RESTRUCTING SPARE PARTS SUPPLY CHAIN IN NORTH EUROPE

Lappeenranta–Lahti University of Technology LUT

Industrial Engineering and Management, Master's thesis

2024

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Examiner: Docent Petri Niemi

ABSTRACT

Lappeenranta–Lahti University of Technology LUT

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Restructuring spare parts supply chain in North Europe

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54 pages, 21 figures and 14 tables

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Keywords: supply chain, spare parts, centralizing, decentralizing

This thesis was made for a group of companies operating in the machinery trade in seven countries in North Europe. The thesis was about optimizing the spare parts inventory and supply chain for one machine brand to maximize profits without having a negative impact on the customer experience.

The main objective was to investigate whether it makes sense to centralize or decentralize spare parts storage. Centralization tends to reduce procurement costs but increases transport costs. With decentralization, spare parts are physically closer to the customer, but delivery times do not necessarily differ whether the parts are in a closer warehouse or in the central warehouse of the whole group.

The literature review looked at what has been previously found when studying centralization or decentralization. The different options were modeled by calculating the profit of the group's spare parts sales by modeling the actual sales figures of 2022 in all seven countries. The principle of the modeling was to compare the current model of three central warehouses to both the 100% centralization in one warehouse and the centralization of slow-moving spare parts only.

Both the literature review and the modeling with real figures suggest that, at group level, slow-moving spare parts should be centralized in one warehouse, while fast-moving parts should be decentralized close to the customer. Another point to consider is that the IT-systems of the different countries should have visibility to all warehouses, and the IT-systems should support the common inventory management of the whole group.

TIIVISTELMÄ

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Tämä opinnäytetyö tehtiin konekaupan alalla seitsemässä Pohjois-Euroopan maassa toimivalle yritysryhmälle. Opinnäytetyön aiheena oli yhden konemerkin varaosavarastoinnin ja toimitusketjun optimointi tuloksen maksimoimiseksi ilman, että se vaikuttaa negatiivisesti asiakaskokemukseen.

Päätavoitteena oli tutkia, onko järkevää keskittää vai hajauttaa varaosavarastointia. Keskittämisellä on taipumus vähentää hankintakustannuksia, mutta lisätä kuljetus-kustannuksia. Hajautetussa mallissa varaosat ovat fyysisesti lähempänä asiakasta, mutta toimitusajat eivät välttämättä eroa siitä, ovatko varaosat lähempänä sijaitsevassa paikallisessa keskusvarastossa vai koko konsernin keskusvarastossa.

Kirjallisuuskatsauksessa tarkasteltiin keskittämisen ja hajauttamisen aikaisemmat havainnot. Eri vaihtoehtoja mallinnettiin laskemalla koko yritysryhmän varaosamyynnin voitto mallintamalla vuoden 2022 todelliset myyntiluvut kaikissa seitsemässä maassa. Mallinnuksen periaatteena oli verrata nykyistä kolmen keskusvaraston mallia sekä 100-prosenttiseen keskittämiseen yhteen varastoon että vain hitaasti liikkuvien varaosien keskittämiseen.

Sekä kirjallisuuskatsaus että mallinnus todellisilla luvuilla viittaavat siihen, että hitaasti liikkuvat varaosat tulisi keskittää yhteen keskusvarastoon, kun taas nopeasti liikkuvat varaosat olisi hajautettava lähelle asiakasta. Toinen huomioon otettava seikka on se, että eri maiden tietojärjestelmillä olisi oltava näkyvyys kaikkiin varastoihin ja tietojärjestelmien olisi tuettava koko konsernin yhteistä varastonhallintaa.

PREFACE

A Master's degree from university of technology was already on my mind when I graduated with a bachelor's degree more than 24 years ago, and I decided to realize this dream before my 50th birthday.

Studying *industrial engineering and management* was rewarding and interesting. Again, I learned a lot of things that I can use directly in my work. It was great that I could also do my thesis in my own workplace and as the work progressed, I got to know more about the sister companies in different countries.

I would like to thank my employer, my company mentor Christen and my university examiner Petri. And a special thanks to Minna, who "kicked me" to get the job done.

One piece of advice for other graduates: a divorce while writing your thesis is not a good idea. The thesis took much longer than I had planned, but now –tired and happy – the big work is done.

Turku, 14.10.2024

Tommi Salento

SYMBOLS AND ABBREVIATIONS

Greek characters

σ	Standard deviation
σ_D	Standard deviation of demand during lead time

Dimensionless quantities

CLS	Desired cycle service level
CV	Coefficient of Variation
D	Average
L	Lead time
n_1	Number of existing warehouses
n_2	Number of future warehouses
Q	Lot size
X_1	Existing inventory
X_2	Future inventory

Abbreviations

AI	Artificial intelligence
CW	Central warehouse
D365	Microsoft Dynamics 365
EDI	Electronic data interchange
ERP	Enterprise Resource Planning

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1 Introduction

On average, companies spend 60-80% of their total cost on material purchases, which has a major impact on their profitability and performance. (Iloranta et al. 2012, 21-23)

Generally speaking, centralizing reduces inventory levels and improves availability. On the other hand, reducing the number of warehouses increases freight costs, because of longer transport distances and smaller packages. Economic results of centralization vary widely between business types. (Milewski et al. 2022, 3-4.)

Although the turnover of spare parts is typically quite small compared to the turnover of machinery sales, spare parts typically make up a significant part of the total operating margin.

Based on these factors, the topic of this thesis is very important and relevant to the group company.

1.1 Background

This case concerns the spare part business of a multinational group company with operations in four Nordic and three Baltic countries. Each company in the group operates as a separate limited company, but the owner is 100% the same.

The group's strategy is to be the market leader and the preferred option for customers, and to achieve this position, the after-sales and spare parts service must be at a high level. On the other hand, a high level of service tends to increase business costs in many ways. A solution must be found that optimizes business performance in the cross-pressure of customer satisfaction and inventory reduction.

The group's spare part logistics is organized via three central warehouses: southern Sweden, Latvia and southern Finland. Each central warehouse's inventory is based on the corresponding area's demand, and each company has a local purchase team. The group's management intends to partly centralize spare parts' storage in southern Sweden in the coming years.

All seven companies in the Nordic and Baltic countries represent the same main agricultural machine brand. Until now, the companies have operated in their own ERP-systems. Within a few years, the ERP-solution for all the companies will be based on the same Microsoft Dynamics 365 platform. It gives all seven companies visibility of each other's stock and enables cross-ordering and joint planning. Considering that, now is the optimal time to analyze different supply chain options.

The group company wants to investigate the possibility and implications of centralizing the storage of spare parts in southern Sweden. There has been no previous extensive research on this topic.

The vision is to gain benefits for the group in inventory management, productivity, and product availability by integrating the supply chain management in seven countries.

1.2 Research objectives and scope

The current supply chain solution with three central warehouses within a radius of 450 km from each other probably is not the most efficient way to operate. Figure 1 shows the current logistic model with three central warehouses (purple arrows) and another possible logistic model with one central warehouse (red arrows). In both cases, spare parts can be delivered overnight to an outlet close to the end-customer.

It is assumed that there are many possibilities for higher margins and lower inventory levels with the same service level from the customer's perspective. Each warehouses' inventory is based on local demand and the discount depends on the order type: annual order has the highest discount and express order the lowest. The greater the proportion of sold spare parts ordered in an annual order, the higher the achieved margin.

By combining three central warehouses, a higher proportion of spare parts can be ordered at a better discount and the group level inventory value decreases. Freight costs are a different story and need to be considered when calculating the overall profitability. The group has a great possibility to earn more money with spare parts by improving the supply chain for spare parts.

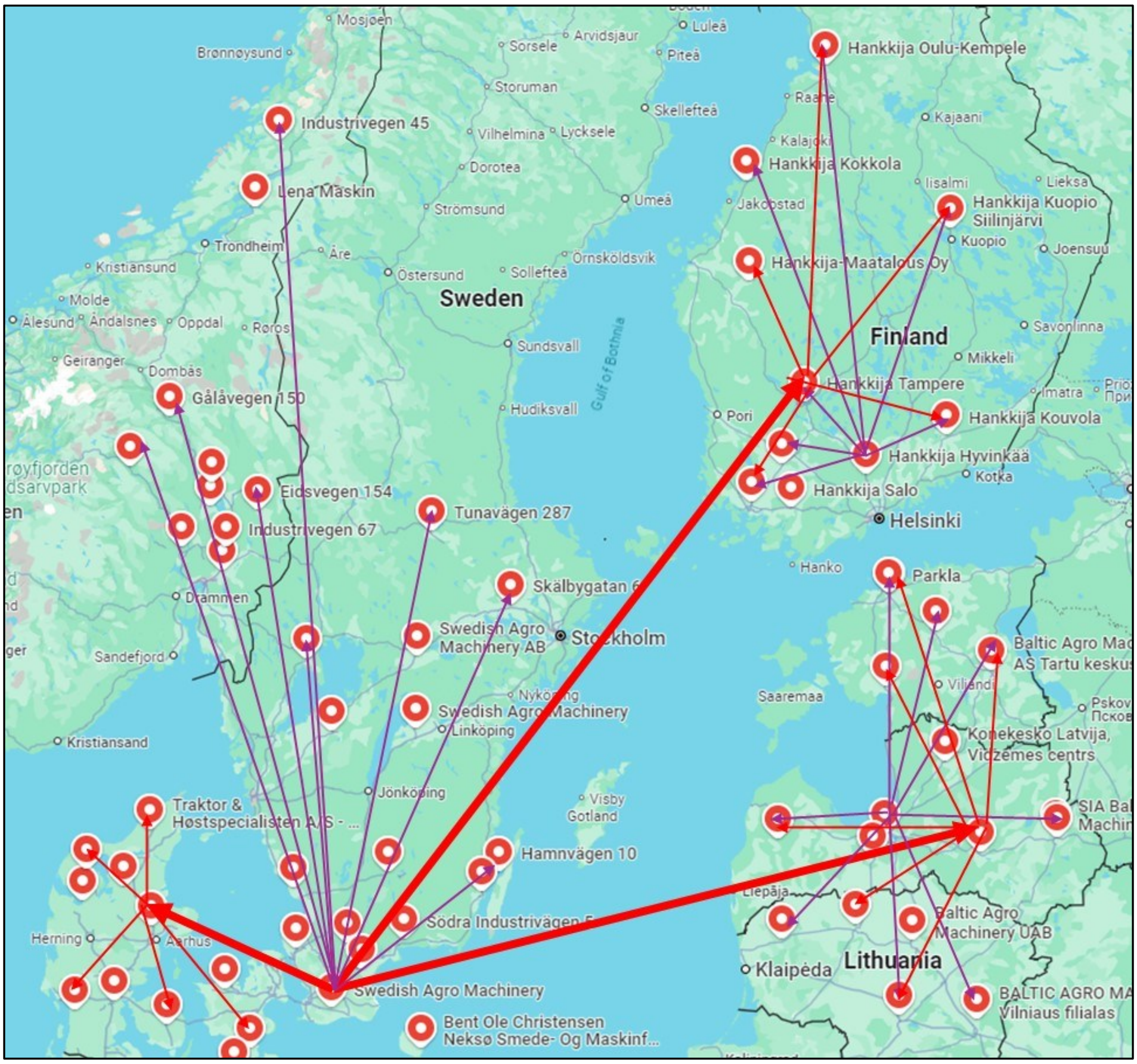

Figure 1. Overnight delivery is possible both in the 1 central warehouse (red arrows) and the 3 central warehouses (purple arrows) model

The main objective of this thesis was to identify the best operating model for spare parts supply chain at the group level.

