YRKESHÖGSKOLAN NOVIA

Tool Delivery Optimization for Wärtsilä Field Service

Analyzing Freight Dynamics, Costs, and Hub Allocation

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Abstract

This thesis has been conducted on behalf of Wärtsilä Marine Solutions to optimize parts of their tool management process within the Field Service Tools Management department. Currently, finding tools from different locations is challenging due to poor-quality tool registration. Additionally, there are no global processes for tool deliveries and proper reports.

The purpose of this thesis is to provide Wärtsilä with a more detailed overview of their tool deliveries and assess whether it is cost-beneficial to establish a central tool hub based on delivery patterns. Furthermore, the work aims to determine the most optimal location for such a hub.

Various methods have been used to achieve this, including interviews and questionnaires, to gain a better understanding of the process. Relevant data has been collected from databases such as SAP and Salesforce. The Center of Gravity method has been used to calculate the most suitable location for a tool hub.

The conclusions of the thesis include recommendations on how Wärtsilä should consider the results, and the discussion section presents suggestions for further research.

Language: English
Key Words: Tool delivery, tool delivery costs, tool hub, tool management, Center of Gravity method, key success factors

EXAMENSARBETE

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Titel: Verktygsleveransoptimering för Wärtsilä Field Service: Analysering av fraktdynamik, kostnader och hubballokering

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Abstrakt

Detta examensarbete har utförts på uppdrag av Wärtsilä Marine Solutions för att optimera delar av deras verktygshanteringsprocess inom Field Service Tools Management avdelningen. För närvarande är det utmanande att hitta verktyg från olika platser på grund av bristfällig kvalitet på registreringen av verktygen. Dessutom saknas det processer för verktygsleveranser och ordentliga rapporter.

Syftet med detta examensarbete är att ge Wärtsilä en mer detaljerad översikt över deras verktygsleveranser samt att bedöma om det är kostnadseffektivt att etablera en central verktygshubb baserat på leveransmönster. Vidare syftar arbetet till att fastställa den mest lönsamma placeringen för en sådan hubb.

För att uppnå detta har olika metoder använts, inklusive intervjuer och frågeformulär för att få en bättre förståelse av processen. Relevant data har samlats in från databaser som SAP och Salesforce. För att beräkna det mest lämpliga platsen för en verktygshubb har tyngdpunkts metoden använts.

Examensarbetets slutsatser inkluderar rekommendationer för hur Wärtsilä bör beakta resultaten, och i diskussionsavsnittet presenteras förslag på vidare forskning.

Språk: Engelska
Nyckelord: Verktygsleverans, kostnader för verktygsleverans, verktygshubb, verktygshantering, tyngdpunktsmetoden, viktiga framgångsfaktorer

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1 Introduction

This bachelor's thesis is written on behalf of the Field Service Tools Management department at Wärtsilä. The process began with a meeting with the supervisor at Wärtsilä to collectively determine the purpose of the work.

The introduction chapter provides background information on why the thesis was conducted, the problems to be investigated, and the purpose of the work. Chapter two gives a brief overview of Wärtsilä and its operations. Chapter three presents relevant theory for the thesis, while chapter four describes the methods used to achieve the results. The result is presented in chapter five. Chapter six focuses on the conclusion, the information gathered, and the recommendations. Finally, a discussion chapter is included in chapter seven.

1.1 Background

The background to this thesis is that Wärtsilä already 2013 realized the need for improved management of its tools. Wärtsilä is increasingly investing in specialized tools, which requires a better overview of the tool inventory.

Finding tools from different locations is challenging because tool registration is of poor quality. Tool delivery processes and proper reports are also missing.

Wärtsilä plans to establish tool hubs worldwide to centrally store the tools based on their area of use and delivery destination to meet this need. By establishing tool hubs, the availability of the tools would increase, and with sufficient research, delivery costs and times could be reduced by identifying the most optimal location for each tool hub.

The tool management process includes how the tools are delivered and which method is most cost-effective. The tools are currently delivered either through a delivery company or in the service engineer's luggage. The choice between these options is based on various factors such as weight, size, and the level of planning for the specific job.

1.2 Problem Area

Wärtsilä is currently facing several challenges regarding the management of its tools, resulting in a lack of overview of tool handling. The problems that will be focused on in this thesis are:

- Determining the number of tool deliveries from Finland, Vaasa, and the Netherlands, Schiedam.
- Determining the total costs of tool deliveries regarding the above locations.
- Analyzing the tool delivery process for service engineers and their perception of it.
- Investigating the costs of excess baggage on flights for service engineers.
- Evaluating the economic advantages of establishing a tool hub.
- Identifying the most optimal location for a tool hub.
- Assessing whether delivering the tools with a delivery company or a service engineer is more cost-effective.

1.3 Purpose

The purpose of this thesis is to provide Wärtsilä with a more detailed overview of their tool deliveries to assess whether it is economically advantageous to establish a central tool hub based on delivery patterns. To determine the economic advantages of implementing a tool hub, the most optimal location for its placement must be established first. By comparing the current costs of tool deliveries from existing locations with the potential costs of deliveries from a more central location, one can assess if there are economic benefits to centralizing the deliveries. The results of this work will provide Wärtsilä with an improved understanding of tool deliveries and guidance to decide where and whether it is economically advantageous to establish a tool hub.

1.4 Delimitation

This thesis has been limited to solely focusing on tool deliveries from Finland, Vaasa, and the Netherlands, Schiedam. This decision was made because it was not practically feasible to gather information on tool deliveries from other locations within the given timeframe of the project. However, by limiting the analysis to these locations, sufficient information can be collected to achieve the desired outcome.

2 Briefly about Wärtsilä

Wärtsilä is a global leader in innovative technologies and lifecycle solutions for the marine and energy sectors. The company is deeply committed to promoting innovation in sustainable technology and services to support its customers in improving both their environmental and economic performance. (Wärtsilä, 2024)

With a primary focus on two business areas, Wärtsilä Energy and Wärtsilä Marine, the company offers balanced engine-based power plants for future fuels, hybrid solutions, and advanced technology for energy storage and optimization within the energy sector, including the groundbreaking GEMS Digital Energy Platform. In the marine sector, Wärtsilä provides performance-based agreements and lifecycle solutions, spare parts services, and access to an extensive global network of marine experts. (Wärtsilä, 2024)

With 17 800 employees across 280 locations in 79 countries, Wärtsilä is a global presence spanning continents, offering innovative solutions and expertise worldwide. In 2023, Wärtsilä reported a net sales of 6 billion euros. (Wärtsilä, 2024)

3 Theory

This chapter aims to provide relevant theory to support the methods used in Chapter 4 and the results presented in Chapter 5. The presented theory covers tool hubs/distribution centers and data collection systems such as SAP, Salesforce, and Dispatch notes. Furthermore, the chapter will discuss how a Warehouse Management System (WMS) functions and how it can be implemented in Wärtsilä's new tool hubs.

3.1 Tool hubs/distribution centers

As mentioned in the introduction, Wärtsilä plans to place tool hubs worldwide. In Chapter 4.5, the most economically advantageous locations for Wärtsilä to place a tool hub have been calculated based on the center of gravity method. Four different analyses have been conducted based on tool deliveries from both the Netherlands and Finland, with two analyses for each country's distribution center. These analyses have identified the four most optimal geographical locations for placing a tool hub. In this chapter, the concept of a tool hub will be explained, along with why it is economically advantageous for a company to use one.

A tool hub, also known as a distribution center, is an important component in supply chain management. In Wärtsilä's case, a distribution center receives, stores, and distributes tools to projects where service engineers need them. (Dixit, 2023)

A distribution center serves as a centralized location for collecting, sorting, and preparing products for further delivery. Through a distribution warehouse, companies can optimize transportation costs and delivery times. (Dixit, 2023)

A warehouse management system (WMS) can be implemented to optimize inventory management in a distribution warehouse. This system simplifies the company's inventory and logistics operations. Chapter 3.4 provides more details about WMS. (Ongoing, 2024)

The advantages of using a distribution warehouse include streamlined inventory management, faster deliveries, centralized order handling, reduced transportation costs, the possibility of additional services, and scalability. (Luther, 2022)

However, companies must also consider drawbacks. A distribution warehouse must be carefully managed to avoid issues with order handling. Poor organization or warehouse layout can make operations inefficient. (Luther, 2022)

In summary, distribution centers play a critical role in improving supply chain efficiency and business growth by reducing costs and enhancing delivery speeds. They centralize order handling and can effectively manage larger orders. However, they require careful operation and are vulnerable to potential disruptions that can affect their efficiency.

3.2 The strategic importance of the location of a tool hub/distribution center

Chapter 3.1 describes what a tool hub (distribution center) is and this Chapter 3.2 discusses considerations for selecting a location for a tool hub. Chapter 3.5 explains how to determine the most optimal location using the COG (Center of Gravity) method, a mathematical technique often used for selecting distribution center locations. Chapter 4.5 presents analyses based on the COG method.

When choosing the location for a tool hub, various aspects at different decision-making levels must be considered. (J. Heizer, B. Render & C. Munson, 2024)

The key success factors for the decision are:

Country decision

1. Political risks, government rules, attitudes, incentives
2. Cultural and economic issues
3. Location of markets
4. Labor talent, attitudes, productivity, costs
5. Availability of supplies, communications, energy
6. Exchange rates and currency risk

Region/community decision

1. Corporate desires
2. Attractiveness of region (culture, taxes, climate, etc.)
3. Labor availability, costs, attitudes towards unions
4. Cost and availability of utilities
5. Environmental regulations of state and town
6. Government incentives and fiscal policies

7. Proximity to raw materials and customers
8. Land/construction costs

Site decision

1. Site size and cost
2. Air, rail, highway, and waterway systems
3. Zoning restrictions
4. Proximity of services/supplies needed
5. Environmental impact issues
6. Customer density and demographics

(J. Heizer, B. Render & C. Munson, 2024)

In Chapter 4.5, analyses based on the COG (Center of Gravity) method have been conducted, identifying four different locations that would be most optimal for placing a tool hub for Wärtsilä. These locations are presented in Chapter 5.4 and take into account tool deliveries from both Finland and the Netherlands.

Chapter 6 considers which geographical location would be best for a tool hub based on a combination of the results from the COG method and the key success factors.

3.3 Data Collection Systems

Various data systems have been used to collect the necessary information for this thesis. The information has then been processed in Chapters 4.3 and 4.4. The processed information from these chapters is presented later in the results Chapter, Chapter 5. The data systems used to collect information are SAP, Salesforce, and Wärtsilä's web portal for dispatch notes. This chapter will explain how these data systems function.

3.3.1 SAP

Wärtsilä uses SAP, an ERP system, for its operational needs. In this thesis, SAP has been utilized to gather information needed to calculate, among other things, the costs of tool deliveries from Finland and the Netherlands, as detailed in Chapter 4.3. SAP data has also been used to calculate the costs of excess baggage on flights, presented in Chapter 4.4.1. Furthermore, SAP data has been employed to compare these costs with the expenses of tool deliveries by a transportation company, as outlined in Chapter 5.2 and 5.3.

SAP, standing for System Analysis Program Development, is one of the world's leading producers of software for business process management. They develop solutions that facilitate efficient data processing and information flow between organizations. (SAP, Vad är SAP-system, 2024)

Essentially, SAP assists companies and organizations of all sizes and industries in running their operations profitably, adapting continuously, and growing sustainably. (SAP, Vad är SAP-system, 2024)

Using an ERP system within a company entails efficient data management. By utilizing SAP, companies can reduce their administrative and operational costs while obtaining accurate and up-to-date information, which is cost-effective. Other advantages include SAP enabling efficient data management, enhancing transparency, preventing duplication of work, and increasing productivity by making data accessible anytime, anywhere. Additionally, SAP is a highly adaptable ERP system capable of meeting requirements across various business domains and operational conditions. (Kandamplayil, 2023)

3.3.2 Salesforce

Salesforce has been used to gather information about job locations, meaning that the cities where various projects have been carried out have been cross-checked. The results of calculations using Salesforce can be found in Chapter 4.3.

Salesforce is a company that manufactures cloud-based software to help businesses find customers, increase sales, and provide outstanding service to their clients. Their product suite, Customer 360, integrates teams in sales, service, marketing, commerce, and IT to provide a unified view of all customer information. Salesforce helps businesses deepen their relationships with both customers and employees. (Salesforce, 2024)

Salesforce is a CRM system that manages customer data and provides businesses with a comprehensive view of all interactions and relationships that customers have with the company. (Columbus, 2021)

Salesforce's benefits include the ability to build strong customer relationships by consolidating all customer data, interactions, orders, and cases on a simple and easily accessible platform. Companies can reduce administrative work and leverage the technical advantages. (Columbus, 2021)

3.3.3 Wärtsilä web portal over dispatch notes

With the help of Wärtsilä's internal dispatch notes system, the Finnish tool deliveries' destinations have been verified to subsequently utilize this information for calculations in Chapter 4.3. Through this system, the number of tool deliveries sent to each city has also been determined, aiding in the calculations in Chapter 4.5.1 where the center of gravity has been determined based on the tool deliveries. This has enabled determining where it would be most optimal to place a tool hub based on the Finnish tool deliveries.

3.4 Warehouse Management Systems

In this chapter, the first step is to explain what a WMS (Warehouse Management System) is to provide a thorough understanding of the subject. Next, the possibility of implementing a WMS in Wärtsilä's new tool hubs will be examined, along with how this would improve tool management.

Chapter 6 describes the current problems coordinators and service engineers experience with poor control over tools. These problems could be solved with the help of a WMS. To begin, the following sections will explain what a WMS is.

Tool warehouses form the backbone of many manufacturing and maintenance companies, and efficient management is crucial to ensuring smooth production and service processes. In this pursuit of efficiency and precision, the warehouse management system plays a crucial role by offering tool warehouses a powerful and sophisticated software solution to optimize their material flows.

A warehouse management system for tool warehouses is not just a tool but a partner designed to meet this area's specific needs and challenges. By integrating advanced features such as tool tracking, inventory optimization, and work order management, a WMS empowers you to handle tools and accessories with a higher degree of efficiency and accuracy.

One of the primary advantages of a WMS for tool warehouses is its ability to optimize inventory utilization and improve the availability of key tools and materials. By providing real-time data on inventory status, tool location, and demand, the system can help reduce the time spent searching for tools and increase the availability of necessary materials for production and maintenance.

A WMS for tool warehouses also enables more efficient work order management by automating picking, packing, and delivery processes. By providing clear instructions and guidance to staff, the system reduces the risk of errors and delays in handling work orders, resulting in faster and more efficient production and maintenance processes.

Another advantage of a WMS for tool warehouses is its ability to track and manage the tool lifecycle, including maintenance and calibration. Automating the monitoring of tool measurements and maintenance schedules ensures that tools are in optimal condition and reduces the risk of downtime due to faulty or unavailable tools.

In summary, a warehouse management system is an indispensable solution for companies with tool warehouses seeking to optimize their inventory management and improve their production and maintenance efficiency. By offering advanced features for tool tracking, inventory optimization, and work order management, a WMS enables a smoother and more profitable operation for businesses in this sector. (SAP, What is a warehouse management system (WMS)?, 2024) (Hopstack, 2024) (Ongoing, 2024) (Bitlog, 2024)

Now that one has explained what a WMS is and how it can help companies manage their tools, one will examine the possibility of implementing such systems in Wärtsilä's new tool hubs.

As mentioned earlier in this chapter, tool management is problematic. Interviews and questionnaires, documented in Chapters 4.1 and 4.2, reveal a lack of control over the tools. Good tool management from the start is important to prevent the same issues from arising in the new tool hubs.

One of the problems was that the location of the tools was not always known, but with the help of a WMS, Wärtsilä can more easily track where the tools are. As previously described, there is the ability to track and manage the tools, which would improve control over them.

Wärtsilä can automate maintenance schedules by using a WMS. This would ensure that the tools are kept in optimal condition and reduce the risk of them being defective or unavailable when needed.

3.5 The Center of Gravity Method

In Chapter 4.5, the geographically optimal location for a tool hub will be investigated, considering Wärtsilä's needs for tools within the countries and cities where these tools are used. The center of gravity method will be used to determine the most optimal location.

