lahendus oleks küll olemasolevaga võrreldes kliendile raha säästnud, kuid oleks suurendanud seda tehes CO_2 jalajälge, siis kuidas seda hinnata. Kas mõni tegur on teistest olulisem, kui jah, siis millise piirini?

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APPENDICES

Appendix 1. Cost elements with description for scenario 0. TCO calculation

Description	Value	Comment	Accuracy level
Annual plastic tray consumption	98 000 pc	Based on customer forecast	Estimation
Lead time of plastic tray production	22 workdays	Based on trade agreement. Used to calculate average stock level.	Exact
Average deviation in monthly usage	1196 pc	Based on a client forecast and projected monthly usage. Calculation was done with excel average deviation formula	Close estimation
Packaging quantity of trays on EUR pallet on a pallet	480 pc	Based on packing instruction (figure 16). Needed to calculate transportation and warehousing costs	Exact
Cost of workforce (labor cost)	12,32 EUR/h	Based on Estonian average gross wage of 1548 EUR/month and 168 H/month. Used to calculate cost for order handling	Estimation
Days in year	365 days	Based on calendar. Used to calculate warehouse and order handling cost	Exact
Transportation cost Nefab to customer	38 EUR/pallet	Based on agreed pricelist. Used to calculate transporation cost	Exact
Minimal manufacturing quantity	2400 pc	Based on trade agreement. Quantity is fixed to keep promised price	Exact
Sales price of plastic tray	1,45 EUR/pc	Based on trade agreement. FCA incoterms	Exact
Time consumption of stock monitoring and order releasement	0,20 workday	Based on customer feedback. Used to calculate cost for order handling	Estimation
Warehouse cost for a day	0,25 EUR/m^2	Based on Nefab warehouse cost (appendix 2.) Used to calculate customer warehouse cost	Estimation

Appendix 2. Cost elements with description for scenario 1. TCO calculation

Description	Value	Comment	Accuracy level
Time consumption of cleaning and sorting one pallet of trays	1 h/pallet	Based on author esimation that on worker can clean and sort one full pallet of trays in one hour. Used for labor cost in service cost	Estimation
Transportation cost end customer to Nefab	72 EUR/pallet	Based on agreed pricelist. Used to calculate transporation cost	Exact
Warehouse cost for a day	0,27 EUR/m^2	Based on Nefab warehouse costs: rent + utilities + leasing + amortization divided by the warehouse square meters. Used to calculate the service area and warehousing costs in service price	Exact
Production price of a tray	0,92 EUR/pc	Based on production calculations. Used to calculate the cost of creating pooling material.	Exact
Cost of workforce (labor cost)	12,32 EUR/h	Based on Estonian average gross wage of 1548 EUR/month and 168 H/month. Used to calculate cost for order handling	Estimation
Work area needed to provid the service	8 m^2	Based on a measurement of one long table and area needed for movement. Used to calculate the cost of workarea.	Estimation
Pool size	12 000 pc	Based on a projected peak monthly usage with additional 20% for safety	Close estimation