The research questions were:

1. What is the effect on the margin, inventory value and freight costs, if the central warehouse for all main brand's spare parts is in southern Sweden?
2. What is the effect on the margin, inventory value and freight costs, if main brand's local fast movers are stored in local central warehouses, but slow movers are stored in the main central warehouse in southern Sweden?

Available sales and margin statistics from seven countries, logistics data from three central warehouses, price lists and discount tables were used to answer the research questions.

The thesis analyses were done only on the main brand’s spare parts. All land-based companies are selling this brand and by focusing on it, a real case can be made, and the results can be used in the future.

1.3 Structure of the thesis

The thesis structure is described in an input/output chart in figure 2.

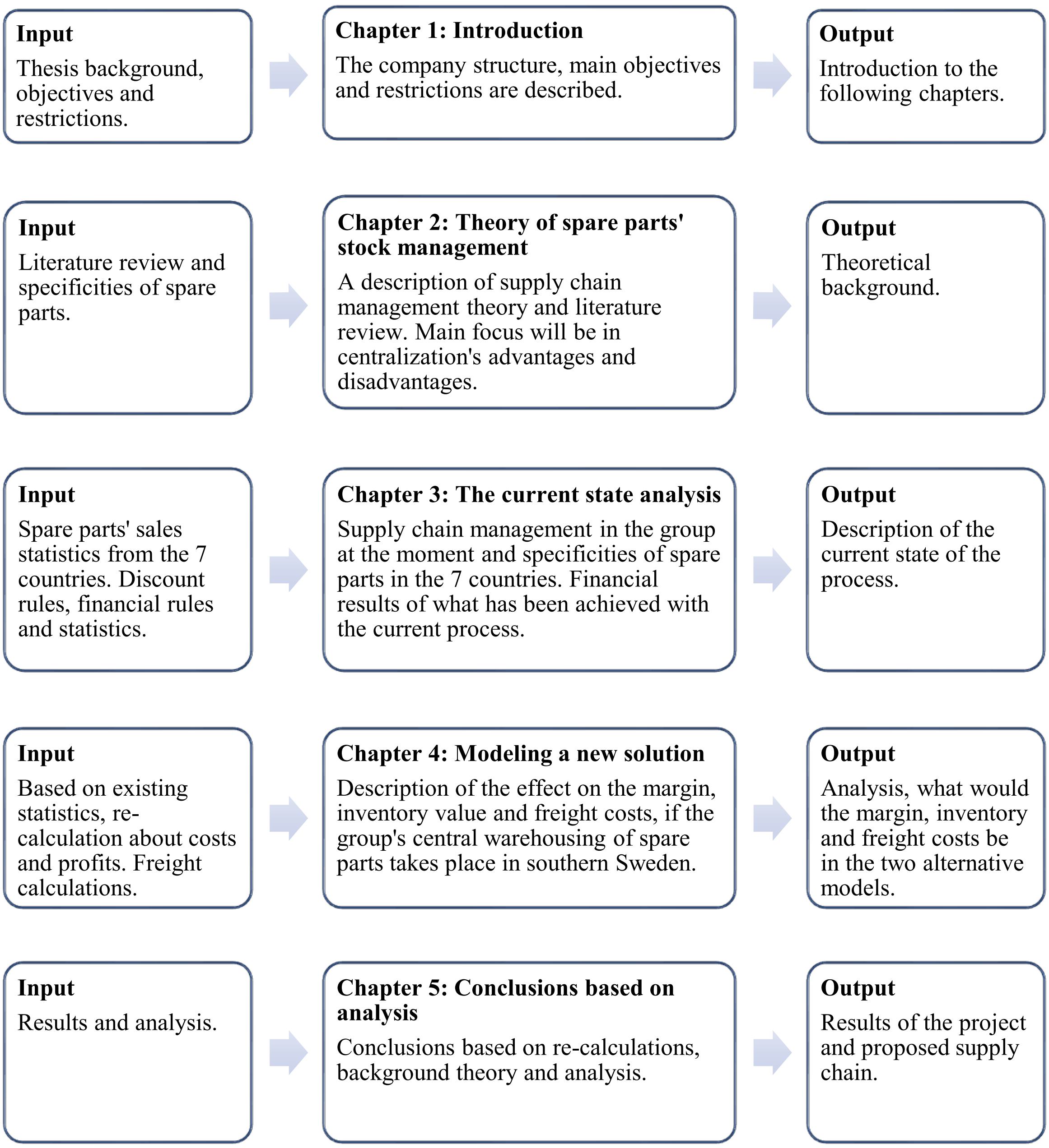

Figure 2. Input/output chart about the project report’s structure

2 Spare parts inventory management

This chapter explains the basic formulas and terms used in this thesis. It also reviews what previous literature and studies have found about the advantages and disadvantages of centralizing and decentralizing. Modern inventory forecasting will also be explained because the use of modern software is essential to optimize large and complex supply chains.

2.1 Inventory types

To understand the principles of stocking spare parts, this chapter outlines the main factors that influence stocking.

The inventory consists of cycle inventory and safety inventory. Cycle inventory is dependent on the lot size. Safety inventory is dependent on the demanded service level, the standard deviation of demand and delivery time. Raising the safety inventory level increases product availability and on the other hand also increases the inventory holding costs. (Chopra et al. 2013, 271, 315-318)

2.1.1 Cycle inventory

$\boldsymbol{Cycle\ inventory} = \frac{\boldsymbol{Q}}{\boldsymbol{2}}$, where

$\mathbf{Q}$ is lot size (Chopra et al. 2013, 272).

In the case of this company, the cycle inventory doesn’t significantly change, no matter what the supply chain solution is. If the average demand for one stock remains the same, the cycle inventory will remain at the same level.

2.1.2 Safety inventory

$\boldsymbol{Safety\ inventory\ ss = NORMSINV\ (CLS)\ \sigma_D \sqrt{L}}$, where

CLS is desired cycle service level.

$\boldsymbol{\sigma_D}$ is standard deviation of demand during lead time.

L is lead time (Chopra et al. 2013, 323).

In this case, the company safety inventory level will decrease if the supply chain solution switches from three central warehouses to one because safety inventory is needed to be kept only in one warehouse, not in all three at the same time. The reason is further explained in the next chapter 2.2 (the pooling effect).

Cycle inventory and safety inventory visually illustrated in Figure 3.

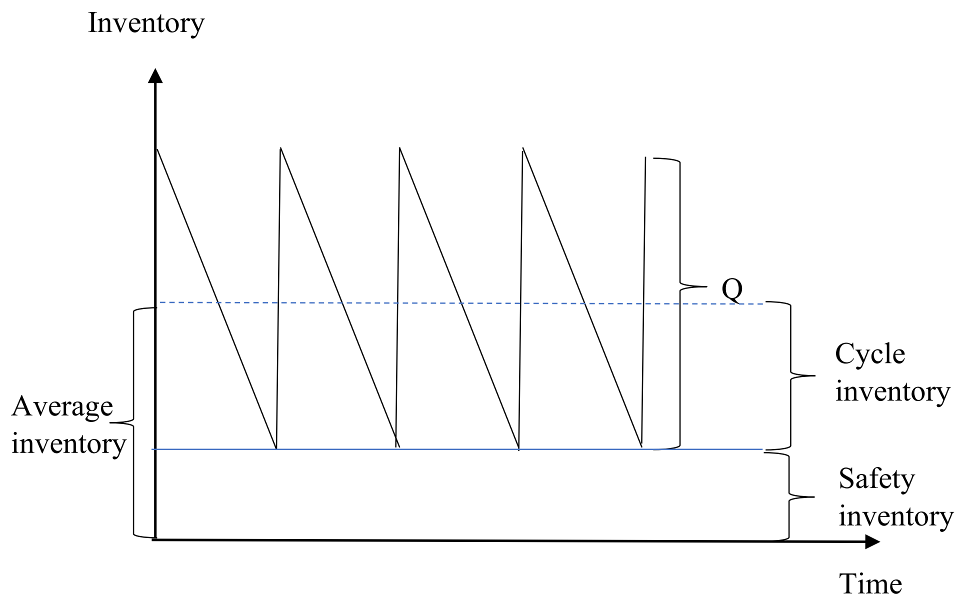

Figure 3. Cycle inventory and safety inventory (Chopra et al. 2013, 315)

2.1.3 Seasonal inventory

The seasonal inventory is built up to meet the demand of the season. Often, manufacturers use low-demand capacity to produce extra stock for a high-demand season. (Chopra et al.

2013, 48.) The case company sells spare parts for agricultural machines and their use is highly seasonal, so forecasting spare parts demand is necessary. Forecasting is often based on historical sales and also qualitative forecasting – people's experience, estimates and subjective information. (Guimaraes et al. 2020, 117-120.)

In the case company, one important factor for seasonal inventory is the purchase terms. The discount for winter orders is significantly higher than for the orders during the season. This is based on the manufacturer's ability to produce and supply spare parts during the off-season at a lower cost than during the high season.

2.2 Inventory pooling

Pooling reduces variability and reduces costs (ordering, inventory, back-orders). Individual variations are pooled by combining demand and lead times. (Oeser. 2015, 7-8.)

The "square root formula" is a well-known law in science, and it makes it possible to model the relationship between the number of warehouses and the level of inventory. Although other simulation and regression methods are now available to consider various factors, the square root formula remains an important tool for calculating the inventory pooling. (Milewski et al. 2022, 18.)

The square root formula:

$\boldsymbol{X_2 = X_1 \sqrt{\frac{n_2}{n_1}}}$, where

$\mathbf{n_1}$ = number of existing warehouses

$\mathbf{n_2}$ = number of future warehouses

$\mathbf{X_1}$ = existing inventory

$\mathbf{X_2}$ = future inventory (Milewski et al. 2022, 4.)

Figure 4 shows how the total inventory changes in relation to the number of warehouses.

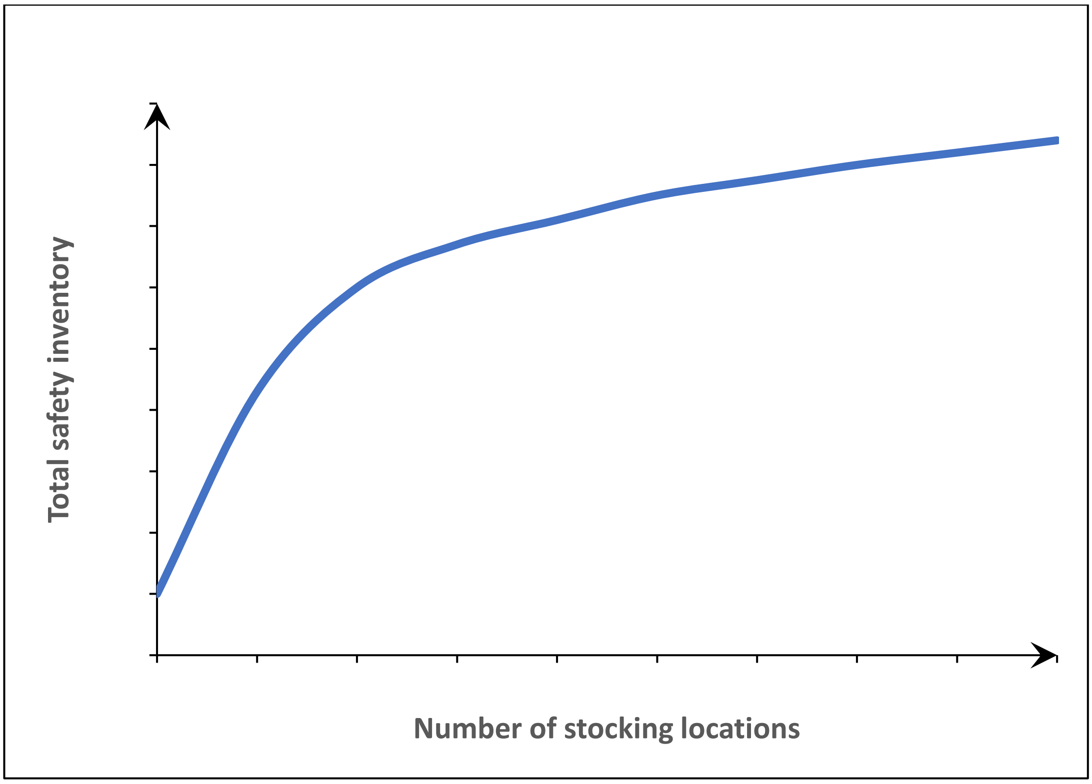

Figure 4. Square-root law (Chopra et al. 2013, 332)

If all the inventory in the case company were pooled from three central warehouses into one warehouse, this would mean:

$$\boldsymbol{X_2 = X_1\sqrt{\frac{1}{3}} \approx X_1 \cdot 0,58}$$

According to the square-root law, the safety stock would be about 58% of the current inventory, if all spare parts were to be pooled in one warehouse. The reason for this phenomenon is that when moving from several stocks to fewer, the variations smooth each other out. Naturally, cycle inventory would remain the same.