Firstly, let's explain the center of gravity. The center of gravity is the point where transportation costs are minimal or the point where the weighted distances from all nodes in a distribution network are minimal. (Brandt, 2024)

The center of gravity method is often used to determine where to place a new distribution center, as is the case in this thesis. (Brandt, 2024)

Now that the center of gravity is understood, it is important to consider its benefits. Firstly, businesses can significantly reduce transportation costs by strategically locating their distribution centers using the center of gravity method, leading to substantial savings. Additionally, proximity to customers results in shorter lead times and faster deliveries, which improves service levels and increases customer satisfaction. (Adlyjess, 2023)

The method also facilitates network restructuring and planning for geographic expansion, allowing companies to adapt to changing market conditions and ensure their distribution networks remain flexible. (Adlyjess, 2023)

Another essential advantage is risk mitigation. By spreading distribution centers across different regions, businesses can reduce supply chain risks and ensure continuity of operations in case of disruptions. (Adlyjess, 2023)

Companies can optimize their operations and maintain competitiveness in today's dynamic business environment by employing the center of gravity method. (Adlyjess, 2023)

The center of gravity method is based on placing the terminal at the center of gravity concerning customers' needs for goods in a given distribution area. The optimal location for the terminal can be determined from three different perspectives using the center of gravity model. One can determine the optimal location based on the result that minimizes transportation work, minimizes transportation costs, or minimizes environmental impact. Combinations of these aspects also make it possible to determine the optimal location. By placing the terminal at the center of gravity, one can minimize the total transportation work, transportation costs, and environmental impact of distribution. (Lumsden, 2019) (J. Heizer, B. Render & C. Munson, 2024)

One can use the method to calculate the optimal location of a terminal for three different models:

- One terminal – multiple customers (*n*)
- One supplier (*m*) – one terminal – multiple customers (*n*)
- Multiple suppliers (*m*) – one terminal – multiple customers (*n*)

The method assumes that the positions of all involved units can be placed in a coordinate system (X_i, Y_i). Simultaneously, only one terminal (X, Y) should be placed and used in the total system for goods distribution. The number of consumers (*n*) and producing units (*m*) to the terminal is unlimited. (Lumsden, 2019) (Kaurila, 2018)

3.5.1 Transportation work

An important and objective component in establishing a quantitative method for locating a terminal is the direct transportation work required to distribute goods from the terminal to customers. According to the customers' needs, the goods in specified quantities (V_{ki}) should be transported in various relationships to the positions of different customers (X_{ki},Y

$_{ki}$). The volume can also be expressed in other quantitative terms, such as the number of passengers, containers, or pallets. (Lumsden, 2019) (Remesaho, 2019)

One terminal – multiple customers

In the "one terminal – multiple customers" model, the terminal serves as a central point for distribution to several customers within a specific area. The transportation work should be minimized based on the customers' demand for goods. By assigning each customer a weight corresponding to their demand (V_{ki}) and a geographical position (X_{ki}, Y_{ki}), each customer's position is given a specific significance ($X_{ki} * V_{ki}$, $Y_{ki} * V_{ki}$) for the terminal's location, depending on the magnitude of the goods demand. (Lumsden, 2019) (Remesaho, 2019)

The total needs of customers ($\sum V_{ki}$) are distributed from the terminal. Consequently, the terminal's importance corresponds to this total demand ($\sum V_{ki}$), and its optimal location (X, Y) can be determined based on the customers' relative significance. The terminal's relative significance should be of the same magnitude as the customers' total significance. The optimal localization must be calculated for one coordinate at a time. (Lumsden, 2019) (Remesaho, 2019)

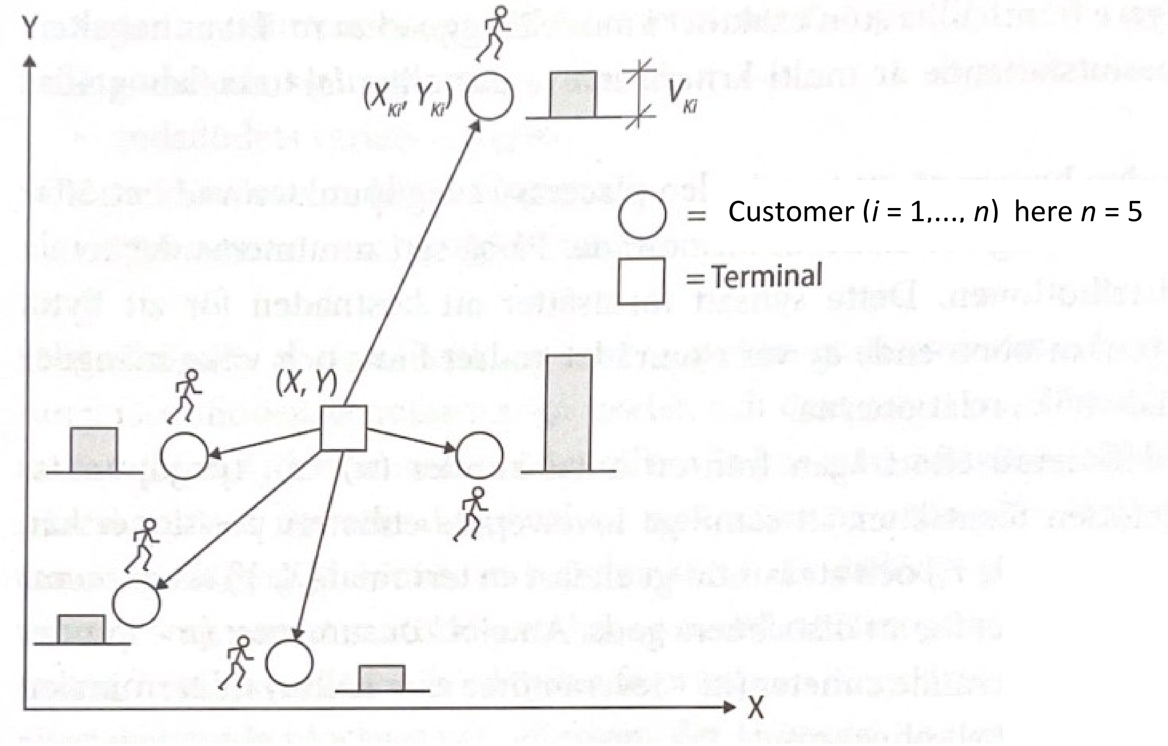

Figure 1: Terminal location based on transportation work - a terminal with multiple customers (Lumsden, 2019)

The terminal's relative significance = Customers' relative significance =>

$$\begin{cases} X * \sum_{1}^{n} V_{ki} = \sum_{1}^{n} (X_{ki} * V_{ki}) \\ Y * \sum_{1}^{n} V_{ki} = \sum_{1}^{n} (Y_{ki} * V_{ki}) \qquad i = 1, \ldots\ldots, n \end{cases}$$

V_{ki} = The volume from terminal to customer i

X_{ki} = X – coordinate for customer i

Y_{ki} = Y – coordinate for customer i

(Lumsden, 2019) (Kaurila, 2018)

By reformulating this relationship, the coordinates of the terminal can be determined for the optimal localization (*X*, *Y*) of the terminal concerning transportation work.

$$\begin{cases} X = \dfrac{\sum(X_{ki} * V_{ki})}{\sum V_{ki}} \\ \\ Y = \dfrac{\sum(Y_{ki} * V_{ki})}{\sum V_{ki}} \qquad\qquad i = 1, \ldots\ldots, n \end{cases}$$

(Lumsden, 2019) (Kaurila, 2018)

A terminal's localization and subsequent establishment are processes that essentially occur only once. Customers' goods needs may change, leading to a change in the optimal localization. In other words, according to the models, the obtained localization should not be taken as an absolute requirement for geographic placement but rather as an indication of a suitable location for establishment. (Lumsden, 2019) (Kaurila, 2018)

One supplier – one terminal – multiple customers

With the model "one supplier – one terminal – multiple customers," a central point for distribution is to be determined. The producer (X_l, Y_l) delivers goods to multiple customers through the terminal. The producer can be compared to a regular customer, except that the goods are delivered to the terminal from the producer. The volume of goods from the supplier (V_l) corresponds to the aggregated customer delivery needs ($\sum V_{ki}$). With the relative significance of customers and the supplier determined, the geographically optimal location of the terminal (X, Y) concerning transportation work can be established. (Lumsden, 2019) (Kaurila, 2018)

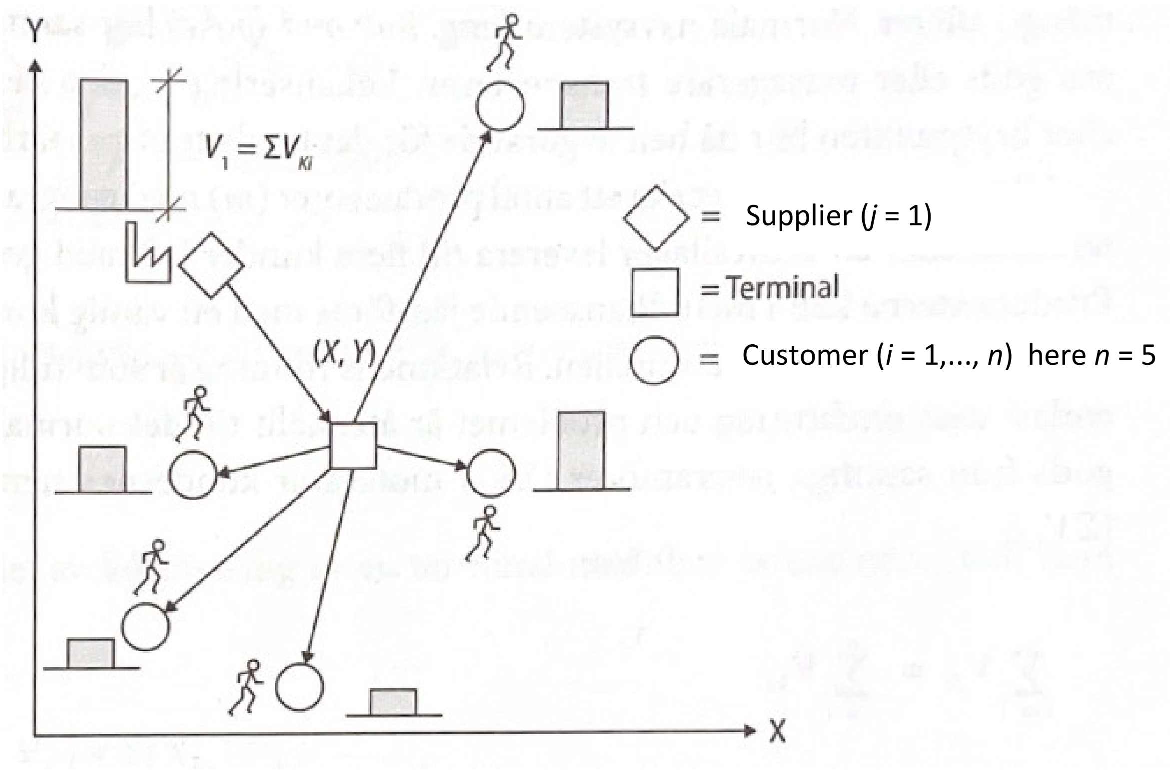

Figure 2: Terminal location based on transportation work - a terminal with one supplier and multiple customers (Lumsden, 2019)

The terminal's relative significance should carry the same weight as the total significance of both customers and the supplier. The terminal's weight is doubled because the entire volume of goods entering the terminal (V_l) also exits the terminal ($\sum V_{ki}$). (Lumsden, 2019) (Kaurila, 2018)

$$\begin{cases} Y * (V_l + \sum V_{ki}) = Y_l * V_l + \sum (Y_{ki} * V_{ki}) \\ Y * (V_l + \sum V_{ki}) = Y_l * V_l + \sum (Y_{ki} * V_{ki}) \qquad i = 1,\ldots\ldots, n \end{cases}$$

$V_l =$ The volume from the supplier to the terminal

$X_l =$ X – coordinate for the supplier

$Y_l =$ Y – coordinate for the supplier

(Lumsden, 2019) (Kaurila, 2018)

By reformulating this relationship, the terminal coordinates can be determined for the optimal localization (X, Y) of the terminal concerning transportation work when there is one supplier and multiple customers.

$$\begin{cases} X = \dfrac{X_l * V_l + \sum(X_{ki} * V_{ki})}{(V_l + \sum V_{ki})} \\ \\ Y = \dfrac{Y_l * V_l + \sum(Y_{ki} * V_{ki})}{(V_l + \sum V_{ki})} \qquad i = 1,\dots\dots, n \end{cases}$$

(Lumsden, 2019) (Kaurila, 2018)

This method is proper when a manufacturer wants to position a distribution center for an entire continent, as well as for a food producer looking to manage distribution from a local hub. (Lumsden, 2019) (Kaurila, 2018)

3.5.2 Transportation costs

The direct transportation work of collecting and distributing goods is an essential and objective criterion when locating a terminal. This direct transportation work incurs transportation costs. To keep transportation costs down, one should strive to align capacity with the needs of each relationship. This means that the transportation costs from the supplier/suppliers (T_{lj}) to the terminal and from the terminal to the customers (T_{ki}) must be considered. These costs are assumed to be variable in their structure. However, the magnitude can vary in supplier and customer relationships. Therefore, the significance of each supplier and customer must be a combination of volume and the variable cost component. In general, the volumes (V_{lj} or V_{ki}) in previous cases can be replaced with a modified significance linked to the variable transportation cost in the relationship between the supplier and terminal ($V_{lj} * T_{lj}$) or between the terminal and the customer ($V_{ki} * T_{ki}$). (Lumsden, 2019) (Kaurila, 2018)

One terminal – Multiple customers

As mentioned earlier, the terminal functions as the center for distribution for several customers within a specific area. The total transportation cost should be minimized based on the customers' demand for goods. Suppose each customer is assigned a weight corresponding to their demand and transportation cost ($V_{ki} * T_{ki}$), geographically located at the customer (X_{ki}, Y_{ki}). In that case, each customer has a specific but varying significance for the terminal's localization (X_{ki} * V_{ki} * T_{ki}, Y_{ki}, V_{ki}, T_{ki}). With this approach, each customer has a varying significance for the terminal's localization depending on the size of the goods demand and the transportation cost. (Lumsden, 2019) (Kaurila, 2018)

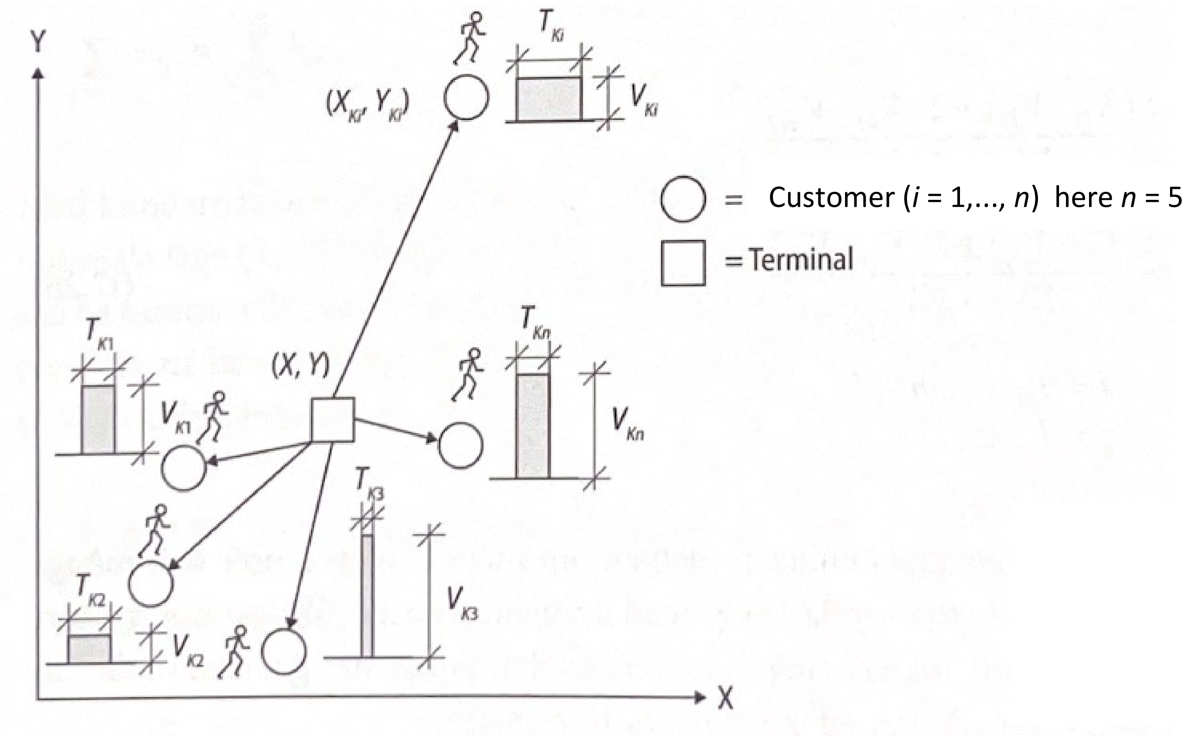

Figure 3: Terminal location based on transportation cost - a terminal with multiple customers (Lumsden, 2019)

The total needs of customers (∑ V_{ki}) are distributed from the terminal. The significance of the terminal corresponds to the total transportation cost {∑ V_{ki} * T_{ki})} and is geographically located at the assumed localization (X, Y). The terminal's relative significance is linked to this weighting {X * ∑(V_{ki} * T_{ki})}. The geographically optimal location of the terminal (X, Y) concerning transportation costs can be determined with customers' newly established relative significance. The terminal's relative significance should carry the same weight as the total significance of customers because all deliveries originate from the terminal:

$$
\begin{cases}
X * \sum (V_{ki} * T_{ki}) = \sum (X_{ki} * V_{ki} * T_{ki}) \\
Y * \sum (V_{ki} * T_{ki}) = \sum (Y_{ki} * V_{ki} * T_{ki}) \qquad i = 1, \ldots\ldots, n
\end{cases}
$$

T_{ki} = Variable transportation cost per ton-kilometer to customer i.

(Lumsden, 2019) (Kaurila, 2018)

By reformulating this relationship, the coordinates of the terminal can be determined for the optimal localization (X, Y) of the terminal concerning transportation cost.

$$\begin{cases} X = \dfrac{\sum(X_{ki} * V_{ki} * T_{ki})}{\sum(V_{ki} * T_{ki})} \\ \\ Y = \dfrac{\sum(Y_{ki} * V_{ki} * T_{ki})}{\sum(V_{ki} * T_{ki})} \qquad i = 1, \ldots\ldots, n \end{cases}$$

(Lumsden, 2019) (Kaurila, 2018)

There may be variations in transportation costs over time in each relationship for the specific situation. This means that the deviation in localization based on transportation costs can be drastic compared to the corresponding deviation based on transportation work. (Lumsden, 2019) (Kaurila, 2018)

One supplier – one terminal – multiple customers

In a manner similar to the previous case, the method can be used to determine a central point focusing on transportation costs between the producer (X_l, Y_l) and the terminal and multiple customers. The producer can be compared to a regular customer, except that the goods are delivered from the producer to the terminal. The volume of goods from the supplier (V_l) corresponds to the aggregated customer delivery needs ($\sum V_{ki}$). Typically, the delivery is a large and concentrated flow, resulting in low transportation costs (T_l). The significance of this volume is linked to the transportation cost between the supplier and the terminal ($T_l * V_l$). The geographically optimal location of the terminal (*X*, *Y*) concerning transportation costs can be determined when the relative significance of customers and the supplier is established. (Lumsden, 2019) (Kaurila, 2018)

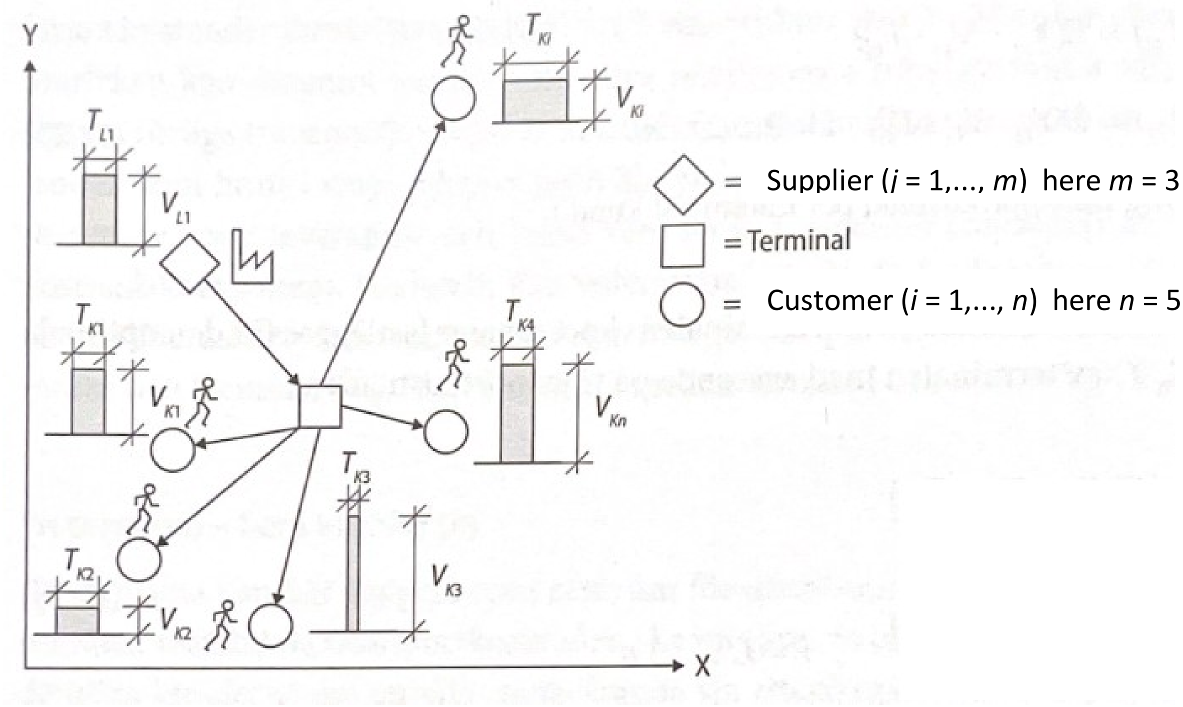

Figure 4: Terminal location based on transportation cost - a terminal with one supplier and multiple customers (Lumsden, 2019)

The terminal's relative significance should have the same magnitude as the total significance of customers and the supplier. The terminal is weighted for both incoming and outgoing transportation costs $\{T_1 * V_1 + \sum(V_{ki} * T_{ki})\}$. (Lumsden, 2019) (Kaurila, 2018)

$$\begin{cases} X * \left[T_l * V_l + \sum(V_{ki} * T_{ki})\right] = X_l * T_l * V_l + \sum(X_{ki} * T_{ki} * V_{ki}) \\ Y * \left[T_l * V_l + \sum(V_{ki} * T_{ki})\right] = Y_l * T_l * V_l + \sum(Y_{ki} * T_{ki} * V_{ki}) \end{cases}$$

V_l = The volume from the supplier to the terminal

X_l = X – coordinate for the supplier

Y_l = Y – coordinate for the supplier

T_l = Variable transportation cost per ton-kilometer for the supplier

By reformulating this relationship, the terminal coordinates can be determined for the optimal localization (*X*, *Y*) of the terminal concerning transportation cost when there is one supplier and multiple customers.

$$
\begin{cases}
X = \dfrac{X_l * T_l * V_l + \sum(X_{ki} * T_{ki} * V_{ki})}{T_l * V_l + \sum(V_{ki} * T_{ki})} \\
\\
Y = \dfrac{Y_l * T_l * V_l + \sum(Y_{ki} * T_{ki} * V_{ki})}{T_l * V_l + \sum(V_{ki} * T_{ki})} \qquad i = 1, \ldots\ldots, n
\end{cases}
$$

(Lumsden, 2019) (Kaurila, 2018)

It is a highly efficient method that can be used at various levels to place a distribution center for an entire continent and manage distribution in a local food distribution scenario. (Lumsden, 2019) (Kaurila, 2018)

4 Method

This chapter describes the various methods that have been used to achieve the results presented in Chapter 5. The methods used include interviews, questionnaires, data collection using SAP, Salesforce, and dispatch notes, random samplings, and the center of gravity method.

4.1 Interviews

To gain a deeper understanding of the tool management process, approximately 15 interviews have been conducted with tool owners, coordinators, and service engineers. Most of the interviews have been conducted with individuals in Finland. However, some have also been conducted with representatives from the Netherlands and the United Kingdom to investigate potential differences in the tool management process between different geographical areas.

4.1.1 Tool Owners

The responses from the interviews with the tool owners are presented below in the form of a bullet list:

- The number of monthly tool deliveries with a transportation company varies from 0 to 20 per month, with an average delivery frequency of 10 per month.

- The number of tools typically delivered per delivery varies from 1 to 10. However, a Finnish tool owner estimates that during longer field service jobs, between 20 and 60 tools can be delivered per delivery once per quarter.
- Russia, Brazil, Argentina, Pakistan, and Bangladesh, were mentioned as problematic areas to send tools.
    - Russia mentioned due to the world situation and difficulties regarding paperwork.
    - Brazil mentioned due to difficulty with visas, customs, and tax issues.
- Less than 10-15 % of outgoing tool deliveries are delayed.
- Returned deliveries are delayed much more frequently. A Finnish tool owner emphasized the importance of follow-up regarding returned tool deliveries.
- There are relatively few urgent deliveries attributed to effective planning and communication.
- According to tool owners, the biggest challenges in the tool management process are delays in tool return and keeping them in good condition.

4.1.2 Coordinators

The responses from the interviews with the coordinators are presented below in the form of a bullet list:

- If possible, tools are transported in the service engineers' luggage.
- Sometimes, it is necessary for the tools to be delivered by a transportation company.
    - Factors such as the weight of the tools and the amount of luggage a service engineer has already when traveling, decide how the tools are being delivered.

- When tools are transported with a transportation company, it is primarily by airfreight, followed by truck and rarely by sea freight.
- To get estimated freight costs, the Finnish coordinators can contact the Finnish tool owners.
    - An estimate is not always necessary.
- The customer and Wärtsilä share the responsibility for return deliveries equally.
- According to the coordinators, the biggest problem in the tool management process is the long time for return deliveries and the lack of an overall picture of the tools currently.

4.1.3 Service engineers

Three service engineers were interviewed in total, two from Finland and one from the Netherlands. One of the Finnish service engineers works with marine installations, while the other specializes in electrical and automation engineering. The interview responses are presented in a bullet list below:

- In the Netherlands, the coordinator usually plans the tools for a service assignment.
- In Finland, the service engineer often plans the tools themselves.
    - Electrical and automation engineers do not require as much planning as those working with marine installation.
- Service engineers typically carry hand tools in their toolboxes, and they always bring them with them on assignments.
- Service engineers usually have to pay for excess baggage on flights.
    - Anything over 27 kg is considered excess, with the maximum limit being 32 kg.
- Bringing tools as luggage is relatively simple, but having more than three bags can get tricky. Additionally, bringing chemicals on flights can be complicated.

- The service engineer from the Netherlands and the one working with marine installation mostly use customer’s tools.
    - They feel confident doing so, primarily since they usually work on newer installations.
    - When working on older installations, they feel less secure.
- The service engineers in the electrical and automation field only sometimes use customers' tools.
    - Usually, when they use more extensive tools, the customer provides them.

4.2 Questionnaire

A survey regarding the handling of tools during service engineers' work trips was sent to approximately 75 service engineers, and 35 responses were received. All exact responses to the survey questions are attached in Appendix 1, 2, and 3.

- The survey results indicate that most service engineers plan their tools before a job trip, with only a few exceptions where they do not plan their tools.
- Service engineers almost always bring their personal toolboxes on work assignments.
- The tools they bring are usually general tools or hand tools such as:
    - Electrical instruments
    - Tools for sensor assembly/cable laying
    - Wrenches
    - Screwdrivers
    - Multimeters
    - Measuring tools
    - Sometimes special tools

  - Appendix 2 shows all responses where the service engineers have specified which tools they use.

- Most service engineers find it sometimes complicated to bring their tools when traveling.
- Occasionally, the tools needed are unavailable on-site in time.
- The majority of the service engineers have to pay for excess baggage on flights.
- The customer's tools are used sparingly, but it emerged that they are still used.
- The responses were consistent regarding how confident they feel about using the customer's tools, but slightly more responses indicated that most of the service engineers feel confident.
- As the final question in the survey, the question was asked about what they consider the biggest problem in the tool management process:
  - Many mentioned that it is difficult to find and gather all the necessary tools before going on a job trip.
  - Sometimes, their luggage goes missing at the airport.
  - The tools needed are not always available, requiring them to go to different stores to find all the tools needed for the work trip.
  - The problem of tools not being in good condition is considered a challenge.
  - In Appendix 3, all responses can be seen.

4.3 Calculation of costs for tool delivery, including quantity and delivery locations

This section will analyze relevant data regarding outgoing tool deliveries dispatched in 2023 to gain insights into the costs, the number of deliveries, and the destinations for these shipments. The logistics centers included in the calculation will be the Finnish logistics center in Vaasa and the Dutch logistics center in Schiedam. In Chapter 4.5, this data will be used to calculate the centroids of the tool deliveries dispatched from the logistics centers in Finland and the Netherlands. The center of gravity method will be applied to perform these calculations.

4.3.1 Calculation of the logistics center in Vaasa, Finland

Initially, data was collected about the logistics center in Vasa. This data included specific information such as the number of outgoing tool deliveries made in 2023 and their destinations. Additionally, the costs for both inbound and outbound tool deliveries were calculated.

To determine the number of outgoing tool deliveries for 2023, a list of orders with booked outgoing delivery costs was needed. The process started by reviewing all dispatch notes from 2023 and transferring this data to an Excel spreadsheet from Wärtsilä's dispatch note web portal. Since dispatch notes did not exclusively cover tool deliveries for the specific plant, obtaining an additional Excel list from SAP with all orders from 2023 for the relevant facility was necessary. However, the SAP list included not only orders with tool delivery costs.

Since both lists contained order numbers, the Excel VLOOKUP function was used to match and create a new list with only the rows that had matching order numbers. This new list contained only orders with booked tool deliveries.

In the new Excel list, orders were filtered based on the coordinator who created them. Orders created by irrelevant coordinators were filtered out, resulting in a list of 31 orders.

Each order number was individually reviewed in Wärtsilä's dispatch note web portal to determine the number of outgoing deliveries per order. At the same time, the number of outgoing deliveries for each order was noted. In total, 38 outgoing tool deliveries had been carried out for all 31 orders, according to data from SAP and Wärtsilä's dispatch note web portal.

During this process, the delivery address for each tool delivery was also noted from Wärtsilä's dispatch note web portal, allowing the mapping of each delivery to a specific country and city. In Table 1, the number of tool deliveries transported to various countries is presented, along with the total quantity of tool deliveries from Wärtsilä Finland's logistics center during the year 2023.

Table 1: List of all outbound tool deliveries from Wärtsilä Finland's logistics center during 2023, including the number of deliveries and destination locations.

	Country and city	Latitude	Longitude	Amount of deliveries
1	Estonia, Tallinn	59,43739	24,7499	8
2	Norway, Bergen	60,39114	5,31953	3
3	Finland, Vaasa	63,09429	21,62028	2
4	Finland, Vantaa	60,29217	25,0357	2
5	Italy, Palermo	38,11513	13,36964	2
6	Malta, Kalafrana	35,81603	14,53769	2
7	United States, Lucedale	30,92529	-88,58827	2
8	Åland Islands, Möckelö	60,10035	19,89985	1
9	Finland, Pietasaari	63,67411	22,69266	1
10	Finland, Turku	60,45124	22,26471	1
11	French Polynesia, Punaauia	-17,59393	-149,61197	1
12	Germany, Berlin	52,51775	13,39014	1
13	Greece, Piraeus	37,94349	23,64637	1
14	Italy, Genova	44,40527	8,94713	1
15	Italy, Trieste	45,64941	13,77473	1
16	Japan, Kawasaki	35,57051	139,63239	1
17	Norway, Rubbestadneset	59,81628	5,26482	1
18	Norway, Søvik	62,54733	6,27825	1
19	Poland, Szczecin	53,42795	14,55458	1
20	Singapore, Pandan Cres	1,30479	103,76206	1
21	Spain, Denia	38,83891	0,10488	1
22	Netherlands, Hoofddorp	52,30631	4,68984	1
23	United Arab Emirates, Dubai	25,2124	55,27549	1
24	United States, Harvey Louisiana	29,90363	-90,0753	1
Logistics center	Finland, Vaasa	63,09374	21,62511	38

Each order number was individually reviewed using SAP to calculate the delivery costs. The total delivery costs for all 38 outbound tool deliveries amounted to 41 012,24 €, while the costs for inbound tool deliveries were 18 179,48 €. These costs were recorded in the latest Excel file, which also recorded the number of deliveries and the destination for each delivery.

Table 2: Total inbound and outbound tool delivery costs for the Finnish distribution center year 2023

Total delivery costs 2023	
Total inbound delivery costs	18 179,48 €
Total outbound delivery costs	41 012,24 €
Total inbound & outbound delivery costs	59 191,72 €

Table 2 displays both inbound and outbound delivery costs for the logistics center in Finland, Vaasa 2023.

4.3.2 Calculation of the logistics center in the Netherlands

The same data regarding tool deliveries that was collected for the logistics center in Vaasa, Finland, was also compiled for Wärtsilä's logistics center in the Netherlands. This data includes information on the number of outbound tool deliveries, their destination locations, and costs for both incoming and outgoing tool deliveries. However, more detailed data was collected for the Netherlands because they have an external logistics center where the tools are stored, requiring a more in-depth investigation than Finland's logistics center.