2.3 Coefficient of variation

The coefficient of variation (CV) describes the relationship between the standard deviation and the average. The formula is

$$CV = \frac{\sigma}{D} \cdot 100\ \%$$

σ = standard deviation

D = average

Coefficient of variation is related to this thesis, as a higher CV indicates high variability in demand and a low CV indicates low variability.

2.4 Centralization and decentralization

Centralization means that at least the purchase contracts are negotiated at the head office. In some cases, it also means that a separate purchasing department handles all purchasing. Opposite of centralization is decentralization, where purchase decisions are done in each department or location. (Karjalainen 2010, 88)

Basically, there are two factors to consider when comparing centralization and decentralization: customer needs and the cost of responding to customers' needs. Supply chain costs include:

- total logistic costs, which include:
  - inventories
  - transportation
  - premises/handling
- information

Figure 5 shows how the total logistic costs and response time change with centralization and decentralization. (Chopra et al. 2013, 69-73). As customer satisfaction is important to the case company's strategy, response time must be excellent, but its cost cannot be excessive.

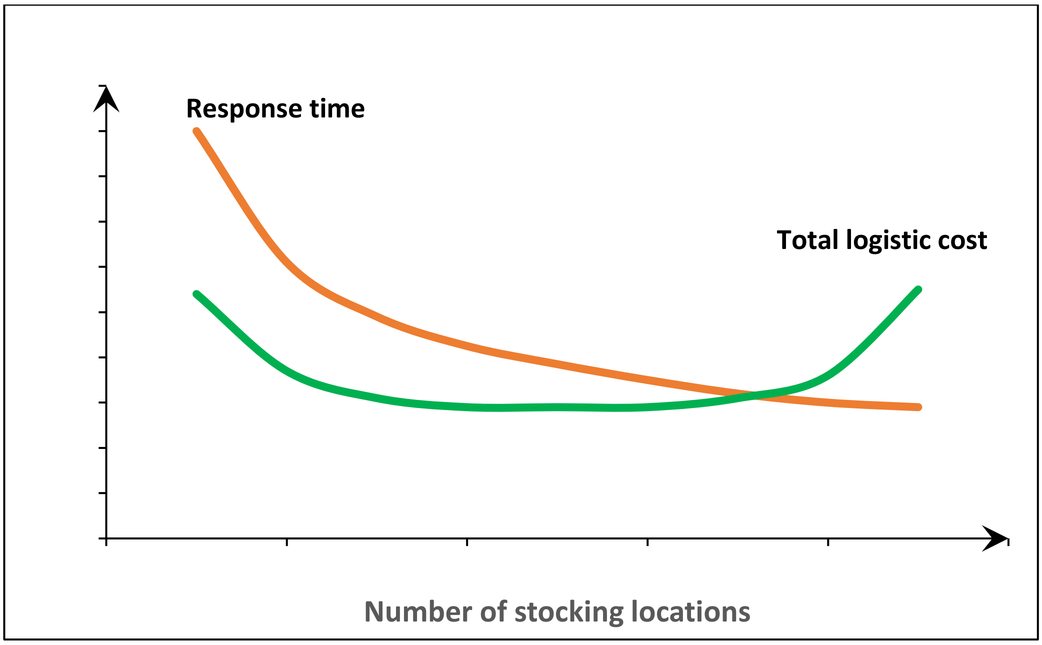

Figure 5. Total logistic cost and response time change with centralization and decentralization. (Chopra et al. 2013, 73)

Customers generally expect the shortest possible response time and, according to the graph, the more stocking locations there are, the shorter the response time. But at some point the costs become prohibitive. Industry and market will play a role, but the optimum stocking rate curve seems to be just before the curves cross.

2.4.1 Centralization's advantages

The academic consensus is that centralization should lower purchase prices. According to studies, centralization normally generates a 10-15% savings and in some sectors it has been documented to generate even 20-35% savings. Better purchase prices are possible through the pooling of negotiation power, but centralization also has other advantages, such as the sharing of know-how or resources and the coordination of strategies. (Karjalainen 2010, 88-89, 96.)

Effective coordination between different branches requires that the decision maker knows all the decisions. In a centralized model, this is naturally the case, as the decision maker is the same manager. (Alonso et al. 2008, 161)

As explained in chapter 2.2, reducing the amount of warehouse locations, also reduces the level of inventory in the entire network. This is so, since the amount of safety inventory can be reduced. At the same time, the availability of products in the remaining stocks is also improved. (Milewski et al. 2022, 3.)

Centralization will also reduce obsolescence and shortages. This has been studied in hospitals, for example, and it has been found that obsolescence and shortages are significantly reduced by reducing the number of storage locations. At the same time, it has been observed that the average age of products received by end-users has improved. (Abbasi et al. 2016, 212.) Based on my own 24 years of experience with spare parts, not all spare parts expire, but the quality and usability of many spare parts weakens as a result of excessive storage. For example, such parts include rubber spare parts, chemicals, and control units that change versions frequently. This is another reason why it is advantageous not to store spare parts for a long period of time.

The centralized model allows for both information sharing and centralized management. Studies have found cost savings of 1.8% if information is shared and 4% if inventory is managed centrally. But the above is not always the case. In some cases, information sharing will produce a better outcome than centralized management. (Jacobs et al. 2013, 2004-2005)

Typically, in many supply chains, fast-moving items with a low coefficient of variation are decentralized close to the customer. But low-moving items have a high coefficient of variation, and centralization can significantly reduce the total safety inventory. (Chopra et al. 2013, 335.) When speaking about spare parts, there are many expensive and low demand products, that are urgently needed in the case of a breakdown. From the customer’s point of view, it is often critical that a spare part is quickly available, and centralizing will improve the slow-movers’ availability. (Karsten et al. 2012, 311.)

Figure 6 shows an example of an expensive product with low demand. Only a few conveyor augers are sold each year in the whole group. The difference in purchase price between an annual order and an express order is more than €500, so a successful annual order will generate a significant additional profit. On the other hand, capital and storage costs will eat additional profits if the spare part stays in stock for too long. By centralizing, the best purchase price can be obtained and without the high risk of the spare part remaining in stock for too long.

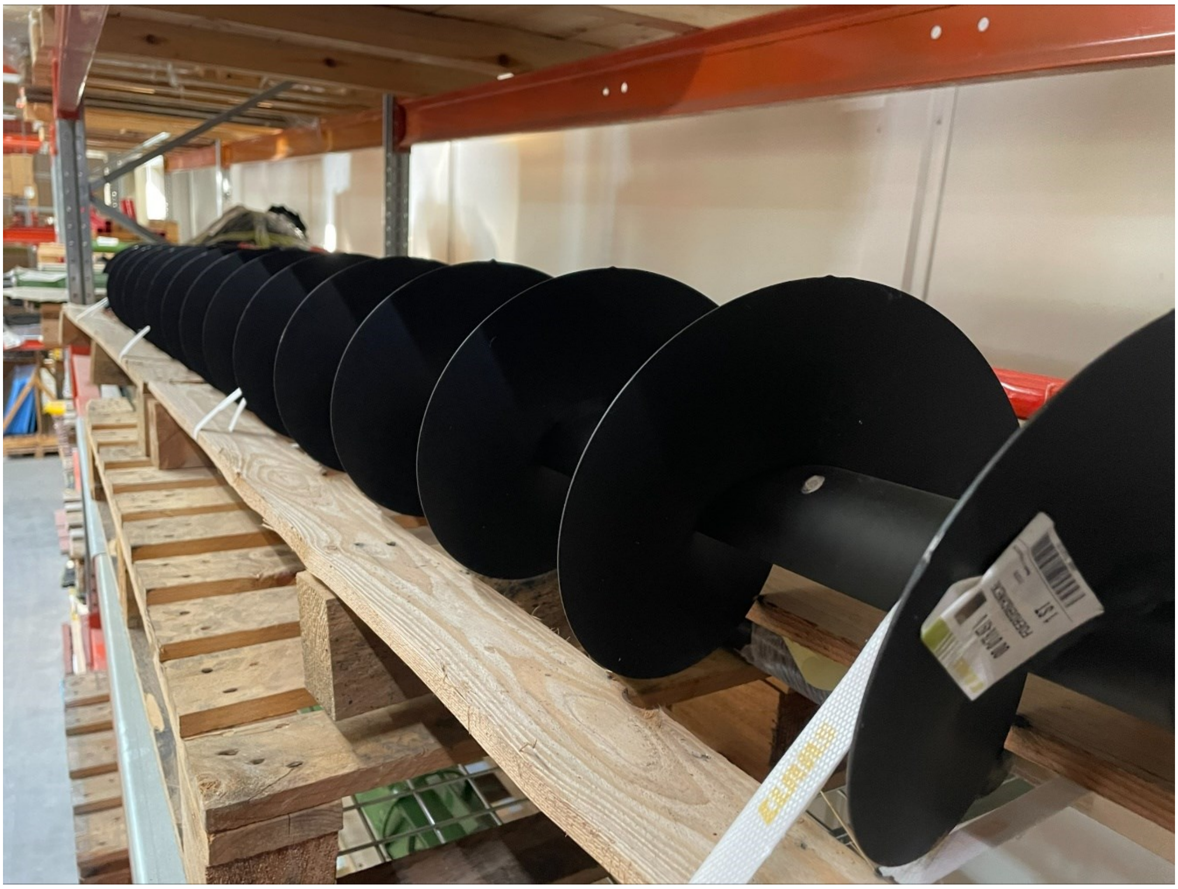

Figure 6. Conveyor augers are sold only a few pieces annually across the 7 countries

In addition to centralization, pooling can be done by replenishing empty stock from another owned stock where the product is still available, thereby achieving significant savings. (Karsten et al. 2012, 311.)

2.4.2 Centralization’s disadvantages

One of the main challenges in centralization is that while it reduces purchase cost, it also tends to increase logistic costs. Especially if the solution is a partly centralized inventory system, there are many variables. (Lee et al. 2008, 1169.)

Typically, fast-moving products have a low coefficient of variation and centralization would increase transport costs. Furthermore, in a fully centralized solution the fast-moving products would be further away from the customer and the response time for customer demand could worsen. (Chopra et al. 2013, 335-336)

Centralization often increases the hierarchical levels of companies and limits communication from top-down. Entrepreneurial behavior and motivation may then decrease. In addition, the organization's ability to identify new market opportunities may be weakened. (Caruana et al. 1998, 25.)