Wärtsilä's external logistics center in the Netherlands is managed by the company Snelweg. After analyzing all orders with tool deliveries, it was noted that Snelweg only transports Wärtsilä's tools within the Netherlands. Other transport companies, such as DHL, FedEx, and Logicall Airfreight, handle all other tool deliveries destined outside the Netherlands.

The process for collecting data for the Netherlands tool deliveries differed from that in Finland. It was significantly more complicated and required several discussions and meetings with various individuals from Wärtsilä's team in the Netherlands. In the end, it was decided to contact Snelweg directly, which is responsible for handling Wärtsilä's tools in the Netherlands.

After two meetings with the warehouse manager at Snelweg, an agreement was reached on the necessary data to continue the process. The warehouse manager sent a report containing all tool deliveries they had carried out for Wärtsilä. The report was filtered to display Wärtsilä's service order numbers, enabling the review of all tool delivery orders in SAP.

Subsequently, all 2023 Dutch service orders for facility NL13, which had tool delivery costs registered according to the report from Snelweg, were compiled into an Excel spreadsheet. The list also contained orders related to the workshop. However, since tool delivery costs for the workshop were not of interest, these orders were filtered out by extracting a new list from SAP containing only relevant work centers.

The final Excel list of tool deliveries for The Netherlands (related to facility NL13) in 2023 is a crucial document that now contains only relevant orders. It provides a comprehensive overview of the orders and has 104 order numbers, which will be instrumental in our cost calculation process.

The next step in the process is to calculate all delivery costs, both inbound and outbound. Each order number from the final Excel list of Dutch (facility NL13) tool deliveries for 2023 was manually checked in SAP. Since Snelweg handles Wärtsilä's tools, they charge a handling fee in addition to their transport costs. Therefore, it was decided to separate Snelweg's transportation and handling costs to understand how much Wärtsilä pays for their services. As previously mentioned, Snelweg only transports within the Netherlands. The remaining delivery costs from DHL, FedEx, and Logicall Airfreight, which usually handle deliveries outside the Netherlands, were noted separately.

Below is an example of how delivery costs may appear when booked on an order. In this specific case, the costs for "Logicall Airfreight B.V." have been calculated separately, as well as the costs for "Snelweg Logistics B.V." (handling costs) and finally, the costs for "Snelweg Transport & Koeriersservice" (transport costs). The costs for "Wärtsilä Services Switzerland AG" are irrelevant and, therefore, have not been included in any calculation.

Σ Value in Obj. Crcy	ObCur	Name of offsetting account
219,73	EUR	Accrued accounts payable, external, manual
219,73-	EUR	
219,73	EUR	Logicall Airfreight B.V.
6,04	EUR	Snelweg Logistics B.V.
6,04-	EUR	
6,04	EUR	
102,92	EUR	
76,00	EUR	
54,80	EUR	
145,52	EUR	Snelweg Transport & Koeriersservice
58,21	EUR	
36,02	EUR	Wärtsilä Services Switzerland AG
25,10	EUR	
724,34	**EUR**	

Figure 5: Example of how delivery costs can be booked on an order (this is order 11223558)

Below in Table 3 and Table 4 are all inbound and outbound tool delivery costs calculated for the Netherlands (related to facility NL13) in 2023.

Table 3: Detailed inbound and outbound tool delivery costs 2023 for the Netherlands (facility NL13)

Inbound Delivery Costs 2023			Outbound Delivery Costs 2023		
Delivery costs (Outside NL)	**Snelweg delivery costs (within NL)**	**Snelweg handling costs**	**Delivery costs (Outside NL)**	**Snelweg delivery costs (within NL)**	**Snelweg handling costs**
39 692,35 €	37 029,10 €	12 297,38 €	17 187,20 €	18 464,15 €	475,84 €

Table 4: Total inbound and outbound tool delivery costs 2023 for the Netherlands (facility NL13)

Total delivery costs 2023	
Total inbound delivery costs	89 018,83 €
Total outbound delivery costs	36 127,19 €
Total inbound & outbound delivery costs	125 146,02 €

Table 5: List of all outbound tool deliveries from Wärtsilä Netherlands's logistics center during 2023, including the number of deliveries and destination locations.

	Country and city	Latitude	Longitude	Amount of deliveries
1	Lithuania, Klaipeda	55,70471	21,14246	9
2	Singapore	1,27828	103,84968	8
3	Spain, Las Palmas	28,12774	-15,43294	3
4	Netherlands, Harlingen	53,17563	5,42602	3
5	Netherlands, Kampen	52,55756	5,90817	3
6	Netherlands, Roden	53,13815	6,43199	2
7	Netherlands, Amsterdam	52,36595	4,90804	2
8	Netherlands, Kruiningen	51,44934	4,03369	2
9	United Arab Emirates, Dubai	25,22125	55,26572	1
10	Philippines, Manila	14,60296	120,98973	1
11	Spain, Astillero	43,39779	-3,82126	1
12	Netherlands, Dordrecht	51,81496	4,69512	1
13	Poland, Gdansk	54,34649	18,65144	1
14	Italy, Trieste	45,65013	13,77851	1
15	Netherlands, Zwijndrecht	51,8113	4,62769	1
16	Netherlands, Zwolle	52,51704	6,08433	1
17	USA, Philadelphia	39,95435	-75,12627	1
18	England, Fareham	50,85485	-1,18887	1
19	Germany, Berlin	52,5117	13,39987	1
20	Romania, Galati	45,43561	28,00423	1
21	Germany, Hamburg	53,54914	9,98821	1
Logistics center	Netherlands, Schiedam	51,9166	4,39856	45

In Table 5, the number of tool deliveries transported to various countries is presented, along with the total quantity of tool deliveries from Wärtsilä Netherlands's logistics center during the year 2023.

4.4 Data collection over excess baggage on flight costs

According to the responses to the questionnaire sent to the service engineers (Appendix 1), most service engineers always bring their personal toolbox with them when they are out on a job. Based on interviews with some of the service engineers and coordinators, it was discovered that they also bring along tools beyond those in their personal toolboxes.

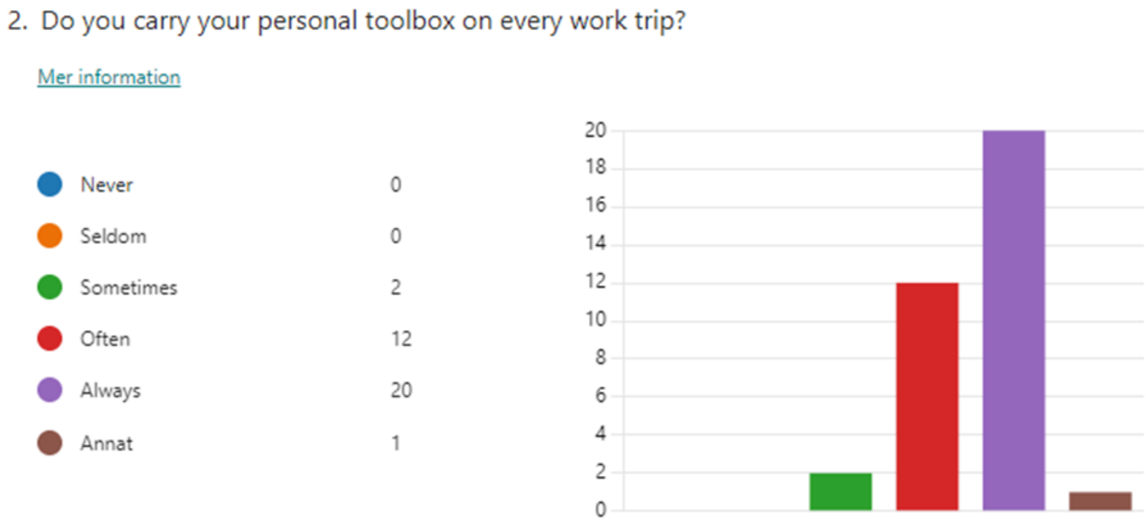

Figure 6: The results for question 2 from the questionnaire sent to the service engineers

As most assignments are carried out abroad, service engineers must bring their personal toolbox and possibly other tools as checked baggage when flying to those locations. The questionnaire included a question about how often they need to pay for excess baggage during flights, and the response indicated that almost all service engineers frequently or always have to pay for excess weight.

Figure 7: The results for question 4 from the questionnaire sent to the service engineers

The responses from the questionnaire sent to the service engineers led to a closer examination of the costs associated with excess baggage on flights to understand better how these expenses were distributed and to assess whether it would be more cost-effective to send the tools to the job location instead using an external freight company such as DHL or FedEx, for instance. A detailed analysis was conducted on the excess baggage costs for flights throughout the entire year of 2023 for Finnish orders (related to facility FI14).

4.4.1 Costs for excess baggage on flight for Finnish orders (related to facility FI14) and random cost sampling for individual Finnish orders

Available data from SAP was utilized to calculate the costs of excess baggage on flights for Finnish orders (facility FI14). The responsible controller for facility FI14 was contacted, and a meeting was scheduled with her and two other knowledgeable individuals in the field. During the meeting, the most effective approach for obtaining the costs of excess baggage on flights was determined. Subsequently, a list was exported from SAP to Excel, where the excess baggage costs on flights for all Finnish orders were filtered to make only excess baggage on flight costs visible.

The total sum of costs for excess baggage on flights in 2023 for Finnish orders (facility FI14) amounted to 78 603,78 €.

Table 6: Total excess baggage on flight costs for Finnish orders (facility FI14) year 2023

Excess baggage on flight costs for FI14, 2023
78 603,78 €

To further investigate the costs of excess baggage on flights for the Finnish service engineers, 14 random samples were also conducted to analyze the individual orders' excess baggage on flight costs. This was initiated due to the observation that some excess baggage on flight costs were significantly high. Therefore, a more in-depth examination was conducted to assess whether it would be more advantageous for service engineers to bring the tools on the flight and pay for overweight baggage or if using a delivery company would be more economical.

By conducting several random samples, a better understanding of the costs to various destinations worldwide where service engineers travel could be obtained. It is important to note that the costs vary depending on the excess weight. The random samples were selected using the Excel list generated from SAP, which displayed all Finnish orders (related to facility FI14) with excess baggage costs.

The service work report compiled by the service engineer was utilized to ensure the reliability of the job location for each order. This choice was made because the job location information in ServiceWorkForce is not always reliable. To confirm that the service engineer traveled to the specified job location in the service work report, travel receipts from the service engineer retrieved from Concur were reviewed.

The individual costs of excess baggage on flights for each order were retrieved from the Excel list generated from SAP, which shows all orders with associated excess baggage on flight costs. Additionally, a cross-check in SAP was conducted to ensure that each order's excess baggage on flight costs matched the costs in the Excel list.

The number of individual tickets with excess baggage on a flight has been recorded in the random samples to gain an overview of the distribution of costs. Since the excess weight is not specified on each ticket, it has not been possible to note the excess weight at each sampling occasion. Instead, in Chapters 5.2 and 5.3, a more detailed analysis of a few chosen tickets where the excess weight is specified will be performed. The cost of excess weight based on weight and flight distance will be compared to evaluate whether sending the tools via a delivery company, such as DHL, FedEx, Logicall Airfreight or Vaasahuolinta - Vasaspedition, would be more cost-effective.

Below is an image of what a typical excess baggage ticket usually looks like. It contains essential details such as the name of the service engineer, the excess weight in kilograms, and the price for the excess weight. These excess baggage tickets are retrieved from Concur, where the service engineers' travel receipts are recorded.

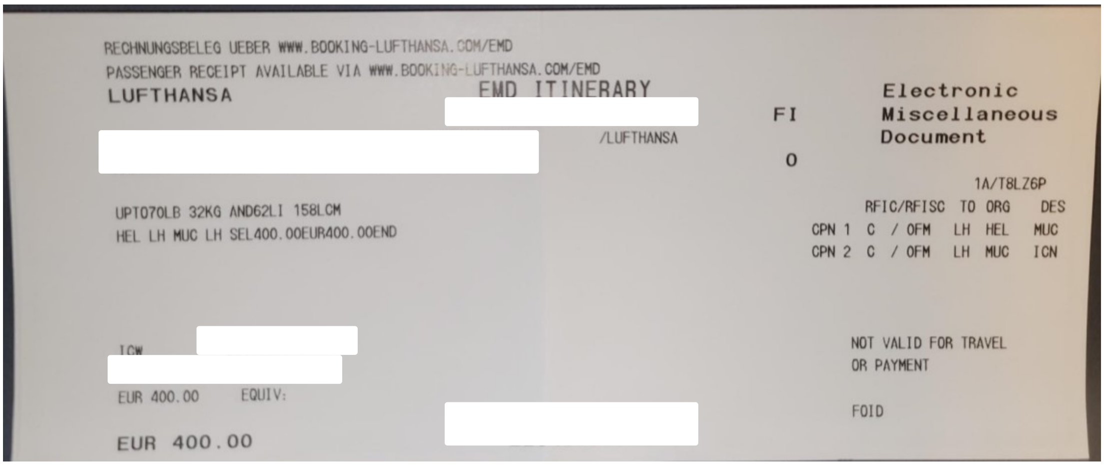
RECHNUNGSBELEG UEBER WWW.BOOKING-LUFTHANSA.COM/EMD
PASSENGER RECEIPT AVAILABLE VIA WWW.BOOKING-LUFTHANSA.COM/EMD
LUFTHANSA
EMD ITINERARY
FI
Electronic Miscellaneous Document
/LUFTHANSA
0
1A/T8LZ6P
RFIC/RFISC TO ORG DES
CPN 1 C / 0FM LH HEL MUC
CPN 2 C / 0FM LH MUC ICN
UPT070LB 32KG AND62LI 158LCM
HEL LH MUC LH SEL400.00EUR400.00END
ICW
NOT VALID FOR TRAVEL
OR PAYMENT
EUR 400.00 EQUIV:
FOID
EUR 400.00

Figure 8: An example of how excess baggage on a flight ticket usually looks

Multiple excess baggage tickets for flights for a single order are required because service engineers have to make stopovers and change flights, requiring new tickets for each flight. The excess baggage costs for both the outbound and return journeys are included in the random sample details.

Later in Chapter 5.2 and 5.3, based on the random samples conducted on Finnish orders, a comparison will be made regarding the costs of excess baggage to some destinations to assess whether it is more economical for the Finnish service engineers to fly with the tools in their luggage to these places instead of sending the tools via a delivery company.

Random sample 10

Order nr: **9000019055**

Job location: **Miami, USA**

Total excess baggage on flight costs on the order: **970,56 €**

Number of excess baggage on flight tickets: **8**

430,00	EUR
278,24	EUR
180,00	EUR
54,55	EUR
8,46	EUR
8,20	EUR
5,64	EUR
5,47	EUR

Figure 9: Individual costs listed for each ticket on order 9000019055, random sample 10

Random sample 14

Order nr: **11248875**

Job location: **Singapore**

Total excess baggage on flight costs on the order: **943,94 €**

Amount of tickets: **5**

363,49	EUR
328,05	EUR
160,00	EUR
82,40	EUR
10,00	EUR

Figure 10: Individual excess baggage on flight costs listed for each ticket on order 11248875, random sample 14

One has chosen not to record all 14 random samples conducted in this study but only two of them, as only samples 10 and 14 will be analyzed more thoroughly. All random samples conducted can be found in Appendix 4. The purpose is to compare the costs of excess baggage on flights when the Finnish service engineer brings tools as luggage with the costs of using a transport company to send the tools from Finland to the same destination.

4.5 Analysis using The Center of Gravity Method

The center of gravity method will be used to analyze the optimal location for a tool hub, based on tool deliveries for transportation work for Wärtsilä's logistics center in Finland, Vaasa, and in the Netherlands, Schiedam.

In total, four analyses will be conducted, two for each logistics center. The first analysis for both logistics centers will take into account both tool deliveries and the location of the logistics center. The second analysis for both logistics centers will only consider where the tool deliveries have been delivered.

By conducting two different analyses for each logistics center, one obtains two different options for placing a tool hub based on each logistics center. This means that multiple options will be available for consideration, thereby increasing the opportunities to find the best solution.

Once the results for the optimal geographical centroids are determined through the analysis, it can be anticipated that strategically placing tool hubs at these locations would be beneficial.

4.5.1 Center of Gravity analysis concerning transportation work for the logistics center in Vaasa, Finland.

This analysis, conducted using the center of gravity method, is based on Wärtsilä's logistics center in Vaasa, Finland. In this context, Vaasa serves as the supplier location. The remaining locations in Table 7 will function as customer locations.

One supplier – one terminal – multiple customers

As mentioned earlier, Vaasa is working as the supplier location and is weighted with a factor of 38, corresponding to the total number of outgoing deliveries from Vaasa, as calculated in Table 1. The remaining locations are weighted based on the total number of received shipments, which amounts to 38.