Centralization will not bring savings to an organization if change management fails. Real advantages of centralization must be visible to everyone who is involved in the process. It is true that if more outlets join the central operation model, more synergy benefits will accumulate. But only if all buyers understand the benefits. (Karjalainen 2010, 90.)

2.4.3 Decentralization’s advantages

Especially for fast-moving products, supply chain transport costs are lower with decentralization. Products are also closer to the customer and the demand response time is shorter. (Chopra et al. 2013, 336.)

In a decentralized model, decision makers are closest to the customer and have the best knowledge about local demand. But local decision-makers must coordinate enough with each other; otherwise too much weight may be placed on local conditions (Alonso et al. 2008, 164). Decentralization also often reduces bureaucracy (Vagstad 1998, 961). Cooperation in a decentralized supply chain seems to be very important, and information sharing can minimize the additional costs of decentralization (Bahroun et al. 2016, 7292-7293).

Figure 7 shows an example of fast-moving decentralized products. Filters are sold daily, and it wouldn’t make any sense to deliver each filter to the customer from the central warehouse. Typically, the price for a filter is €10-30 and the transport cost of a single piece from the central warehouse to the customer would be €5-10. But when ordered in weekly transport with other fast-moving products, the cost per filter is less than €1. And the filter is then immediately available to local customers.

Figure 7. Filters are fast-movers in all locations, and it makes sense to decentralize those close to the customers

2.4.4 Decentralization's disadvantages

Slow-moving products typically have a high coefficient of variation. If these types of products are decentralized, it will cause a significant increase in the safety inventory level at the organization level. (Chopra et al. 2013, 335)

Because of the double marginalization effect, a decentralized supply chain's performance is often poorer than a centralized supply chain's performance. Each entity in the supply chain takes its own margin, leading to high end-customer prices. This effect can be managed through coordination and agreed supply chain price mechanisms. (Liu et al. 2007, 723.)

Often local decisions are not always coordinated with the rest of the organization (Alonso et al. 2008, 161). Decentralization may also cause off-contract buying, if locally it is believed that they can find the same product at a cheaper price (Karjalainen 2010, 96).

2.4.5 Summary of advantages and disadvantages

Table 1 summarizes the advantages and disadvantages presented in the previous chapters. The optimal solution is neither centralization nor decentralization alone, but an optimal combination of both.

	Advantages	**Disadvantages**
Centralization	+ lower purchase prices + better sharing of information, know-how and/or resources + effective coordination + lower (safety) inventory levels because of polling effect + better availability in the remaining stocks; in particular for slow-movers + reduce obsolescence and shortages	- higher transport costs - more hierarchical levels and limited communication from top-down - organization's ability to identify new market opportunities may be weakened - it can be challenging to manage so that everyone understands the benefits
Decentralization	+ lower transport costs; especially for fast-moving products + products are closer to customer and the delivery time may be shorter + decision makers are close to customer and know local demand + less bureaucracy	- higher (safety) inventory levels; in particular for slow-movers - double marginalization effect may cause higher end-customer prices - local decisions are not always coordinated with the rest of the organization - off-contract buying risk is higher

Table 1: Summary of advantages and disadvantages

The solution must be able to combine the lower purchase prices and provisioning costs of centralization with the lower transport costs of decentralization. The human element must be strongly considered: information must flow, and all parties must understand the advantages and disadvantages.

2.5 Inventory carrying cost

Keeping items in storage waiting for something to happen is very expensive. Interest must be paid on every euro in the warehouse. There are also operating costs. (Rauhala 2011, 189.)

Cost includes the following components:

- Cost of capital: the money is invested in goods in the warehouse and not in an alternative investment.
- Cost of storage: the warehouse has rental and other property management costs.
- Cost of inventory risk: products may be damaged or spoiled during storage. Demand may end.
- Cost of servicing inventory: taxes, insurance, labor costs, material handling costs (forklifts, etc.), packaging.

Figure 8 shows the breakup of inventory carrying costs. (Shenoy et al. 2018, 19-20.)

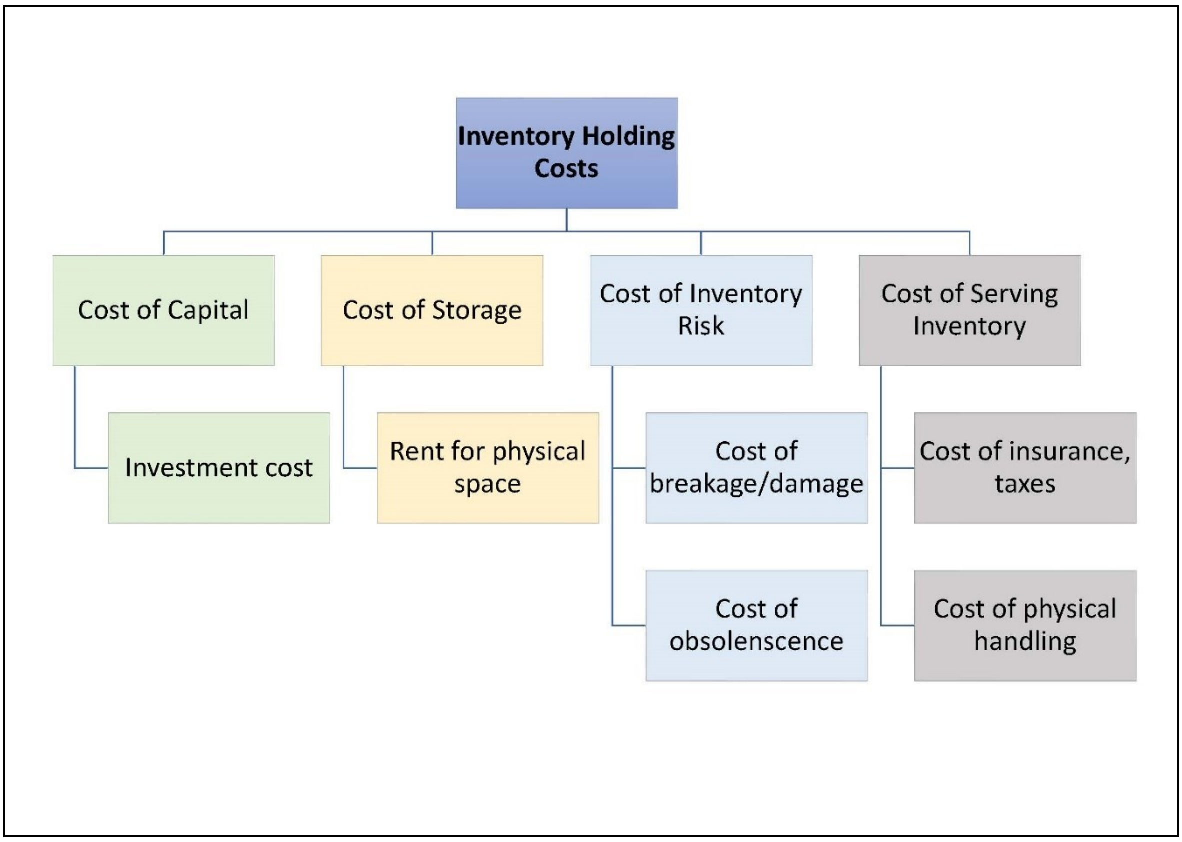

Figure 8. Breakup of inventory carrying costs (Shenoy et al. 2018, 20)

There are indications in the literature as to how much the storage cost typically is. According to Shenoy et al. (2018, 21) inventory carrying cost is approximately 20%. Heikkilä et al. (2013, 134) estimates it's approximately 25% and Rauhala's (2011, 189) estimate has a wide range of 22-48%.

2.6 Write-down

If the estimated future income from the asset is less than the cost of acquisition, the difference should be written down (Finlex. Kirjanpitolaki, chapter 5, 13 §).

Companies have internal rules on write-downs. If a spare part is in stock long enough without any transactions, the system automatically writes down its value. Write-downs are made regularly from the date on which the part is placed in stock. When a spare part has been in stock for a sufficient period of time without any sales, its book value is reduced to zero. The write-down is deducted from the company's profit.

In my own 24 years of experience, there are inevitably some write-downs in the spare parts business because the coefficient of variation in demand for spare parts is often very high. However, the aim should, of course, be to minimize write-downs.

2.7 Modern forecasting

Instead of calculating for example min-max values or order points in Excel to manage spare parts inventory, the modern way is to use commercial software designed for inventory management.

Commercial software usually provides more accurate forecasts than traditional Excel calculations. Modern software makes it easy to test different algorithms against historical data to find the best forecast. These systems allow forecasting based on data from more than just one company. For example, it is possible to define forecasts for a product group or a market. (Chopra et al. 2013, 203.)

Forecasting software is normally based on a descriptive mathematical model – more specifically, a simulation model. The software calculates how spare parts will operate in the supply chain over time as a function of parameters and policies. (Shapiro 2001, 10.)

Most modern software use artificial intelligence (AI). The reason is that there is a massive number of transactions in the retail data. AI enables that data to be used to make faster and more accurate decisions. The system will learn automatically and improve demand forecasts without the need for additional programming. (Hodges et al. 2023.)

One thing to bear in mind in this context is *"maverick buying",* which means that buyers do not follow the program's buying recommendations but place orders at their own discretion. No matter how fancy forecasting software is, if the purchasing suggestions are not followed, the results will not be good. It is probably usually a case of well-intentioned maverick buying – local workers may think they have better buying skills or for example may get better prices. But what local workers don't take into account, is the cost of their own work or the total cost of ownership. (Karjalainen et al. 2009, 255-256.)

3 Current solution

In this chapter, the current supply chain solution is described and the results of the analysis are presented. To make the analysis, all relevant sales and profit data from year 2022 in products number level from all countries were noted. Also, all available logistic data was collected.

3.1 Supply chain in North Europe

The current logistic solution is illustrated in figure 9. For each regional central warehouse, spare parts are ordered from Germany based on local availability. In addition, Danish dealers receive deliveries directly from Germany, as there is no central warehouse in Denmark. The reason for the current Danish model is that the supplier's warehouse in North-Rhine Westphalia is located so close to Denmark that overnight deliveries from there to Danish outlets are possible, and Danish outlets are very big. Furthermore, central warehouses in different countries do not have easy visibility of each other's movements or stock availability.

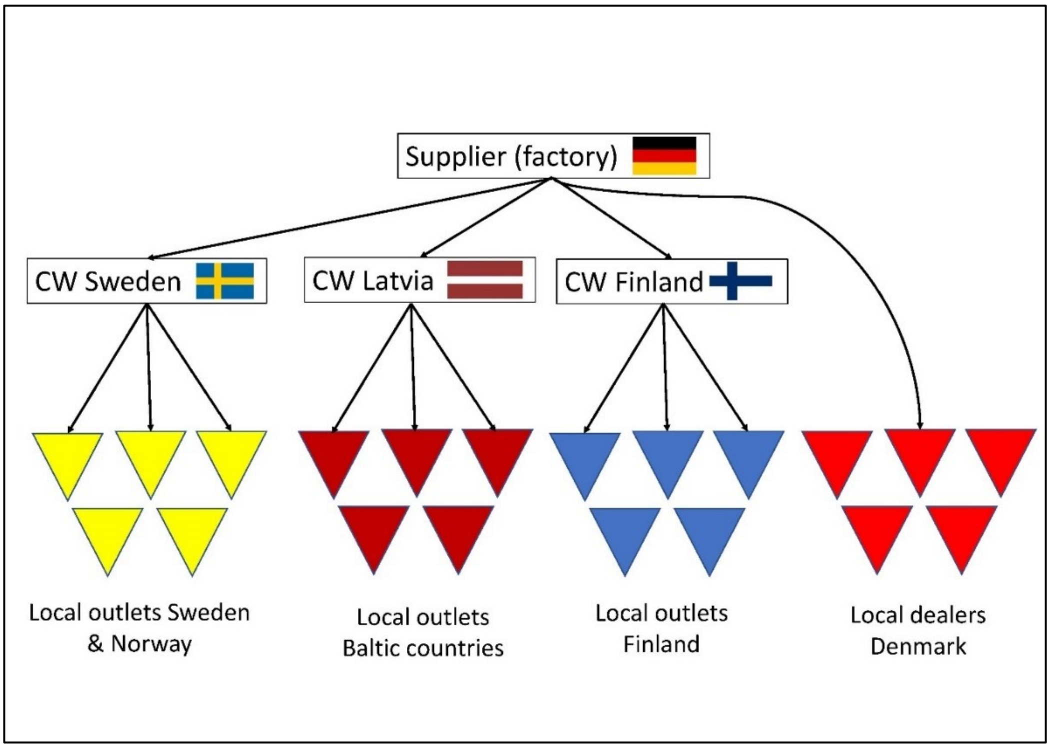

Figure 9. Current logistic solution

Express orders normally follow the same route as stock orders. Only the delivery method is faster, and in Finland and Baltic countries express orders are normally delivered by air freight. But if the customer has an urgent need, direct express deliveries are also possible.