Table 7: Coordinates and weights for the customer locations as well as the supplier for the Finnish logistics center

	Country and city	Latitude	Longitude	Amount of deliveries
1	Estonia, Tallinn	59,43739	24,7499	8
2	Norway, Bergen	60,39114	5,31953	3
3	Finland, Vaasa	63,09429	21,62028	2
4	Finland, Vantaa	60,29217	25,0357	2
5	Italy, Palermo	38,11513	13,36964	2
6	Malta, Kalafrana	35,81603	14,53769	2
7	United States, Lucedale	30,92529	-88,58827	2
8	Åland Islands, Möckelö	60,10035	19,89985	1
9	Finland, Pietasaari	63,67411	22,69266	1
10	Finland, Turku	60,45124	22,26471	1
11	French Polynesia, Punaauia	-17,59393	-149,61197	1
12	Germany, Berlin	52,51775	13,39014	1
13	Greece, Piraeus	37,94349	23,64637	1
14	Italy, Genova	44,40527	8,94713	1
15	Italy, Trieste	45,64941	13,77473	1
16	Japan, Kawasaki	35,57051	139,63239	1
17	Norway, Rubbestadneset	59,81628	5,26482	1
18	Norway, Søvik	62,54733	6,27825	1
19	Poland, Szczecin	53,42795	14,55458	1
20	Singapore, Pandan Cres	1,30479	103,76206	1
21	Spain, Denia	38,83891	0,10488	1
22	The Netherlands, Hoofddorp	52,30631	4,68984	1
23	United Arab Emirates, Dubai	25,2124	55,27549	1
24	United States, Harvey Louisiana	29,90363	-90,0753	1
Supplier	Finland, Vaasa	63,09374	21,62511	38

The formula for calculating the center of gravity for transportation work for the "one supplier—one terminal—multiple customers" model was applied, and the resulting coordinates were obtained, and they are presented in Table 8.

Table 8: The coordinates for the centroid according to the "one supplier - one terminal - multiple customers" model, based on tool deliveries from Finland

	Latitude	Longitude
Center point	**55,48416158**	**32,16191263**

The coordinates from Table 7 and Table 8 are marked on the map below in Figure 11. The red markers, labeled with numbers, represent the customer locations/delivery address end locations, while the yellow marker represents the supplier/distribution center, and the green marker represents the optimal location for placing a tool hub/terminal according to the "one supplier - one terminal - multiple customers" model. The green marker for the terminal is not a definitive location but merely a suggestion for the most optimal position.

Figure 11: Map of the coordinates for the Finnish supplier/distribution center (yellow), customer locations/delivery address end locations (red), and the terminal/optimal tool hub placement (green) according to the "one supplier - one terminal - multiple customers" model, based on Finnish tool deliveries.. (Mapcustomizer, 2024)

One terminal – multiple customers

With this method, the focus will be solely on the customer locations and their weights to determine the optimal position for the terminal without considering the supplier's location.

In this scenario, the formula is applied to calculate the center of gravity concerning transportation work for the "one terminal – multiple customers" model. The results of these calculations are presented in Table 9.

Table 9: Coordinates for the centroid according to the "one terminal - multiple customers" model, based on tool deliveries from Finland

	Latitude	Longitude
Center point	47,87458316	10,53680263

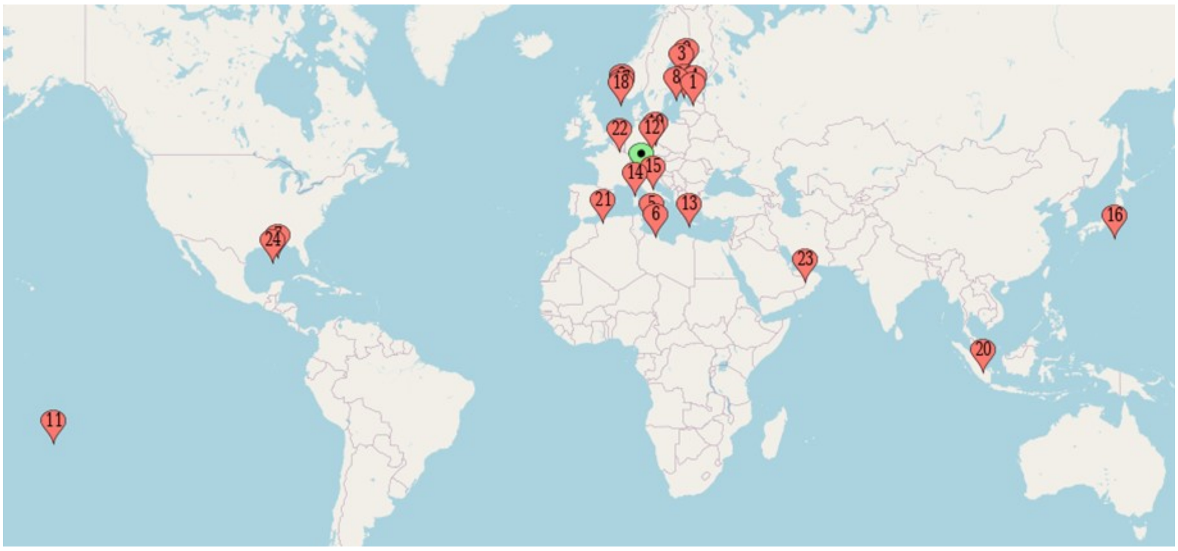

Figure 12: Map of the coordinates for customer locations/delivery address end locations (red) and the location of the terminal/optimal tool hub placement (green) according to the "one terminal - multiple customers" model, based on Finnish tool deliveries. (Mapcustomizer, 2024)

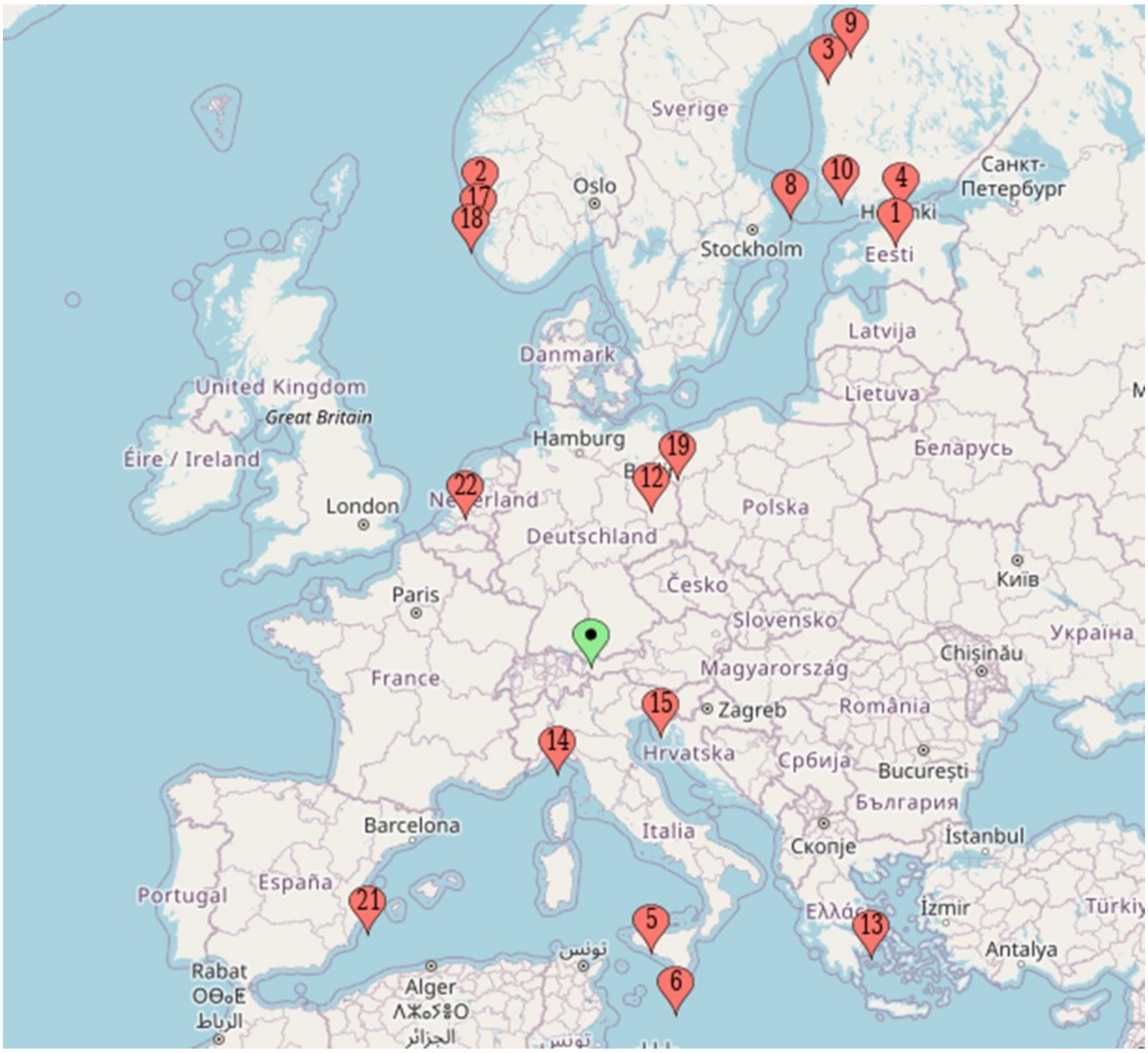

Figure 13: Detailed map of the terminal/tool hub coordinates (green) according to the "one terminal - multiple customers" model, based on Finnish tool deliveries. (Mapcustomizer, 2024)

In Figure 12 and Figure 13, the coordinates for customer locations from Table 1 are displayed, along with the suggested optimal location for the terminal from Table 9. As before, customer locations are marked in red, and the proposed terminal location is marked in green.

4.5.2 Center of Gravity analysis concerning transportation work for the logistics center in Schiedam, Netherlands.

This analysis using the center of gravity method is conducted in the same manner as for Wärtsilä Finland's logistics center and their deliveries. In this case, Wärtsilä Netherlands' logistics center in Schiedam acts as the supplier, while the other locations in Table 10 below act as customer locations. The analysis will be conducted using two different models: "one supplier - one terminal - multiple customers" and "one terminal - multiple customers."

One supplier – one terminal – multiple customers

As previously mentioned, the logistics center in Schiedam will act as the supplier, while the remaining locations will function as customer locations. The coordinates of the terminal will be calculated based on the coordinates of both the supplier and the customer locations.

The supplier/logistics center is weighted with a value of 45, corresponding to the number of outgoing deliveries from the logistics center in 2023 as calculated in Chapter 4.3.2. The other locations in Table 10 are weighted according to the number of received shipments, which totals 45.

Table 10: Coordinates and weights for the customer locations as well as the supplier for the Netherlands (facility NL13)

	Country and city	Latitude	Longitude	Amount of deliveries
1	Lithuania, Klaipeda	55,70471	21,14246	9
2	Singapore	1,27828	103,84968	8
3	Spain, Las Palmas	28,12774	-15,43294	3
4	Netherlands, Harlingen	53,17563	5,42602	3
5	Netherlands, Kampen	52,55756	5,90817	3
6	Netherlands, Roden	53,13815	6,43199	2
7	Netherlands, Amsterdam	52,36595	4,90804	2
8	Netherlands, Kruiningen	51,44934	4,03369	2
9	United Arab Emirates, Dubai	25,22125	55,26572	1
10	Philippines, Manila	14,60296	120,98973	1
11	Spain, Astillero	43,39779	-3,82126	1
12	Netherlands, Dordrecht	51,81496	4,69512	1
13	Poland, Gdansk	54,34649	18,65144	1
14	Italy, Trieste	45,65013	13,77851	1
15	Netherlands, Zwijndrecht	51,8113	4,62769	1
16	Netherlands, Zwolle	52,51704	6,08433	1
17	USA, Philadelphia	39,95435	-75,12627	1
18	England, Fareham	50,85485	-1,18887	1
19	Germany, Berlin	52,5117	13,39987	1
20	Romania, Galati	45,43561	28,00423	1
21	Germany, Hamburg	53,54914	9,98821	1
Logistics center	Netherlands, Schiedam	51,9166	4,39856	45

By applying the formula to calculate the center of gravity for transportation work according to the model “one supplier - one terminal - multiple customers”, the coordinates obtained are presented as results in Table 11.

Table 11: The coordinates for the centroid according to the "one supplier - one terminal - multiple customers" model

	Latitude	Longitude
Center point	46,05525411	15,92016022

On the map below, in Figure 14, the coordinates of customer locations are marked in red, and the coordinates of the supplier/logistics center are marked in yellow. The details are more clearly visible in Figure 15. The center of gravity, indicated in green, is calculated based on the coordinates of the customer locations/delivery addresses and the coordinates of the supplier/logistics center in Schiedam, according to the “one terminal – multiple customers” model.

The green marking for the calculated center of gravity is only a suggestion for the optimal location to place a tool hub.

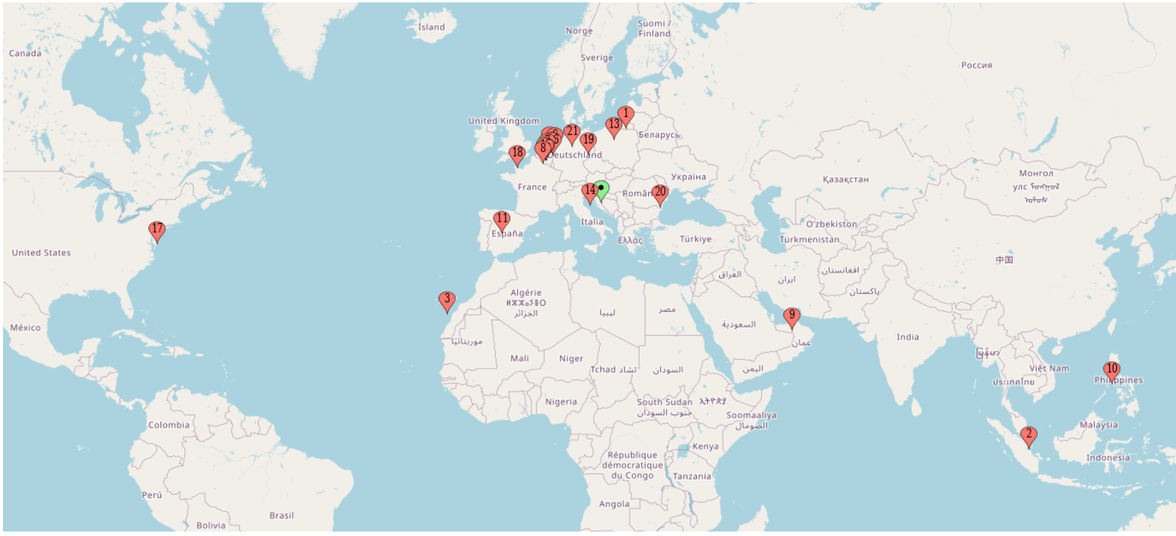

Figure 14: Map of the coordinates for the Dutch supplier/distribution center (yellow), terminal/optimal tool hub placement (green), and customer locations/delivery address end locations (red) according to the "one supplier - one terminal - multiple customers" model, based on Dutch tool deliveries. (Mapcustomizer, 2024)

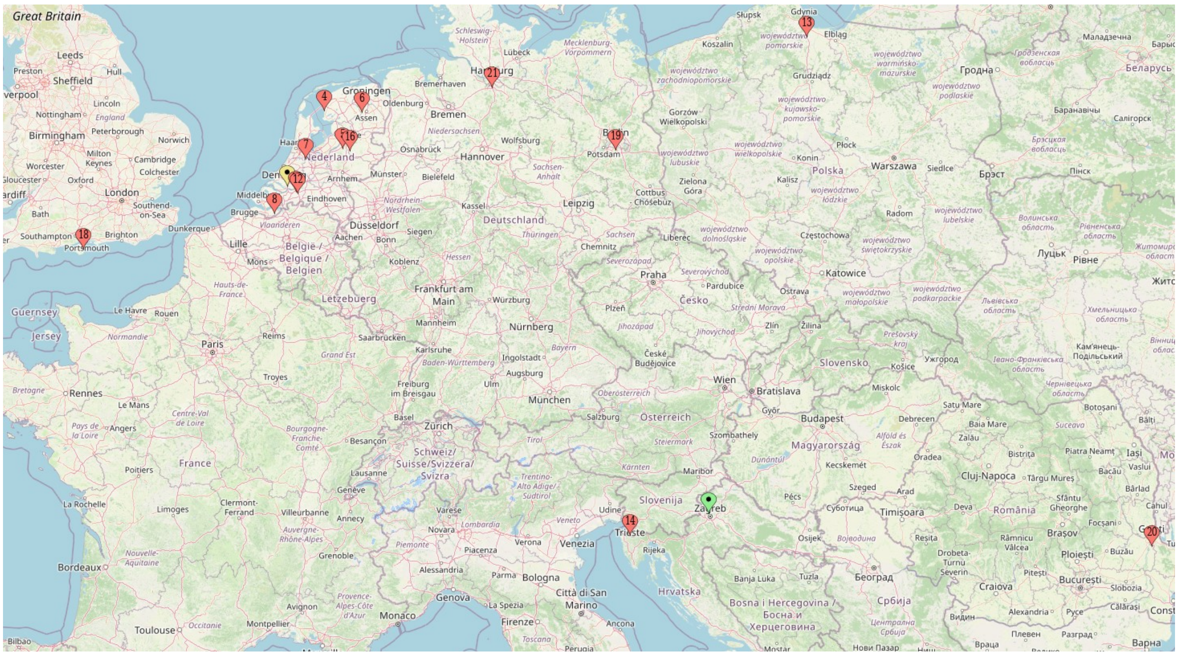

Figure 15: Detailed map of the terminal/optimal tool hub placement (green), the Dutch supplier/distribution center (yellow), and customer locations/delivery address end locations (red) coordinates according to the "one supplier - one terminal - multiple customers" model, based on Dutch tool deliveries. (Mapcustomizer, 2024)

One terminal – multiple customers

In this method, the geographical location of the supplier/logistics center is not taken into account; instead, only the placement of customer locations and their weights determine the optimal location for the terminal.