Transport costs are affected by the following factors:

- Delivery method: truck, economy courier, air freight courier, taxi
- Weight
- Volume
- Delivery distance

3.2 EPR-solution

Currently, there are several ERP-systems in different countries. Each company has limited, if any, visibility of other countries' ERP-systems. For example, in Finland the old AS/400 ERP-system is used for product information management and AS/400 is connected to the Relex-system, which generates purchase proposals. In figure 10 is a view from AS/400 and in figure 11 from Relex.

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_ 316  LAHTI         0,000        1,000        0,000        0,000        0,000
_ 318  PORI          0,000        2,000        0,000        1,000        1,000
_ 331  KUOPIO        1,000        1,000        1,000        0,000        0,000
_ 332  MIKKELI       0,000        0,000        0,000        1,000        1,000
_ 334  JOENSUU       0,000        1,000        0,000        0,000        0,000
_ 335  IISALMI       0,000        1,000        0,000        0,000        0,000
_ 352  VAASA         0,000        2,000        0,000        1,000        1,000
_ 353  KOKKOLA       0,000        1,000        0,000        1,000        1,000
_ 354  JYVÄSKY       0,000        1,000        0,000        1,000        1,000
_ 355  TAMPERE       0,000        1,000        0,000        1,000        1,000
```

Figure 10. View from AS/400-system

Tuotekoodi	Tuotenimi	Ehdotettu määrä	Korjattu määrä	Efektiivinen...	Tilaus...	Til...	Loppusaldo
CA0008137621	MUOVILAAKERI	23.00		23.00	Ei		4.00
CA0008661240	TERÄ ROLLANT 455/375	13.00		13.00	Ei		52.00
CA0009184451	NOUKINKAARI SPRINT / JAGUAR	6.00		6.00	Ei		3.00
CA0009206872	KITKALEVY 150/91MM	5.00		5.00	Ei		0.00
CA0008602300	KAARIPELTI	5.00		5.00	Ei		5.00
CA0008261043	NOUKKIMEN OHJAINLEVY	3.00		3.00	Ei		1.00

Figure 11. View from Relex-system

Some countries are already using Microsoft Dynamics 365 (D365) and in future same platform will be the solution for all local companies – although the implementation of D365 may differ between countries. The D365 gives all seven companies visibility of each other's stock and enables cross-ordering and joint planning.

Presently, for example, the AS/400 and the D365 are not connected at all. In addition to mutual visibility, the advantage of the D365 system will be the EDI connectivity to suppliers, which will facilitate ordering processes. Figure 12 shows an example of a view from D365.

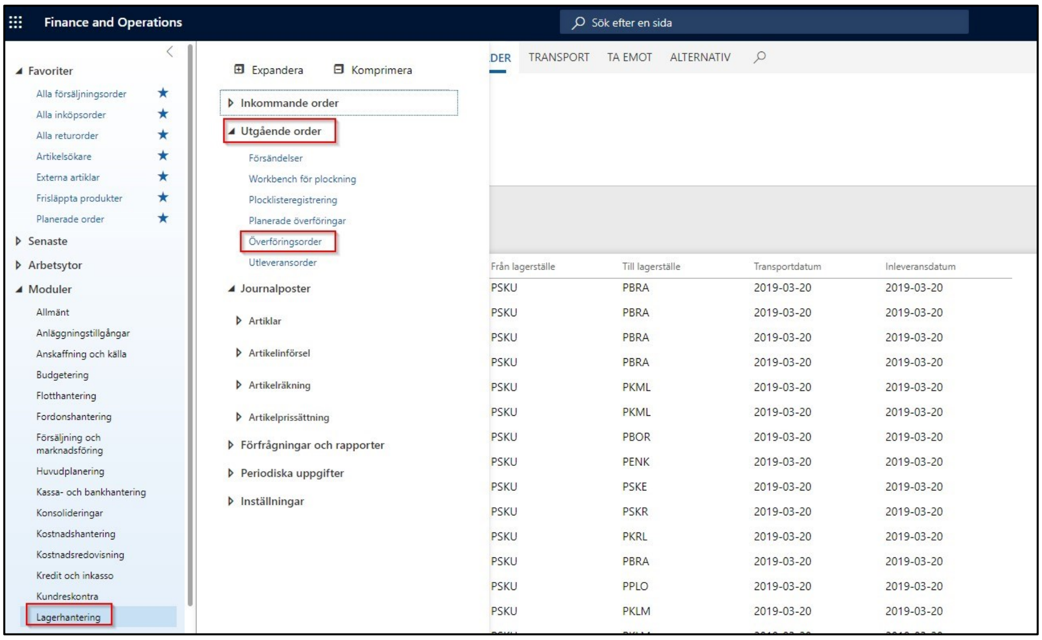

Figure 12. View from Microsoft Dynamics 365

Currently, the companies use different inventory management software programs to calculate order proposals. Thus, there is no need to manually calculate rotary and cycle inventory or min-max points manually because modern software does it. But currently this only happens regionally – there is no possibility to calculate the proposal for all seven countries, for example.

3.3 Order process and organization

Each central warehouse has its own spare part manager, who independently orders spare parts for their area’s warehouse based on local demand using local IT-systems. Companies in the Baltic countries have a long history of buying together. Sweden and Norway also have a bit of co-operation as their CW is the same. Otherwise, there is still no cooperation between the countries in the field of inventory management. Seven countries and seven buyers, but currently co-operation on inventory management is very limited. The organization is illustrated in figure 13. The forthcoming ERP-system with visibility to other countries will open up numerous opportunities to improve co-operation.

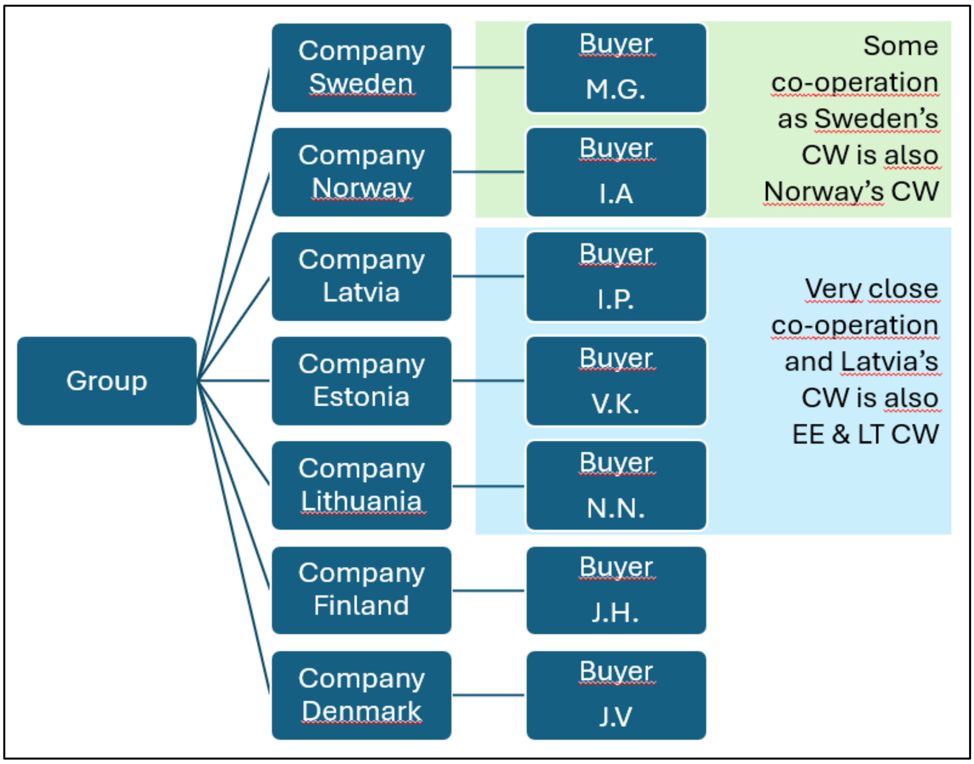

Figure 13: Purchase organization in the group

In winter, annual orders are placed based on sales in previous years. During the season, weekly replenishment orders are placed, as well as daily express orders. There is a different discount for each type of order. As the figure 14 shows, spare parts sales for agricultural machinery are highly seasonal. Therefore, the success of the annual order – with the highest discount and lowest freight cost – is crucial for profitability.

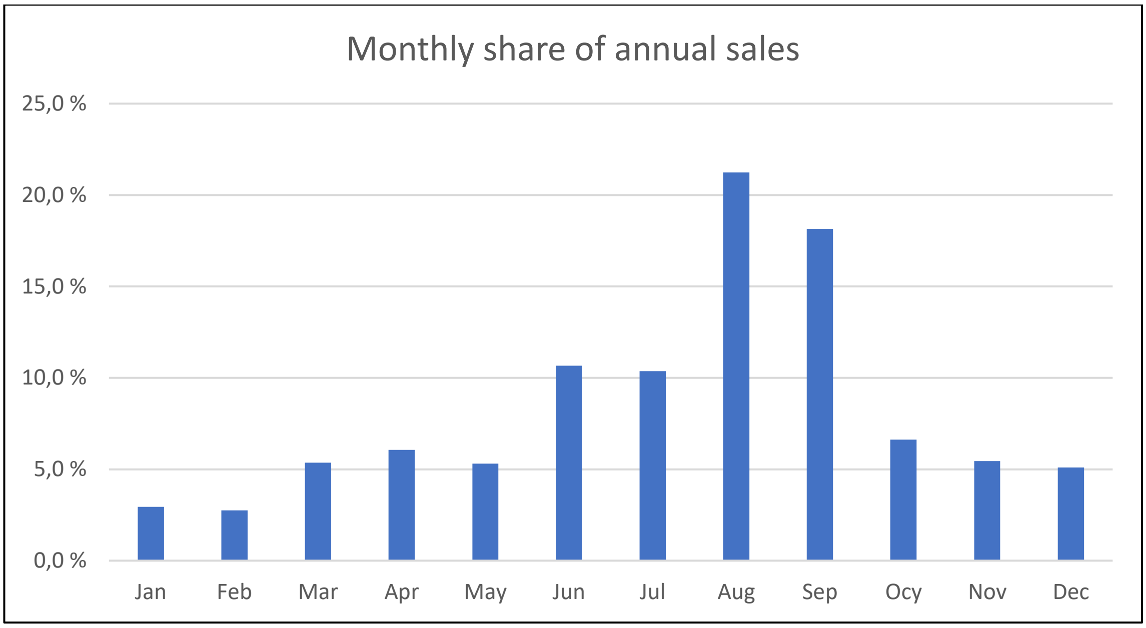

Figure 14. Monthly share of annual sales

3.4 Cost price and discounts

The supplier has a 3-step discount structure:

- Annual order's discount is highest
- Replenishment order's discount is lower than super stock order's
- Emergency order's discount is lowest

Basically, the more the company succeeds in ordering in the annual order, the more it earns. But of course, additional stock value causes additional costs and in case of slow movers there is the risk that the ordered part will never be sold.

3.5 Stock value and costs

The purchasing software calculates a cycle inventory and a safety inventory for each central warehouse based on the sales in the area. This inventory incurs capital cost because the group charges internal interest on inventories. The internal rate, based on the real market rate, is the most visible cost of spare parts in stock. But as explained in chapter 2.5 there are many other significant costs to inventories than just the internal rate.

The interest rate on current assets affects the profits of each company, so its impact must be considered when looking at costs.

3.6 Write-downs

If an individual spare part is not sold from stock for years, its value is written down in steps. These write-downs are deducted from the company's operating result. So, from a profitability perspective, write-downs should be kept to a minimum – although the nature of the parts business makes them impossible to avoid.

The case company’s policy is shown in figure 15. If the product isn’t sold from the stock in four years, its value is written down to zero.

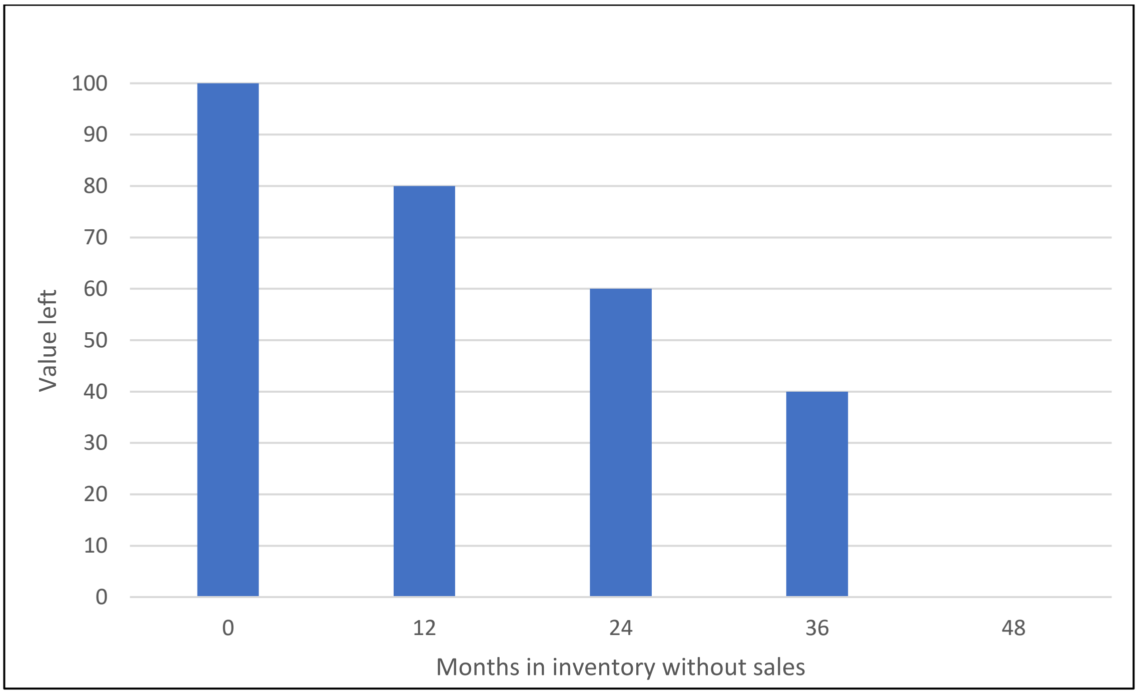

Figure 15. Non-moving spare parts write-downs

3.7 Delivery costs

The following delivery methods from the supplier are currently used:

- Truck, 4-10 working days, depending on the order date (only one delivery/week is possible)
- Road courier, 3 working days
- Air courier, 1-2 working days depending on the area
- Taxi (over-night courier from factory to outlet or end customer), next working day

The size and weight of the spare parts range from a few grams of gasket to the large and heavy machine component shown in figure 16. If the spare part a customer needs is large or heavy and they need it quickly, the transport costs can run into thousands of euros.

Figure 16. Some spare parts are big and heavy.

The cost ratio (€/kg) between different delivery methods is described in table 2. Figures are based on the actual freight invoices of the year 2022.

Table 2. The ratio in the cost is as follows, if the taxi's index is 100

Delivery method	Cost index (per kg)
Truck	1,0
Road courier	6,9
Air courier	11,5
Taxi	100

As you can see, the most expensive transport option is 100 times more expensive than the cheapest option. Thus, the cheapest delivery method, trucking, generates a much better sales profit than the other delivery methods.

It should be noted, however, that taxis are rarely used, and the customer is charged an express fare in that case. But even so, the price advantage of trucking is very significant compared to any of the other delivery methods.

4 Modeling a new solution

In this chapter, it is described how the new models were calculated and what factors were considered. Actual euros have not been documented here, but an index has been used in which the actual purchase cost for 2022 is indicated by an index of 100,0.

4.1 Workflow of modeling

The modeling was based on the master data of spare parts sales for each of the seven countries for the year 2022. Data had to be retrieved from three different ERP-systems in Finland, Denmark, and the Baltics. Product data came from the supplier.

Sales data for all countries were compiled into one big table. A calculation was made for the current situation and for each of the two demand-based logistic models. The calculation included both the modeling of purchase prices and transport and other costs in each model.

The actual transport costs were examined, and a quotation was requested from one of the courier companies outside the existing supply chain. For Finland, freight costs for all scenarios could be calculated very accurately. For the other countries, some assumptions had to be made, which reduced the accuracy of the calculation.

Finally, all costs for all scenarios were added together to make conclusions.

4.2 Alternative supply chain solutions

Two alternative supply chain solutions were modeled based on the research questions:

- Only one central warehouse, located in southern Sweden. This solution is illustrated in figure 17.
- Three central warehouses located in southern Sweden, Latvia and southern Finland for fast-movers and one central warehouse in southern Sweden for slow-movers. This solution is illustrated in figure 18.

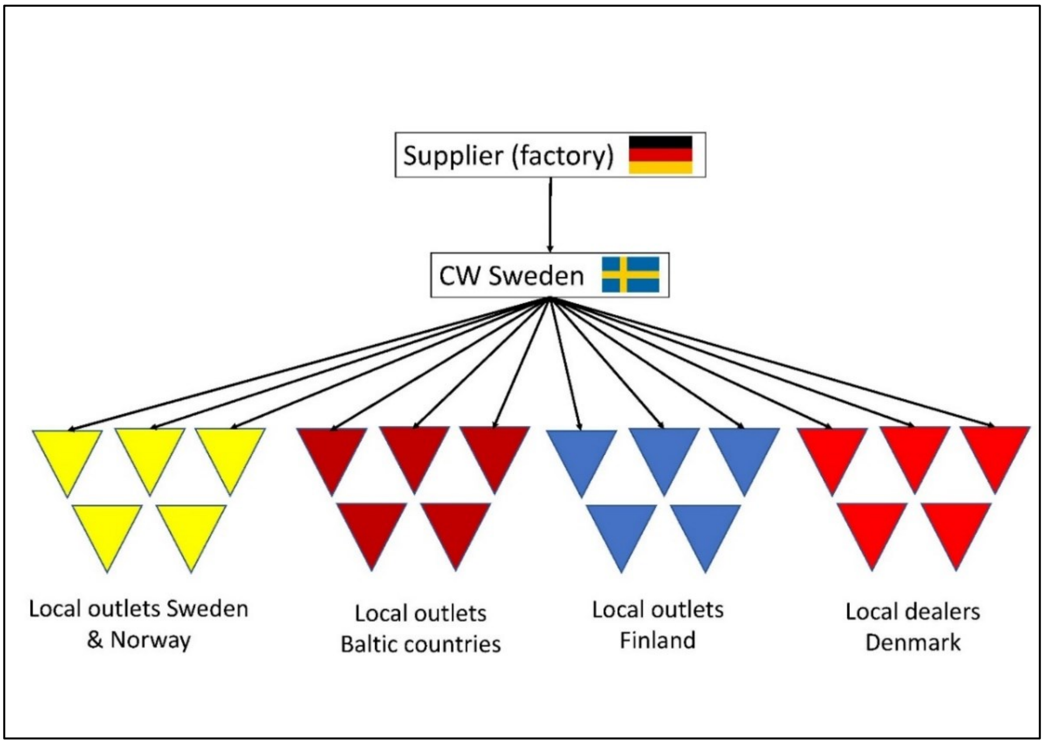

Figure 17. First alternative logistic solution

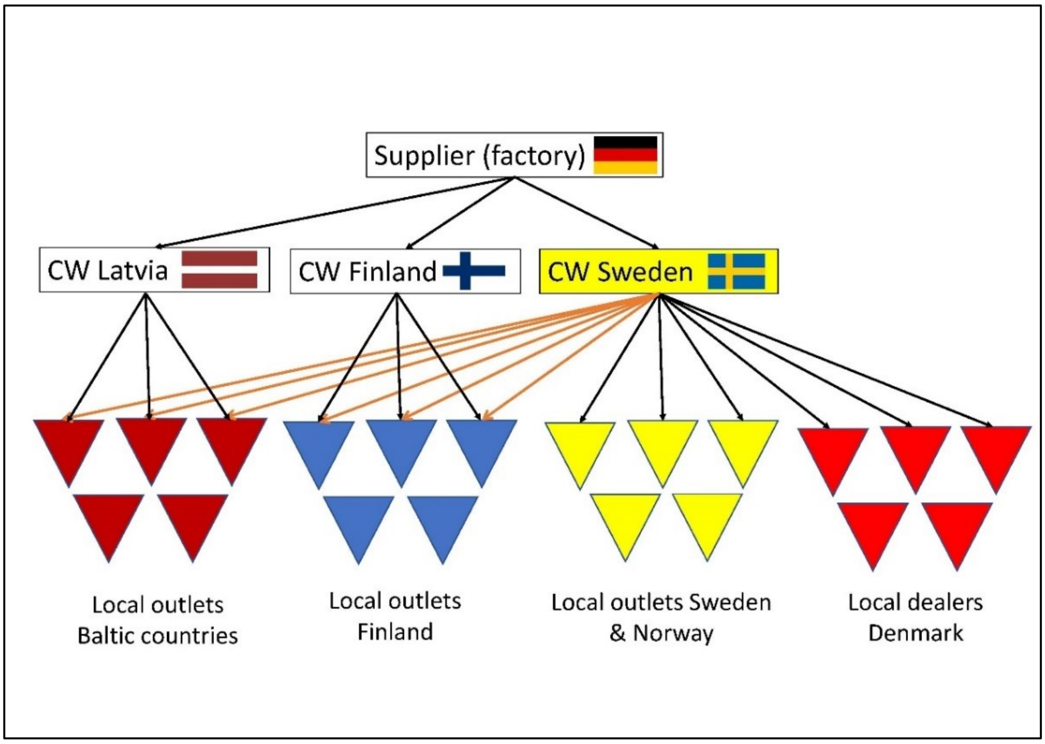

Figure 18. Second alternative logistic solution

4.3 Purchasing models

Finland’s spare part manager was interviewed and according to him spare parts should be divided as follows

- Groups A, B, C and D based on annual sales – in this thesis, the ABCD classes are referring only to sales volume, i.e. those in category A sell the most (10+ units per year) and those in category D are not projected to sell at all; tables 2-4 clarify the issue
- Harvesting machine (H) or tractor (T) parts, because the discount structure differs depending on the type of machine

Table 3 contains a description by Finland’s spare parts manager on how he orders spare parts for each category in the central warehouse. (Heinänen 2022.)

Table 3. Part grouping parameters according to a Finnish spare part manager

Group	Description	Annual sales	Share annual order	Share replenishment	Share express
AH	A-parts for harvesting machines	10+	70%	30%	0%
AT	A-parts for tractors	10+	10%	90%	0%
BH	B-parts for harvesting machines	4-9	60%	40%	0%
BT	B-parts for tractors	4-9	10%	90%	0%
CH	C-parts for harvesting machines	1-3	0%	0%	100%
CT	C-parts for tractors	1-3	0%	0%	100%
DH	D-parts for harvesting machines	0	0%	0%	0%
DT	D-parts for tractors	0	0%	0%	0%

For spare parts, it is possible to obtain significant additional discounts on annual orders. For this reason, the spare parts manager has tried to maximize the share of annual order, considering the variation between years, which is why even A-parts are not usually ordered for 100% of sales, but for 70%.

It is not possible to get an extra discount on tractor spare parts in the annual order. Therefore, it makes sense to order tractor parts in replenishment orders throughout the year.

At a general level, C parts (expected sales of 1-3 units per year) are not ordered into stock. Except for a few critical parts.

Table 4. Actual part grouping parameters (varies depending on the country)

Group	**Description**	**Annual sales**	**Share annual order**	**Share replenishment**	**Share express**
AH	A-parts for harvesting machines	10 +	34 - 48%	34 - 60%	4 - 21%
AT	A-parts for tractors	10 +	0 - 25%	49 - 97%	3 – 39%
BH	B-parts for harvesting machines	4 - 9	12 - 35%	27 - 58%	23 - 55%
BT	B-parts for tractors	4 - 9	0 - 16%	38 - 59%	26 - 59%
CH	C-parts for harvesting machines	1 - 3	9 - 14%	34 - 52%	36 - 59%
CT	C-parts for tractors	1 - 3	0 - 9%	31 - 48%	43 - 69%
DH	D-parts for harvesting machines	0	0%	0%	0%
DT	D-parts for tractors	0	0%	%	0%

Demand varies from year to year, and different countries' spare parts managers have had slightly different policies for ordering from the central warehouse. Table 4 shows the actual variation between countries.

The purpose of this thesis is not to calculate the optimal purchase amounts, but to compare different supply chain solutions. For this reason, the best possible different order points are not mathematically calculated, but averages are used that are as close as possible to the actual ones used in 2022. I therefore used the ratios shown in table 5 based both on an interview with a spare parts manager and on actual ordering behavior in different countries.

Table 5. Part grouping parameters that were used in modeling

Group	Description	Annual sales	Share annual order	Share replenishment	Share express
AH	A-parts for harvesting machines	10 +	70%	25%	5%
AT	A-parts for tractors	10 +	10%	85%	5%
BH	B-parts for harvesting machines	4 - 9	45%	45%	10%
BT	B-parts for tractors	4 - 9	10%	80%	10%
CH	C-parts for harvesting machines	1 - 3	0%	50%	50%
CT	C-parts for tractors	1 - 3	0%	50%	50%
DH	D-parts for harvesting machines	0	0%	0%	0%
DT	D-parts for tractors	0	0%	0%	0%

4.4 Modeled product range

In table 6 it is modeled how many different product numbers (on average) were in 2022 in each central warehouse based on the parameters in table 5. Each central warehouse stores only fast-moving spare parts in its area. Sweden's central warehouse didn't include the Danish demand, as Danish dealers received deliveries directly from Germany.

Table 6. Current situation (2022) modeled

	Sweden	Latvia	Finland
A	4145	4693	826
B	4144	4199	859
C			
Total	**8289**	**8892**	**1685**

In table 7 it is modeled how many different product numbers (on average) each central warehouse would have had if the slower moving products for the whole group had been stored in Sweden. The advantage of this model is that a much larger number of products would have been bought into stock at a better discount (annual or replenishment order).

Finland is an extreme example: in the current situation, the stock of spare parts purchased at a good discount is around 1700 product numbers, but in the new model, the group's central stock would be around 16000 product numbers higher.

Table 7. Modeled situation, where Latvia's and Finland's CWs keep in stock all fast-moving items

	Sweden	Latvia	Finland
A	6977	4693	826
B	5974	4199	859
C	4653		
Total	**17604**	**8892**	**1685**

8 models how many different product numbers (on average) there would have been in Sweden if it were the only central warehouse for the main supplier's spare parts. In this model there wouldn't be any spare parts in Latvia or Finland.

Note that the Swedish stock has the same number of product numbers as in the previous model (group A/B products).

Table 8. Modeled situation, where Sweden would be the only CW for the whole group

	Sweden	Latvia	Finland
A	9801	0	0
B	7803	0	0
C	0	0	0
Total	**17604**	**0**	**0**

4.5 Modeling purchase costs

Sales data were available for all 7 countries at line level. Data included:

- product number
- product group
- product weight
- sales in pieces in each country
- sales in euros in each country

In the first step, all this information was gathered into a single master file as shown in the example in figure 19.

Product information			Finland			Denmark			Norway			Sweden			Lithuania			Latvia			Estonia		
Discription	Group	Weight	Pcs	€-sales	€-	Pcs	€-sales	€-	Pcs	€-sales	€-	Pcs	€-sales	€-	Pcs	€-sales	€-	Pcs	€-sales	€-	Pcs	€-sales	€-
TWINE GUIDE	H3	0,097 kg																			1	68,00 €	16,93 €
KNIFE	HC	0,008 kg				5	28,27 €	12,59 €	5	34,20 €	19,22 €	15	138,71 €	98,75 €									
COMPRESS.SPRING	HC	0,021 kg										1	4,74 €	3,62 €									
WASHER	HC	0,010 kg				6	13,85 €	5,92 €	1	2,77 €	1,59 €	1	1,05 €	0,01 €									
LEG SPRING	HC	0,026 kg										1	16,56 €	13,47 €									
SPRING	H3	0,010 kg	2	10,48 €	5,70 €							7	47,46 €	38,89 €									
UPPER LIP	H3	0,011 kg										1	27,65 €	20,95 €									
CLAMPING PLATE	H3	0,149 kg	2	224,84 €	118,63 €							1	146,41 €	102,66 €									
TONGUE	H3	0,034 kg										2	243,64 €	151,36 €									
BEARING	H3	0,426 kg				1	129,57 €	54,52 €	1	154,85 €	89,30 €	1	58,39 €	0,84 €									
TWINE FINGER ASS.	H3	0,096 kg							1	81,82 €	45,00 €	1	32,80 €	0,98 €	3	95,91 €	25,35 €						

Figure 19. Master data about 2022 sales

The next step was to calculate the procurement costs for the different scenarios per country and per product number. For this calculation, the following additional data was available:

- net price for each order type (annual, replenishment and emergency order)

- product grouping (A/B/C/D) and machine type of spare part (harvesting machine or tractor)
- purchase parameters from Table 5
- internal profit from Swedish central warehouse

The calculation of costs also took into account the relative shares of the different types of orders. An example of this calculation is shown in figure 20. The calculation was made based on the sales volume of each of the seven countries and finally the totals for the group as a whole were calculated.

Product information		FINLAND			FINLAND calculation										All Superstock
	Discription	Pcs	€-sales	€-margin	Qty-gr	Part group	Super Stock Orde	Replishment Orde	Express Order	SE price	Express	A/B-prod in FI	C-prod SE	C-prod Express	From SE
000251	SPRING	2	10,48 €	5,70 €	C	CH	0,00 €	2,23 €	2,39 €	4,63 €			4,63 €		3,81 €
000363	UPPER LIP				D	DH	0,00 €	0,00 €	0,00 €						
000373	CLAMPING PLATE	2	224,84 €	118,63 €	C	CH	0,00 €	49,31 €	53,11 €		106,21 €			102,41 €	84,38 €
000482	TONGUE				D	DH	0,00 €	0,00 €	0,00 €						
000560	BEARING				D	DH	0,00 €	0,00 €	0,00 €						
000572	TWINE FINGER ASS.				D	DH	0,00 €	0,00 €	0,00 €						

Figure 20. Calculations based on 2022 master data