In this case, the formula is applied to calculate the center of gravity concerning transport work for the "one terminal - multiple customers" model. The result of the calculation is presented in Table 12.

Table 12: The coordinates for the Center of Gravity according to the "one terminal - multiple customers" model.

	Latitude	Longitude
Center point	40,19390822	27,44176044

Figure 16: Map of the coordinates of the terminal/optimal tool hub placement (green) and the customer locations/delivery address end locations (red) on the map according to the "one terminal - multiple customers" model, based on Dutch tool deliveries. (Mapcustomizer, 2024)

In Figure 16, the coordinates for the customer locations listed in Table 10 are displayed along with the suggested optimal location for the terminal according to the "one terminal - multiple customers" model, listed in Table 12. The customer locations are marked in red, and the suggested terminal location is marked in green.

5 Results

In this chapter, the results based on the calculations in Chapter 4, supported by the theory in Chapter 3, will be presented. The results include the total tool delivery costs for the logistics center in Vaasa, Finland, and the logistics center in Schiedam, the Netherlands. Additionally, the most cost-effective delivery method will be presented, along with four optimal locations for placing a tool hub based on deliveries from the logistics centers in Vaasa and Schiedam.

5.1 Total tool delivery costs for Finland and The Netherlands year 2023

Table 13 presents all tool costs for Finnish tool deliveries in 2023. It includes both the costs for inbound and outbound tool delivery.

Table 13: Total tool delivery costs for Finnish tool deliveries year 2023

Total tool delivery costs for FI14, 2023	
Total inbound delivery costs	18 179,48 €
Total outbound delivery costs	41 012,24 €
Total inbound & outbound delivery costs	59 191,72 €

Table 14 presents the tool delivery costs for The Netherlands in 2023, including the costs for inbound and outbound tool delivery.

Table 14: Total tool delivery costs for Dutch tool deliveries year 2023

Total tool delivery costs for NL13, 2023	
Total inbound delivery costs	89 018,83 €
Total outbound delivery costs	36 127,19 €
Total inbound & outbound delivery costs	125 146,02 €

Table 15 provides a more detailed description of inbound and outbound tool delivery costs. It specifies the costs for Snelwegs delivery and handling charges and other delivery costs outside the Netherlands.

Table 15: Detailed description of outbound and inbound tool delivery costs for the Netherlands (facility NL13) year 2023

Inbound Delivery Costs 2023			Outbound Delivery Costs 2023		
Delivery costs (Outside NL)	Snelweg delivery costs (within NL)	Snelweg handling costs	Delivery costs (Outside NL)	Snelweg delivery costs (within NL)	Snelweg handling costs
39 692,35 €	37 029,10 €	12 297,38 €	17 187,20 €	18 464,15 €	475,84 €

5.2 Tool delivery costs to Singapore with service engineer luggage vs delivery company year 2023

Initial calculations have been conducted for all cost differentials for Finnish and Dutch orders to facilitate comparisons of respective costs and overweight. These calculations include the costs and overweight for service engineers when traveling with the tools in their luggage, as well as the costs and overweight when a delivery company transports the tools.

A summary table clarifies in Chapter 5.2.3 the cost and weight differences between transportation methods and the country from which the tools were transported.

5.2.1 Service engineer luggage costs

Finnish order 11248875

In Chapter 4.4.1, a random sample was conducted to investigate the costs of excess baggage when a service engineer travels abroad from Finland on assignment. In sample number 14, it was noted that the job site was in Singapore and that five excess baggage tickets had been booked at a total cost of 943,94 €. Upon closer examination of order number 11248875 in SAP, it was determined that the five tickets had been booked for two Finnish service engineers.

Random sample 14

Order nr: **11248875**

Job location: **Singapore**

Total excess baggage on flight costs on the order: **943,94 €**

Amount of tickets: **5**

363,49	EUR
328,05	EUR
160,00	EUR
82,40	EUR
10,00	EUR

Figure 17: Reference to random sample 14

The route, costs, and overweight in kilograms for Finnish service engineer number 1:

- Helsinki/Doha, Doha/Hanoi, Hanoi/Singapore: €160 overweight
- Phuket/Singapore: €328.05 overweight, 44 kilograms
- Singapore/Ho Chi Minh City: €363.49 overweight, 48 kilograms
- **Total costs for service engineer 1:** €851.54, with overweight ranging from 44 to 48 kilograms.

The route, costs, and overweight in kilograms for Finnish service engineer number 2:

- Vaasa/Helsinki, Helsinki/Singapore: 82,4 € overweight (€10 excess baggage for the company, luggage left behind)
- **Total costs for service engineer 2:** 92,4 €, overweight not specified.

Total costs and overweight for Finnish service engineer 1 & 2:

- The total cost for excess baggage on the flight for both Finnish service engineers is **943,94 €**. Service engineer number 1's excess baggage weight is 44-48 kilograms. However, the ticket for service engineer number 2 does not specify the excess baggage weight, meaning that the total sum for excess baggage costs cannot be determined with 100% certainty.

Dutch order 11233613

According to SAP, the excess baggage cost on order 11233613 from the Netherlands to Singapore is 865,81 €, divided among two service engineers. Since the Dutch travel receipt reporting differs from the Finnish reporting, the route cannot be determined solely by reviewing the travel receipts. To ensure that the service engineers have traveled from the Netherlands to Singapore, one must consult the travel report from Concur to see where the excess baggage tickets were purchased.

The route, costs, and overweight in kilograms for Dutch service engineer 1:

- **Total costs for service engineer 1:** 524 €, overweight 14 kg

The route, costs, and overweight in kilograms for Dutch service engineer 2:

- **Total costs for service engineer 2:** 341,81 €, overweight 10 kg

Total costs and overweight for Dutch service engineer 1 & 2:

- The total cost for both service engineers is **865,81 €**, and the overweight weighs **24 kilograms**. However, this cannot be confirmed entirely, as the route has not been verified through the travel receipts.

Dutch order 11276617

The route, costs, and overweight in kilograms for Dutch service engineer:

- On this Dutch (related to facility NL13) order, with number 11276617, SAP shows that the cost of excess baggage on the flight from the Netherlands to Singapore is **200,77 €** for one service engineer. The weight in kilograms of the excess baggage is not specified on the ticket.

5.2.2 Delivery company costs (airfreight)

Delivery from Finland to Singapore:

In Chapter 4.3.1, Table 1, it can be noted that tools have been delivered from Helsinki to Pandan Cres, Singapore. The specific delivery is booked under order number 11257652, which has been retrieved from the Excel list where all Finnish tool deliveries (related to facility FI14) and costs are listed.

- According to SAP, the costs for air freight with Vaasahuolinta – Vasaspedition amount to a total of 1133 €. The delivery cost is 841 €, the customs clearance is 25 €, and forwarding expenses abroad are 267 €, making up the total delivery price of 1133 €. The weight for this tool delivery is 287 kilograms.

MAWB: 105-00562192 HAWB: 2081812										
11257652	1 CS	LIFTING DEVICE					287 kg	0,762 m3		
					Chargeable weight		287 kg			
Charge	*Units*	*Unit*	*U-Price*	*Curr*		*Total*	*Net EUR*	*VAT %*	Tot. EUR	
Freight Helsinki - Singapore	1,00	CNS	841,00	EUR	/ CNS	841,00	841,00	C) 0,00	841,00	
Customs Clearance	1,00	CNS	25,00	EUR	/ CNS	25,00	25,00	C) 0,00	25,00	
Forwarding Expenses Abroad	1,00	CNS	267,00	EUR	/ CNS	267,00	267,00	C) 0,00	267,00	

Figure 18: Detailed description of the transport with Vaasahuolinta-Vasaspedition from Helsinki to Singapore.

Delivery from the Netherlands to Singapore 1:

- Airfreight with VCK Logistics from the Netherlands to Singapore cost 776,25 €, weighing 125 kilograms. The total amount, as depicted in Figure 19, airfreight charges amount to 692,5 €, security surcharge is 18,75 €, security screening is 35 €, and handling charges are 30 €.

Origin	Schiphol Airport	AWB No.	618-25789735
Destination	Singapore	House Doc.	EX2305940
Flight	SQ323	Transport Date	14-03-23
Pieces	2	Act. Weight	125,0 kg
Goods	Spare Parts for Wartsila Diesel Engine	Chg. Weight	125,0 kg
Reference no.	11205119-0040		
Contact Person			
For your office	Schiedam		

Description	**Tax %**	**Amount**
Airfreight charges	0	692,50
Security surcharge	0	18,75
Security Screening	0	35,00
Handling charges	0	30,00
	Total EUR	**776,25**

Figure 19: Detailed description of the transport with VCK logistics from the Netherlands to Singapore.

Delivery from the Netherlands to Singapore 2:

- Airfreight from the Netherlands to Singapore weighing 59 kg costs a total of 370,43 €.

Origin	Schiphol Airport	AWB No.	618-29706806
Destination	Singapore	House Doc.	EX2322164
Flight	SQ323	Transport Date	01-10-23
Pieces	2	Act. Weight	59,0 kg
Goods	Spare parts - M.V. VOLVOX TERRANOVA	Chg. Weight	59,0 kg
Reference no.	11276617-0080		
Invoice no.	11276617-0080		

Description	Tax %	Amount
Airfreight charges	0	265,50
Road transport	0	25,90
Security Screening	0	35,00
Handling charges	0	30,00
Fuel surcharge road	0	5,18
Airline fuel surcharge	0	8,85
	Total EUR	**370,43**

Figure 20: Detailed description of the transport with VCK logistics from the Netherlands to Singapore

5.2.3 Summary of tool delivery costs and overweight to Singapore

In Table 16 and Table 17, a summary of the costs and overweight for tool deliveries from both Finland and the Netherlands to Singapore are presented.

Table 16: Summary of the costs and overweight for various transportation methods from Finland to Singapore.

Tool delivery to Singapore from Finland		
Type of transportation	**Cost**	**Weight**
By service engineer case 1	851,54 €	44-48 kg
By service engineer case 2	92,40 €	undefined
By delivery company	1 133 €	287 kg

Table 17: Summary of the costs and overweight for various transportation methods from the Netherlands to Singapore.

Tool delivery to Singapore from Netherlands		
Type of transportation	**Cost**	**Weight**
By service engineer case 1	524,00 €	14 kg
By service engineer case 2	341,81 €	10 kg
By service engineer case 3	200,77 €	undefined
By delivery company case 1	776 €	125 kg
By delivery company case 2	370 €	59 kg

From the tables, Table 16 and Table 17, it is clear that it is generally more cost-effective to use a delivery company to deliver the tools. The costs incurred when service engineers must pay for excess baggage on flights are significantly higher because the weight of their luggage does not reach the same level as when the tools are delivered by a delivery company. In other words, one can deliver heavier shipments with a delivery company and still pay less for the shipping costs.

5.3 Tool delivery costs to USA with service engineer luggage vs delivery company costs in the year 2023

Initially, all costs for Finnish (related to facility FI14) and Dutch (related to facility NL13) orders have been calculated to enable comparisons of costs and overweight. This includes costs and overweight for service engineers when traveling with the tools in their luggage, as well as costs and overweight when the tools are transported by a delivery company.

A summary table clarifies in Chapter 5.3.3 the cost and weight differences between transportation methods and the country from which the tools were transported.

5.3.1 Service engineer luggage costs

Finnish order 9000019055

Sample number 10 had order number 9000019055, which had 970,56 € in registered excess baggage costs for flights. The costs for eight tickets are divided between two Finnish service engineers.

Random sample 10

Order nr: **9000019055**

Job location: **Miami, USA**

Total excess baggage on flight costs on the order: **970,56 €**

Number of excess baggage on flight tickets: **8**

430,00	EUR
278,24	EUR
180,00	EUR
54,55	EUR
8,46	EUR
8,20	EUR
5,64	EUR
5,47	EUR

Figure 21: Reference to random sample 10.

The route, costs, and overweight in kilograms for Finnish service engineer number 1:

- The cost for SmarteCart (luggage cart) at the airport in the USA: 5,64 € + 8,46 €.
- The total costs for service engineer nr 1: 5,64 € + 8,46 €, and no direct overweight costs were incurred on the flight.

The route, costs, and overweight in kilograms for Finnish service engineer number 2:

- Vaasa/Helsinki: 170 € for overweight
- Helsinki/Dallas Fort Worth: 260 € for overweight
- Dallas Fort Worth/Miami: 278,24 € for overweight, with a total weight of 46 kilograms
- Smartecart costs at the airport in the USA: 5,47 € + 8,20 €
- The total cost for service engineer nr 2: 721,91 €, with overweight 46 kg

Total costs and overweight for Finnish service engineer 1 & 2:

- Since the remaining ticket costs apply to the return journey, the total excess baggage costs for the flight amount to 736,01 € for the trip from Vaasa to Miami, USA. According to one of the tickets, the excess baggage is 46 kilograms.

Dutch order 11228955

The route, costs, and overweight in kilograms for Dutch service engineer:

- Dutch (related to facility NL13) order 11228955 has excess baggage costs for the flight amounting to €90 for one service engineer from Amsterdam to Philadelphia. The excess baggage paid for is up to 23 kilograms.

5.3.2 Delivery company costs (airfreight)

Delivery from Finland to the USA

- In Chapter 4.3.1, Table 1, it can be noted that tools have been delivered from Helsinki to New Orleans. The specific delivery is booked under order number 9000026425, which has been retrieved from the Excel list where all Finnish (related to facility FI14) tool deliveries and costs are listed.

  This tool delivery has been transported by Vaasahuolinta-Vasaspedition and has a weight of 162 kg. The total cost for the delivery is €617, of which the freight cost is €592 and the customs clearance is €25.

9009000026425	1 CS	TOOL BOX		162 kg	0,422 m3
			Chargeable weight	162 kg	

Charge	*Units*	*Unit*	*U-Price*	*Curr*		*Total*	*Net EUR*	*VAT %*	Tot. EUR
Freight Helsinki - New Orleans	1,00	CNS	592,00	EUR	/ CNS	592,00	592,00	C) 0,00	592,00
Customs Clearance	1,00	CNS	25,00	EUR	/ CNS	25,00	25,00	C) 0,00	25,00

Figure 22: Detailed description of the transport with Vaasahuolinta-Vasaspedition from Helsinki to New Orleans.

Delivery från Nederländerna till USA

- Only one order of tool freight from the Netherlands to the USA, weighing 4 kilograms and costing €57.02, was found.

6659131216	11228955-0030	31-01-23	RTM, ROTTERDAM WARTSILA SUCEN Rob de Mooy Port 519 Havenstraat 24 NL-3115 HD, SCHIEDAM	PHL, WEST PHILADELPHIA RING MARITIME SERVICES INC Agency Ring 216 W.Powhatan Ave Ship's spare in transit US-19029, ESSINGTON Pennsylvania	EXPRESS 12:00 nondoc	4,00 W	1	42,16	 FUEL SURCHARGE EMERGENCY SITUATION	 13,66 1,20	B B B	42,16 13,66 1,20 57,02
Service Sub Total - EXPRESS 12:00 nondoc						4,00	1	42,16		14,86		57,02

Figure 23: Detailed description of the transport with DHL from the Netherlands to Philadelphia.

5.3.3 Summary of tool delivery costs and overweight to USA

A summary of the costs and overweight for tool deliveries from Finland and the Netherlands to the USA is presented in Table 18 and Table 19.

Table 18: Summary of the costs and overweight for different transportation methods from Finland to the USA.

Tool delivery to USA from Finland		
Type of transportation	**Cost**	**Weight**
By service engineer case 1	14,10 €	No actual overweight costs
By service engineer case 2	721,91 €	46 kg
By delivery company	617 €	162 kg

Table 19: Summary of the costs and overweight for different transportation methods from the Netherlands to the USA.

Tool delivery to USA from Netherlands		
Type of transportation	**Cost**	**Weight**
By service engineer case 1	90,00 €	up to 23 kg
By delivery company	57,02 €	4 kg

Similar to the previous case where transportation costs from Finland and the Netherlands to Singapore were compared, it can be observed from Table 18 and Table 19 that it is generally more cost-effective to utilize a delivery company for tool delivery. The expenses incurred when service engineers must pay for excess baggage on flights are significantly higher, as the weight of their luggage does not reach the same level as when the tools are transported by a delivery company. In essence, heavier shipments can be delivered using a delivery company while still paying less for the shipping costs.

5.4 Optimal placement for a tool hub

According to the calculations using the center of gravity method in Chapter 4.5, the most optimal locations for a terminal/tool hub have been identified. These locations are based on deliveries from two different logistics centers: Wärtsilä Finland's logistics center in Vaasa and Wärtsilä Netherlands' logistics center in Schiedam.

Two options have been identified for the most optimal terminal/tool hub placement for both logistics centers. In the first option, both the logistics center's coordinates and the addresses of the tool deliveries have been taken into account. Only the locations/addresses of the tool deliveries have been considered in the second option.

The optimal locations for placing a tool hub will be presented in the upcoming Chapters 5.4.1 and 5.4.2, depending on the different options and which logistics center is used.

5.4.1 Optimal Placement of Tool Hub Based on Deliveries from Finland, Vaasa

Table 20 presents the most optimal tool hub placement based on deliveries from the logistics center in Vaasa, Finland.

Table 20: Optimal tool hub placements based on tool deliveries from the logistic center in Vaasa, Finland, according to the Center of Gravity method

Optimal placement for the tool hub, based on tool deliveries from Finland	
Alternatives	**Optimal placements for a tool hub**
Based on coordinates of the logistic centrum in Vaasa and delivery addresses	Smolensk Oblast, Russia
Only based on delivery addresses	Friesenried, Germany

The listed options for a tool hub's most optimal geographic location are calculated using the center of gravity method. According to the center of gravity method when taking both the Finnish logistics center and the delivery address end locations into account, the optimal placement for a tool hub is in Smolensk Oblast, Russia, which is presented in Figure 24.

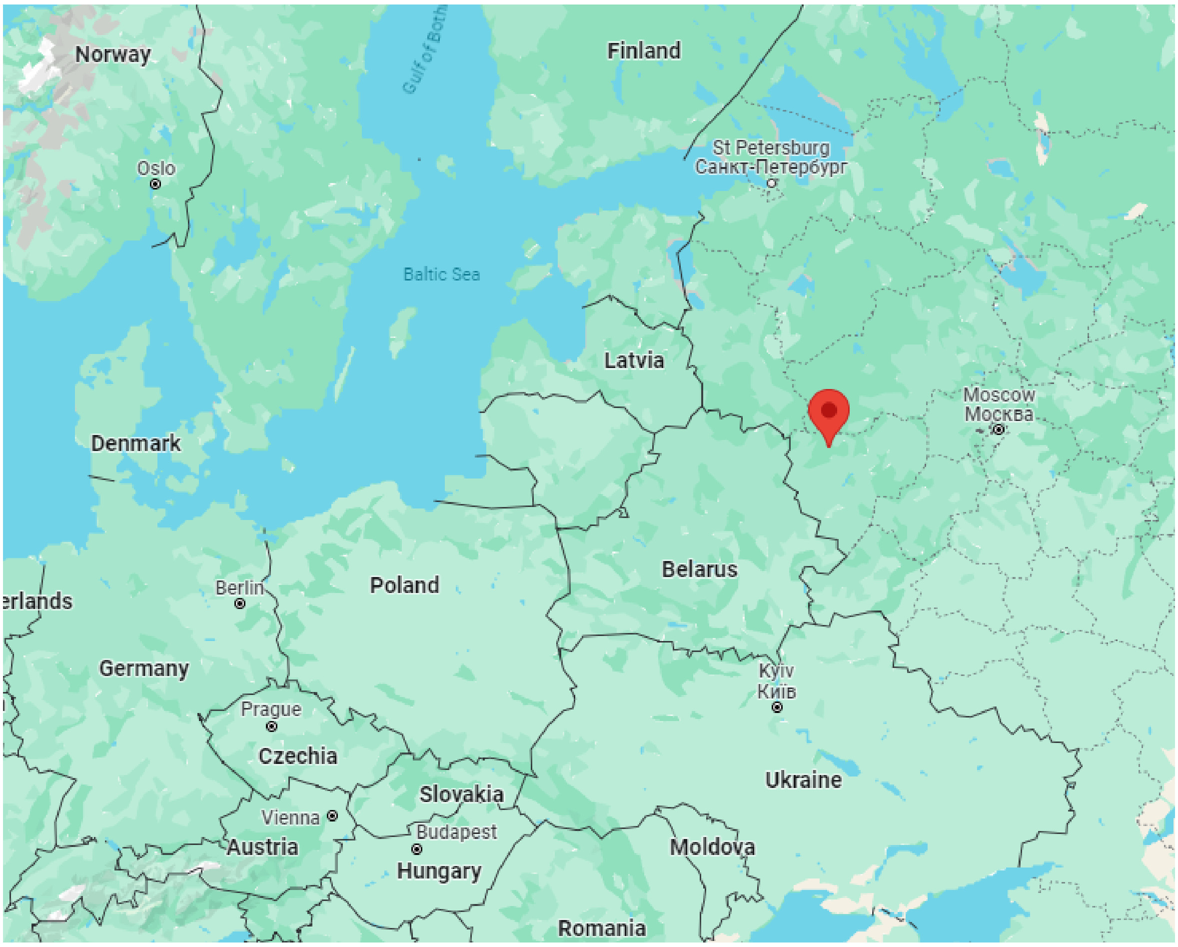

Figure 24: Red pinpoint shows the optimal placement for a tool hub based on the Finnish logistic center's and tool delivery address coordinates according to the Center of Gravity method (according to the "One supplier – one terminal – multiple customers" model. (Mapcustomizer, 2024)

Figure 25 presents the optimal placement for a tool hub based on Finnish tool deliveries when only considering the delivery's address end locations.

Figure 25: Red pinpoint shows the optimal placement for a tool hub based on the tool delivery address coordinates according to the Center of Gravity method, based on Finnish deliveries (according to the "one terminal – multiple customers" model. (Mapcustomizer, 2024)

After analyzing the optimal locations to place a tool hub based on tool deliveries from Finland, Chapter 6 will delve deeper into these options, along with those based on the Dutch logistics center. This will be done using key success factors outlined in Chapter 3.2 to determine the most optimal location for placing a tool hub.

5.4.2 Optimal Placement of Tool Hub Based on Deliveries from the Netherlands, Schiedam

According to the center of gravity method, the most optimal geographic locations or centroids for a tool hub are presented in Table 21. These placements are based on two different alternatives. In the first alternative presented in Figure 26, the coordinates for the logistics center in Schiedam, Netherlands, are used along with all customer locations/tool delivery address end locations, which can be found in Table 5.

Table 21: Optimal tool hub placements based on tool deliveries from the logistics center in Schiedam, Netherlands according to the Center of Gravity method

Optimal placement for the tool hub, based on tool deliveries from the Netherlands	
Alternatives	**Optimal placements for a tool hub**
Based on coordinates of the logistic centrum in Vaasa and delivery addresses	Brezova, Croatia
Only based on delivery addresses	Balıkesir, Turkey

Figure 26: Red pinpoint shows the optimal placement for a tool hub based on the coordinates of the logistics center in the Netherlands and the coordinates of tool delivery addresses (according to the "One supplier – one terminal – multiple customers" model). (Mapcustomizer, 2024)

The second alternative for an optimal placement for a tool hub is presented in Figure 27, is based solely on all customer locations/tool delivery address end locations in Table 5, without considering the coordinates of the Dutch logistics center in the calculation of the centroid.

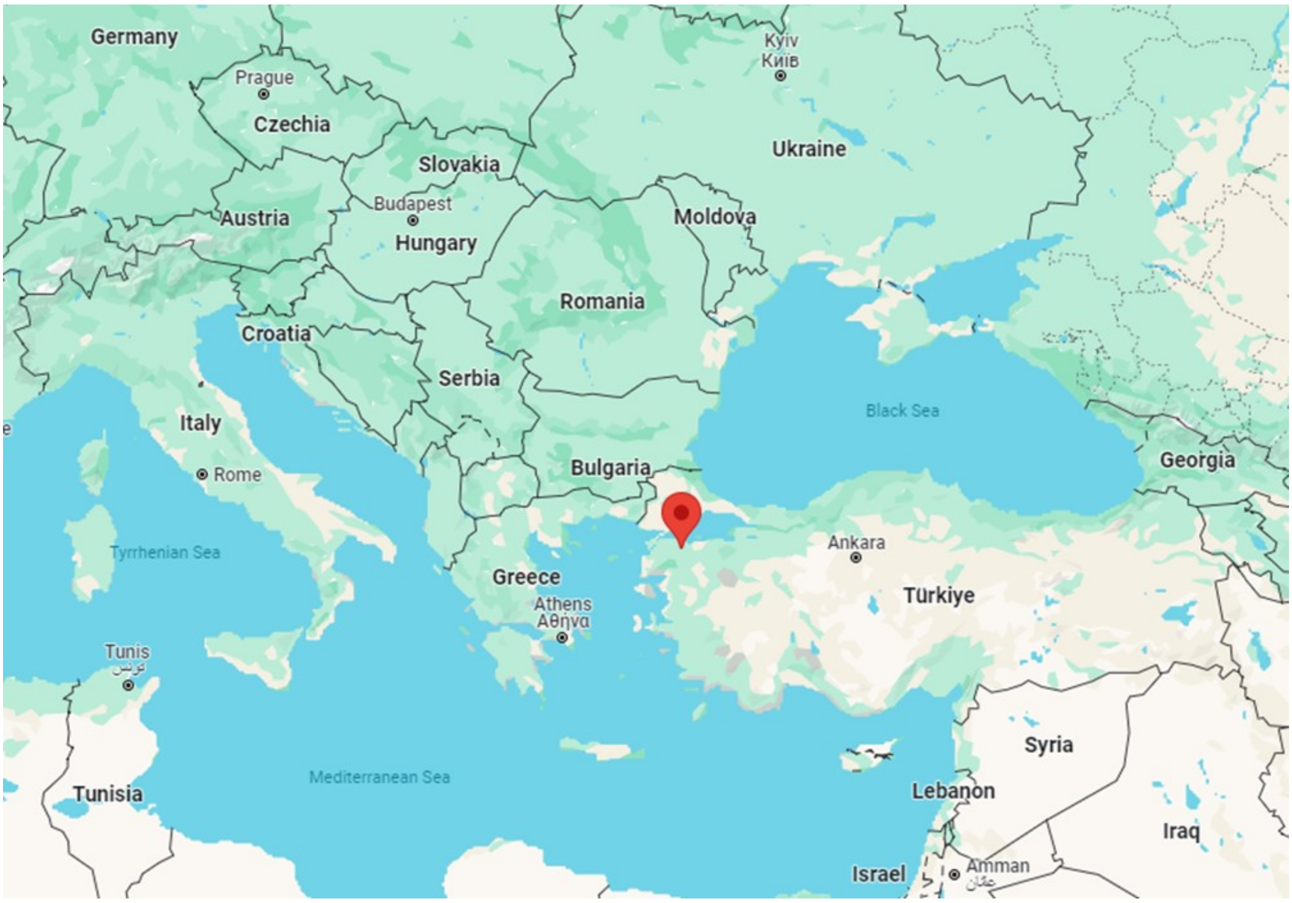

Figure 27: Red pinpoint shows the optimal placement for a tool hub based on the coordinates of tool delivery addresses only (according to the "one terminal – multiple customers" model). (Mapcustomizer, 2024)

After analyzing the optimal locations to place a tool hub based on tool deliveries from the Netherlands, Chapter 6 will delve deeper into these options along with those based on the Finnish logistics center. This will be done using key success factors outlined in Chapter 3.2 to determine the most optimal location for placing a tool hub.

6 Conclusion and recommendations

In the conclusion, a summary of the collected data has been provided. Additionally, various questions have been included to facilitate argumentation and arrive at the most realistic and optimal conclusion.

In previous chapters, the tool delivery costs for two of Wärtsilä's logistics centers have been examined: one in Vaasa, Finland, and one in Schiedam, the Netherlands. These costs are presented in Table 13 and Table 14 and Table 15. Additionally, the number of outbound tool deliveries from both logistics centers has been calculated, and each delivery address has been documented and presented in Table 1 and Table 5.

Based on Table 1 and Table 5, and the calculations done in Chapter 4.5 two different center of gravity analyses have been conducted for both logistics centers to determine the centroid's location. This means that the most optimal placement for a tool hub has been investigated according to the center of gravity method.

One of the center of gravity analyses conducted for both logistics centers was based solely on the locations of the tool delivery addresses. The other analysis, performed for both logistics centers, took into account both the locations of the logistics centers and the locations of the tool delivery addresses. In total, Chapter 5.4 presents four different suggestions for the optimal location for a tool hub.

Table 6 presents data on excess baggage on flight costs for the Finnish orders (FI14 facility). In addition to calculating the total excess baggage on flight costs for Finnish orders, random samples for individual orders were also conducted. The purpose was to compare these excess baggage on flight costs later in Chapters 5.2 and 5.3 with the cost of delivery via a delivery company to a specific location.

Question 1: Is it economically advantageous for Wärtsilä to deploy tool hubs worldwide?

This question is of great significance as Wärtsilä is currently considering deploying a certain number of tool hubs.

Since the logistics center in Schiedam, the Netherlands, is more centrally located in relation to where the tools are delivered, it is relevant to compare the costs of deliveries between the two logistics centers. In Table 22, the Snelweg costs have not been taken into account as they deliver the tools only within the Netherlands, primarily to Wärtsilä's logistics center.

Table 22: Summary of cost per delivery Finland vs Netherlands

Country	Total tool delivery costs	Amount of deliveries	Cost per delivery
Finland	59 191,72 €	38	1 557,68
Netherlands	56 879,55 €	45	1 263,99

Table 22 shows that the cost per delivery from Finland is 293,68 € more expensive than the cost per delivery from the Netherlands.

Based on this analysis, the calculated data show that in terms of cost per delivery, it is cheaper to deliver from the Netherlands, which is more centrally located in Europe. This leads to the conclusion that it would be economically advantageous for Wärtsilä to deploy a tool hub more centrally in Europe.

Question 2: Where would it be most economically advantageous to place a tool hub for Wärtsilä?

All alternatives (countries and cities) below are based on the center of gravity method analysis conducted in Chapter 4.5. The analysis identified four alternatives: two alternatives based on tool deliveries from the distribution center in Schiedam, Netherlands, and two alternatives based on tool deliveries from the distribution center in Vaasa, Finland. In other words, there are two alternative scenarios based on both distribution centers: one scenario considers only the destinations of tool deliveries for determining the optimal placement for a tool hub, and the other scenario considers both the destinations of tool deliveries and the location of the distribution centers.

With support from Chapter 3.2, where the key success factors for choosing a geographical location to place a tool hub are explained, and the alternatives based on the GEO method, one will consider which option is most suitable to place a tool hub.

These are merely suggestions for the placement of a tool hub. These suggestions can be modified to be more tailored to Wärtsilä's current situation:

- **Alternative 1** (based on tool deliveries from Finland, Vaasa): Smolensk Oblast, Russia
    - According to the "one supplier—one terminal—multiple customers" model, the logistics center in Vaasa and the delivery addresses are taken into account.

According to the key success factors, where all factors to be considered have been noted, Russia is not a suitable option for placing a tool hub. Below are the factors influencing the decision listed:

- Political and economic instability: Russia's involvement in current war conflicts is a crucial factor against this option.

- Infrastructure challenges: The country faces challenges with transportation routes and logistics networks, which can affect the efficiency and reliability of distribution.

- Regulatory barriers: Complex regulations, bureaucratic processes, and customs rules pose barriers that make it unsuitable to place a tool hub there.

- Security risks: The risk to transportation and personnel safety is high, especially near borders with other countries.