In table 9 the purchase cost in each country and on group level is modeled. A 100 indicates the whole group's total purchase cost in year 2022. This calculation shows that if the central warehouse had been centralized in 2022, the savings in procurement costs would have been 6.4%. This percentage is based on a mathematical calculation, but in the real world the savings could have been even higher. Cost savings of 10-15% have been quoted in the literature (Karjalainen 2010, 89).

Table 9. Real cost and modeled costs

	FI	**DK**	**SE+ NO**	**SE+NO+DK**	**EE+LV+LT**	**Group total**
Real cost 2022 based on sales	3.81	28.6	28.8	*	38.7	100
All SE with internal CW profit	3.79	*	*	56.0	44.1	104
All SE w/o CW profit	3.28	*	*	51.0	38.7	92.9
Fast-movers in local stock, slow movers in SE with CW profit	3.72	*	*	56.0	39.2	98.9
Fast-movers in local stock, slow movers SE w/o CW profit	3.58	*	*	51.0	38.7	93.3

In 2022, Swedish warehouse used 15% internal margin to cover costs. As described in chapter 2.4., the literature suggests that this cost is at the right level or even too low. However, the scale of centralization in this case is large and further calculations are indeed worthwhile to open up the nature of the internal costs. Another factor to note is that, from the perspective of the individual outlet, internal costs arise in all the models discussed in this thesis. Either the cost is incurred in a centralized Swedish central warehouse, or it is incurred in a decentralized local warehouse. It is a matter for decision whether this cost should be considered. In any case, all the calculations in this thesis show the profitability both with and without the Swedish CW cost. In any case, internal margin should not be overstated.

4.6 Modeling logistic and write-down costs

Detailed information was available on the procurement costs for each country. But the modeling of logistics costs was much less accurate. Logistics information was poorly available, especially for the Baltic countries. The delivery addresses were known, but the actual cost of the logistics could not be determined. The best information was available from Finland and my modeling is based on that.

4.6.1 Transport costs in Finland

Finland’s delivery data was available: 18,959 order lines from year 2022. The data included the following information:

- product number
- order date
- delivery location
- weight
- order type (express or fill-up)

It was also possible to link grouping parameters (AH, AT, BH, BT, etc.) to the same spreadsheet.

Freight tariffs for year 2022 were also available for each transport company. The used transport options were:

- Flight delivery from Sweden central warehouse – Finnish outlets
- Flight delivery from supplier (Germany) – Finnish outlets
- Road delivery from Sweden central warehouse – Finnish main warehouse
- Road delivery from supplier (Germany) – Finnish main warehouse
- Road delivery from Finnish main warehouse – Finnish outlets

Figure 21 shows an example of delivery data.

Product number	Decription	Delivery date	To stock	Qty	Weight / pc	Total weigh	N/P	Qty-gr Grou	Part grou	A/B FIN	Transport company	From stock
CA6005013427	TRANSMITTER	3.1.2022	395	1	0,052	0,052	P	B	BT	D	DANX	Skurup
CA0003537040	HIHNAN KIRISTIN	3.1.2022	373	1	1,641	1,641	P	B	BT	D	DANX	Skurup
CA0005969780	V-RIBBED HIHNA	3.1.2022	373	1	0,36	0,36	P	B	BT	D	DANX	Skurup
CA0005854880	SEALING RING	3.1.2022	373	2	0,116	0,232	P	B	BT	D	DANX	Skurup
CA0007253400	SUOJALAATIKKO	3.1.2022	398	1	1,214	1,214	P	C	CH	D	TNT	Hamm
CA6005021614	WATER PUMP PULLEY	3.1.2022	930	1	0,425	0,425	P	D	DH	D	TNT	Hamm
CA0019543580	KATKAISIN	3.1.2022	355	3	0,037	0,111	P	D	DT	D	TNT	Hamm
CA0011410220	O-RENGAS	4.1.2022	924	2	0,005	0,01	N	A	AT	A	Schenker	Skurup
CA6005028072	O-RENGAS CA6005023305	4.1.2022	924	3	0,003	0,009	N	A	AT	A	Schenker	Skurup
CA0011514480	FLAT GASKET	4.1.2022	924	2	0,012	0,024	N	A	AT	A	Schenker	Skurup

Figure 21. An example of Finland's data. Total data was 18,959 lines

The next steps were to:

- calculate the actual cost from year 2022
- calculate transport cost for 1st option where fast movers were in Finland and slow movers in Sweden
- calculate transport cost for 2nd option where all centrally stocked spare parts are delivered from Sweden
- calculate the change in cost of each model compared to the actual cost – the result of this calculation is shown in table 10

Table 10. Actual and modeled transport costs change in 2022 in Finland (same scale as in previous tables)

	FI
All SE modeled transport cost change	0.30
Fast movers in local stock, slow movers in SE modeled transport cost change	0.05

These figures give a good idea of the cost of air transport. If all spare parts are stocked in southern Sweden and express orders are flown to Finland, the total freight cost is many times higher than if fast-moving products in Finland could be delivered by road from southern Finland and only the less-frequent moving ones would come from Sweden. In both cases, the shipment will arrive at the Finnish store the next morning.

4.6.2 Transport costs in other countries

Sweden and Norway already share a basic storage facility in southern Sweden. Therefore, the basic supply chain would not change in the new model. Cost savings would result from the fact that most of the necessary spare parts would be found in the Swedish warehouse, reducing the number of expensive express deliveries from Germany to both countries.

Unfortunately, the Baltic delivery data was very different from the Finnish delivery data, so it was not possible to implement a calculation in the same format. In addition, the express prices obtained for the Baltic were estimates, so the calculation data was only on an order of magnitude - not an exact result. The result of this calculation is shown in table 11.

Table 11. Actual and modeled transport costs change in 2022 in the Baltics (same scale as in previous tables)

	Baltics
All SE modeled transport cost change	2.19
Fast movers in local stock, slow movers in SE modeled transport cost change	1.22

In the Baltic countries, the new supply chain models would change the situation in the same way as in Finland. The Baltic countries have 10 times the volume of Finland, so at group level there would be potential for considerable savings.

In Denmark, spare parts currently come directly from Germany. Again, there was no exact logistical data used for Denmark, but it is cheaper to transport to Denmark from southern Sweden than from North Rhine-Westphalia. For this reason, the new models would also reduce the logistics costs for Denmark.

4.6.3 Write-down costs

There is a massive variation in write-downs at the moment – both in relative terms and in real euros. This is due to both the different practices for removing non-moving products from stock and due to the history of products in different countries. The cost of write-downs can be found in table 12. In Denmark, it should be noted that - unlike in other countries - some of the outlets are owned by independent dealers. The write-down data for the Danish organization was not available for this thesis, but in general, I find that write-downs by dealers are their own loss, while write-downs by company-owned outlets affect their result.

Table 12. Actual central warehouse write-down costs in 2022 (same scale as in previous tables)

	FI	SE	Baltics	Total cost
Write-down cost 2022	0.293	2.442	0.046	2.781

As a general comment, the main reason for the massive differences is the way things are done in different countries. In the future, companies that perform less well on write-downs should learn from those that perform better.

4.6.4 The pooling effect

Compared to the current situation, the pooling effect would be the biggest if all products from the three central warehouses were centralized in one warehouse. As mentioned in section 2.2, the total safety stock would then be reduced by 42% – based on statistical mathematics. If only slow-moving products are centralized, the overall impact is naturally smaller. Cost change can be found in table 13.

Table 13. Change in cost of capital caused by the pooling effect

	Scenario: all from SE CW	Scenario: Fast movers local - slow movers SE CW
Cost of capital change	-0,30	-0,15

To calculate the impact of the pooling effect, it was first necessary to determine the share of the safety stock in the total stock. No service level or standard deviation was available for the different systems, so the share of the safety stock was estimated empirically. It was then calculated how much the change in inventory value due to the pooling effect affected the cost of capital.

4.7 Summary about purchase and logistic costs

The calculations resulted in a summary of the purchase and logistics costs. This allows us to determine the impact of the different models on the overall profitability at company level.

Table 14 summarizes all the calculations. This was done by comparing the 2022 result with the two scenarios selected. The variables considered were:

- purchase cost
- write-downs
- capital cost
- pooling effect
- change of logistic cost
- labor cost in central warehouses

The Swedish warehouse takes its own internal margin from the running of the central warehouse. As this is an internal accounting, the cost can be taken into account or ignored. In any case, stores will incur costs for central storage, whether centralized or decentralized.

Table 14. Summary about purchase and logistic cost

Cost	**2022 cost**	**Scenario: all from SE CW**	**Scenario: Fact mover local - slow movers SE CW**
Purchase cost SE + NO	28.82	-	-
Purchase cost DK	28.64	-	-
Purchase cost SE + NO + DK	-	51.01	51.01
Purchase cost FI	3.81	3.28	3.58
Purchase cost Baltics	38.74	38.66	38.74
Write down SE CW (estimation)	2.44	1.22	1.22
Write down FI CW	0.29	0.00	0.00
Write down Baltic CW	0.05	0.00	0.00
Capital cost (4%) SE CW	0.60	0.90	0.66
Capital cost (4%) FI CW	0.07	0.00	0.04
Capital cost (4%) Baltic CW	0.31	0.00	0.23
Pooling effect	0.00	-0.30	-0.15
Logistic cost change SE & NO	-	no significant change	no significant change
Logistic cost change FI calculation	-	0.30	0.05
Logistic cost change Baltics estimation	-	2.19	1.22
Logistic cost change DK estimation	-	Slightly smaller than now	Slightly smaller than now
Labor cost change SE CW	-	0.20	0.10
Labor cost change FI CW	-	-0.10	0.00
Labor cost change Baltics CW	-	-0.10	0.00
Labor cost change DK	-	0.00	0.00
Total (without SE 15% margin)	103.77	97.27	96.71
SE 15% internal margin	-	10.59	1.82
Total (with SE 15% margin)	103.77	10.85	98.53

The table 14 summarizes all the calculations made.

From Finland's point of view, centralization is worthwhile in any case: lower procurement costs, even taking into account the increased logistics costs, plus additional savings in capital costs and warehouse staff costs.

Sweden, Denmark and Norway would also benefit significantly from lower purchase prices. The Swedish warehouse labor costs would increase, but the impact would be smaller than the benefits of purchase prices.

The Baltic countries would not benefit from their point of view, but they have a very significant sales volume and it is important to include them in the supply chain.

The centralization of fast-moving products would bring a 5-8% advantage to the group's overall profits.

5 Conclusions

In this chapter, I summarize all the calculations and the findings of the literature review. Some observations had to be excluded from the study and some data was inaccurate – these areas are mentioned in the chapter for possible further research. The chapter also concludes with a recommendation for future action.

5.1 Findings

The aim of the study was to find the best supply chain model for spare parts in the seven countries around the Baltic Sea.

If the central warehousing of all spare parts were to be centralized in Sweden, this would lead to a significant increase in transport costs, as a significant proportion of deliveries are express orders that have to be flown to the site. So that model does not make sense.

At group level, **the best solution, according to the calculations, is to decentralize fast-moving products to the three local central warehouses, while slow-moving products are centralized in southern Sweden.** Doing so allows slow-moving products to be bought into the group at a low price, while at the same time benefiting at the local level from a combination of a low purchase price and low freight costs.

When comparing the last lines in table 13, the calculations show a significant potential savings of 5-8% by changing the supply chain.

All countries would benefit from the reduction in purchase prices brought about by the centralization of slow-moving products. The freight benefit would be based on the fact that a larger number of spare parts would be closer – in the south of Sweden – so that the cost of freight would be lower when ordering them from the warehouse in Sweden than when ordering from the supplier in Germany.

The importance of human behavior and leadership cannot be overemphasized. No matter how greatly the D365-system can be tailored, maverick buying or other anti-process activities will cause big problems. Every single employee involved in the procurement process needs to understand the big picture and the benefits to be gained.

5.2 Further studies

For individual land companies, an important factor in profitability is to know how much the internal margin in the Swedish warehouse takes from central storing – and would it be bigger than the costs in their local central warehouse. It is clear, that there are costs for central storage in Sweden and these costs should be passed on in the transfer prices, but the internal margin should only be taken up to the actual costs – not further. Therefore, the exact cost structure of the Swedish warehouse should be determined, and the internal margin should be determined on that basis.

The number of write-downs of non-moving spare parts has been high, especially in Sweden. It is likely that the centralization of slow-moving products will in itself reduce write-downs, but in any case, one area for further study could be on how to reduce write-downs.

For logistics costs, the data was partly inaccurate. Because logistic cost had a big impact on the overall profitability of the different models, this resulted in inaccuracies and the exact boundary between fast and slow movers could not be determined. Further refinement of the model requires a more detailed analysis of country-specific logistics costs. But on the other hand, the real world tends to work somewhat differently from theory, so the supply model must be iterated to its final form in practice anyway.

5.3 Limitations

This study was carried out in the context of the spare parts supply chain, and a typical feature of the business is that a significant proportion of deliveries are made by express orders, often by airfreight. Because of that, freight plays a bigger part in profitability than in many other sectors.

Another factor influencing the results was the fact that the countries of operation are located in seven countries around the Baltic Sea, which makes logistics challenging.

Due to data gaps, the results are not exact, but the overall picture of what to look for is very clear.

5.4 Recommendations

The recommendation is that in the future, slow-moving spare parts should be stored in a central warehouse in southern Sweden and delivered from there according to customer needs. As before, fast-moving spare parts should be stored in the three regional central warehouses in Sweden, Latvia, and Finland.

6 Summary

The aim of this thesis was to investigate how to organize the storage and supply chain of spare parts in a group of machinery trade companies with operations in seven countries around the Baltic Sea. The current operating model consists of three central warehouses, each independently responsible for the storage of spare parts in its own region, based on the sales history of its own region.

The literature review suggests that it is advisable to store high-volume spare parts, which typically have a low coefficient of variation, close to customers. Conversely, low-moving products with a high coefficient of variation should generally be centralized.

Centralizing usually reduces purchase prices and reduces the number of non-moving products, but on the other hand it increases transport costs. However, the literature suggests that there are other factors other than mathematics in play. Centralization often increases hierarchy levels and takes decision-making further away from the customer. It also requires good people management to ensure that everyone understands the potential benefits available.

Following the literature review, two scenarios were modeled based on actual sales in 2022: centralizing all spare parts in one central warehouse and centralizing only slow-moving spare parts while keeping fast-moving parts in regional central warehouses. The final result of the modeling was the same as indicated in the written review, i.e. the best economic result is achieved by centralizing only the slow-moving parts. Since excellent after-marketing is a strategic objective of the company, the calculation was based on the assumption that the customer would receive spare parts at least as quickly as they are currently.

ERP-systems play a key role in planning future warehousing and supply chain management solutions. As a minimum, the ERP-systems in each country must have a view of the balances in all the other countries and the system must be able to plan the storage in all the countries.

The recommendation is to centralize slow-movers to one central warehouse and continue with fast-movers as before.

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