(TheWorldBank, 2024) (Helenius, 2023)

- **Alternative 2** (based on tool deliveries from Finland, Vaasa): Friesenried, Germany
    - According to the "one terminal - multiple customers" model, only the delivery addresses are taken into account.

The key success factors influencing why it is optimal to place a tool hub in Friesenried, Germany, are as follows:

- Central location in Europe: Germany's central location in Europe makes it ideal for distribution to many parts of the continent and other continents.

- Developed infrastructure: Germany has well-developed infrastructure, including an extensive road and rail network, as well as modern ports and airports, which enable efficient transport and distribution of tools.

- Stable business climate: Germany has a stable business climate and a reliable legal framework, creating a secure environment for business establishment and reducing the risk of uncertainties.

- Customer accessibility: Germany has a large and prosperous consumer market with high purchasing power, which can contribute to shorter delivery times for tool distribution.

- EU membership: Germany is a member of the EU, which means no customs clearance is required within the EU.

- Specific location Friesenried: Friesenried is a small village that may lack necessary logistical and infrastructural conditions. Therefore, it may be advisable to modify this option and place the tool hub in a city near Friesenried, such as Munich or Augsburg, to better leverage all advantages.

- Costs: Germany has relatively high operating costs, which may result in higher expenses than the other alternatives.

  (TheWorldBank, 2024) (Johannesson, 2023)

- **Alternative 3** (based on tool deliveries from the Netherlands, Schiedam): Brezova, Croatia
  - According to the "one supplier—one terminal—multiple customers" model, the logistics center in Schiedam and the delivery addresses are taken into account.

The key success factors influencing why it could be optimal to place a tool hub in Brezova, Croatia, are as follows:

- Geographical proximity to central Europe: This enables efficient distribution of tools to parts of Europe and the Balkan regions.

- Transport infrastructure: Croatia has a relatively well-developed transport infrastructure with highways, railways, and ports. However, it is less developed compared to more industrialized EU countries, which may affect transportation times and costs.

- Cost-effectiveness: Operating costs are generally lower in Croatia compared to other Western European countries, which can contribute to reducing operating costs.

- EU membership: Like Germany, Croatia is a member of the EU, which means no customs clearance is required within the EU. However, there may still be political and economic uncertainties that affect the business environment.

- Business climate: Croatia has made progress in improving its business climate, creating a more predictable and stable environment for business operations.

  (TheWorldBank, 2024) (Kroatienexperten, 2024)

- **Alternative 4** (based on tool deliveries from the Netherlands, Schiedam): Balıkesir, Turkey

  - According to the "one terminal - multiple customers" model, only the delivery addresses are taken into account.

The key success factors influencing why it could be optimal to place a tool hub in Balıkesir, Turkey, are as follows:

- Cost-effectiveness: Similar to the option in Croatia, costs are generally lower in Turkey compared to larger cities in Europe.

- Infrastructure: Turkey has less developed infrastructure compared to other major cities in Europe.

- Regional economic growth: Balıkesir has experienced an increase in industrial activity and economic growth in recent years. This creates a favorable environment for businesses establishing themselves in the region, with access to local suppliers and services.

- Security risks: Turkey has experienced security issues, including terrorism and regional conflicts, at certain times, which can affect the reliability of the supply chain.

- Regulatory and bureaucratic obstacles: The processes for obtaining necessary permits and licenses can be time-consuming and complex, which may delay establishment and increase costs.

- Political and economic instability: Turkey has occasionally experienced political and economic instability, which can impact the business climate.

  (TheWorldBank, 2024) (Styrman, 2024)

Question 3: Is delivering the tools with a service engineer or a delivery company more cost-efficient?

To answer the question, Chapters 5.2.3 and 5.3.3 compare tool delivery costs to Singapore and to the USA, depending on whether the tools are delivered by a service engineer or a delivery company.

Excess baggage on flight costs often arise when service engineers carry the tools as baggage, as the weight becomes significant.

The first thing to note from the summary of the different costs in Chapters 5.2.3 and 5.3.3 is that the excess baggage costs can vary significantly depending on the number of stopovers made, which is an essential factor to consider.

Based on the calculations, the costs for excess baggage on a flight for service engineers are significantly higher than the costs for delivery with a delivery company based on weight. This is an important observation that affects the decision-making process when choosing a delivery method.

Question 4: Is paying for an external company to handle the tools economically advantageous?

During the work, it was noted that Wärtsilä pays a significant amount of money to their external firm, Snelweg, which handles Wärtsilä's tools in the Netherlands, Schiedam. Upon closer examination of all costs related to Snelweg, the total costs for NL 13 outbound and inbound tool deliveries were 125 146,02 €, and of these costs, Snelweg's costs amounted to 68 266,47. It should be noted that Snelweg only delivers within the Netherlands, usually from their warehouse to Wärtsilä's warehouse.

Tool deliveries outside the Netherlands are handled by other delivery companies such as DHL, FedEx, and VCK Logistics. Of the total tool delivery costs of 125 146,02 €, these costs amount to 56 879,55 €.

Given these figures, it is worth considering whether having an external company handle Wärtsilä's tools and tool deliveries is advantageous.

Recommendations

To summarize the results of this research, we can conclude that it is more economically advantageous for Wärtsilä to place a tool hub in a more central location based on the destinations of tool deliveries. Therefore, the recommendation for Wärtsilä is to place the tool hub according to alternative 2, as presented earlier in this chapter. Alternative 2 is based on the destinations of tool deliveries from Finland, meaning a tool hub should be placed in Friesenried, Germany.

This option is based on both the key success factors and the COG analyses. The key success factors are the most crucial, as they suggest that the option in Germany is the most optimal, as the other options do not offer as many advantages as the one in Germany. However, the option should be modified by placing the tool hub near the nearest major city close to the small village of Friesenried, for example, in Munich or Augsburg. However, the downside of the option in Germany is that operating costs are generally higher than in the other options.

Calculations show that it is more cost-effective to transport the tools with a transport company rather than with a service engineer. Therefore, it is recommended that a transport company be used for tool deliveries.

Wärtsilä Netherlands uses the external company Snelweg to handle their tools. It was found that Snelweg's costs constitute a significant part of the total costs for tool deliveries. The recommendation for Wärtsilä is to investigate these costs further and assess how much Snelweg's work facilitates the company. This is to determine whether it would be worth implementing a warehouse management system in the new tool hub to be built.

7 Discussion

This study examined the dynamics, costs, and hub allocation for tool deliveries from Finland and the Netherlands. This chapter summarizes the key results and interprets these findings. It also identifies the study's strengths and weaknesses and describes the practical implications of the results, including how they can be applied in practice. Areas for future research, as well as unanswered and new questions, are also identified.

The results show the total costs for tool deliveries from Finland and the Netherlands in 2023. The study also investigates the cost differences between delivering tools with a transport company and transporting them in a service engineer's luggage to different destinations. Additionally, it highlights the most optimal location for a tool hub.

The total costs for tool deliveries from Finland amounted to approximately 59 000 €, with inbound costs around €18,000 and outbound costs around 41 000 €. The total costs for deliveries from the Netherlands were significantly higher, around 125 000 €, with inbound costs at 89 000 € and outbound costs at 36 000 €.

Due to the high costs, the delivery costs for tool deliveries from the Netherlands were analyzed more thoroughly. Since Wärtsilä in the Netherlands uses Snelweg, an external warehouse, the costs are considerably higher. The costs for Snelweg amounted to approximately 68 000 €, with inbound costs at 49 000 € and outbound costs at 19 000 €.

The results show that it is more cost-effective for Wärtsilä to use transport companies for tool deliveries, as the costs for excess baggage become significant when service engineers carry the tools in their luggage.

This study has achieved the desired results, and based on the conditions, the thesis is successful. It provides Wärtsilä with a new and detailed view of the tool management process.

Many challenges arose during the project, limiting the investigation's scope. The timeframe for the thesis and the difficulty of gathering information about tool deliveries made it impossible to examine deliveries from multiple distribution centers globally. The existing data on tool deliveries, including the number of deliveries, quantity per delivery, costs, delivery methods, and overall control over deliveries, is almost non-existent. This significantly complicated the process and required extensive investigations and discussions with various individuals.

Despite these challenges, the desired results were achieved. The thesis has given Wärtsilä a much better overview of all data related to tool deliveries and provided recommendations and guidance based on carefully calculated assessments.

The study's results have practical implications, including recommendations for where a tool hub should be located. One specific recommendation is to place the tool hub in Germany, and this conclusion has been reached based on a combination of the key success factors and the COG analyses. The results from the calculations of tool deliveries from Finland and the Netherlands give Wärtsilä detailed information about delivery costs and logistics. Comparisons between using a transport company and having service engineers carry the tools in their luggage show that it is more cost-effective to use a transport company.

During the project, it was noted that the overall management of the tools was not functioning optimally. In the questionnaire sent to the service engineers and in interviews, the biggest challenge in the tool management process was identified as the lack of control over the tools. This means that the position of the tools is not always known, the condition is not always good, and delays in returning tools are standard.

Due to these recurring problems and challenges, it might be a good idea for Wärtsilä to conduct future research on the lack of control over the tools. One option to improve control could be to investigate the benefits of implementing a warehouse management system in the new tool hubs.

In summary, this study contributes to a deeper understanding of the tool management process and highlights various perspectives and reflections. By addressing the identified weaknesses, Wärtsilä now has the opportunity to improve its tool management.

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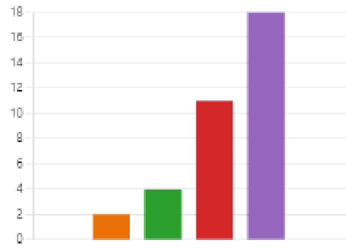
Appendix 1. The questionnaire sent to service engineers

Questionnaire for Service Engineers

35 Svar 07:46 Genomsnittlig tid för att slutföra Aktivt Status

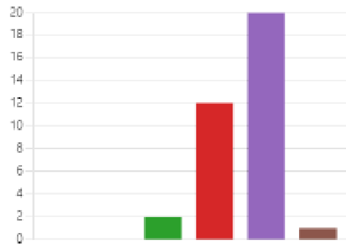
1. Are you planning the tools needed for the service jobs?

Never	0
Seldom	2
Sometimes	4
Often	11
Always	18
Annat	0



2. Do you carry your personal toolbox on every work trip?

Never	0
Seldom	0
Sometimes	2
Often	12
Always	20
Annat	1



3. What kind of tools are you carrying on?

35
Svar

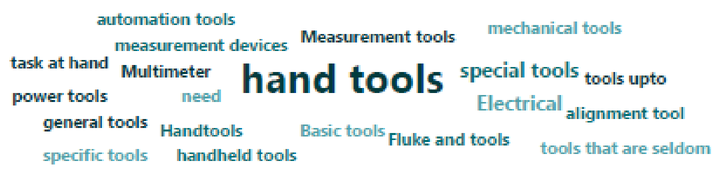
Senaste svar

"Hand tools and some 50SG/DF special tools"

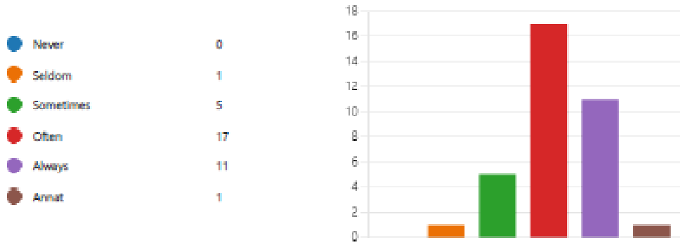
"Electrical instruments and sensor mounting/cabling related tools"

"Hand tools"

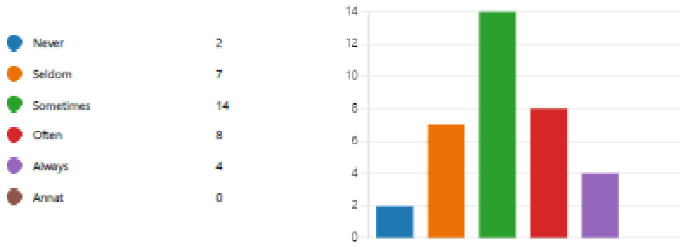
14 svarande (**40** %) har svarat på **hand tools** för den här frågan.



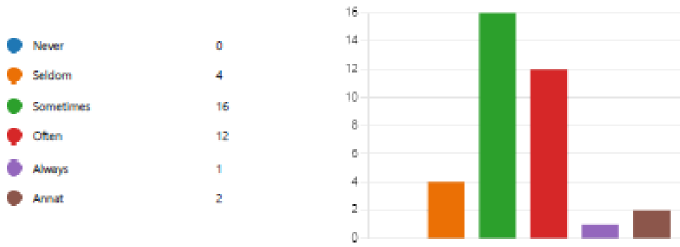
4. Is there usually a need for payment of excess baggage on a flight?



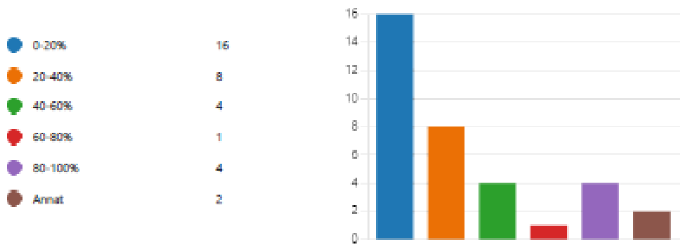
5. Is it complicated to bring tools?



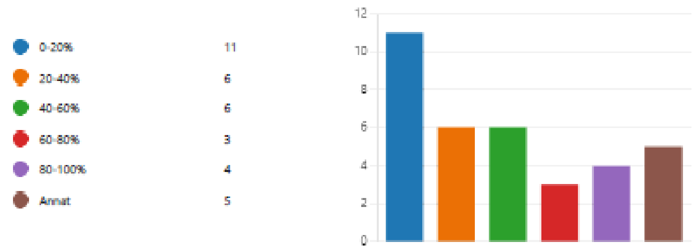
6. How often are the tools not on site when expected?



7. How many percent of cases are you using customer's tools?



8. How many percent of total jobs are you insecure using customer tools?



9. What do you think is the biggest problem in the tool management process?

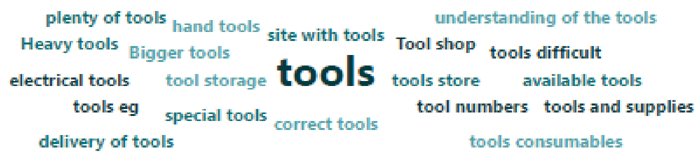
23
Svar

Senaste svar

"In my case there is no tool management process, I have my own tool set"

"Carrying enough tools to the site."

19 svarande (**83** %) har svarat på **tools** för den här frågan.



Appendix 2. Question 3 in the questionnaire in Appendix 1

3. What kind of tools are you carrying on?

35 Svar

ID ↑	Namn	Svar	Språk
1	anonymous	Basic tools and special tools, depending the need.	
2	anonymous	Normal hand tools, and special tools that are seldom, or never found at work site	
3	anonymous	Can't use own tools because they are not CE marked, thereby no insurance.	
4	anonymous	all special tools that we needed to get the final jobs as checking the alignments, timings and so on	
5	anonymous	Small hand tools, spanners, screwdrivers, etc. Multimeter. Several interface adapters (UNIC, frequency converters, etc)	
6	anonymous	Fluke meters, pressure pump, handheld tools	
7	anonymous	Hand tools. Measurement tools	
8	anonymous	Laser alignment tool	
9	anonymous	Electrical and mechanical	
10	anonymous	Handtools like spanners and sockets And almost every time some special tools	
11	anonymous	Hand tools, power tools, sometimes machine specific tools	
12	anonymous	Normal basic tools	
13	anonymous	Handtools ~30kg in a Peli case	

13	anonymous	Handtools, ~30kg in a Peli-case	
14	anonymous	Electrical testing and measurement equipment and regular hand tools.	
15	anonymous	Basic hand tools, electrical and pneumatic tools, measurement devices	
16	anonymous	mechanical tools and measurement instruments	
17	anonymous	Multimeter, many simulator, PC etc etc	
18	anonymous	Basic tools and special tools if needed depends on work	
19	anonymous	Regular hand tools mostly, wrenches, sockets...	
20	anonymous	General hand tools upto 24 / 30mm Measurement equipment & always impact gun	
21	anonymous	Hand tools. Weight of the toolbox 30 kg.	
22	anonymous	Basic electrical automation tools + measurement devices	
23	anonymous	captive bolt pistol, wrenches, etc	
24	anonymous	Handtools	
25	anonymous	flukes, most used screwdrivers, spanners etc, necessary cables, hart modem, speed simulator, oscilloscope etc.	
26	anonymous	Mechanical hand tools, sometimes special tools	
27	anonymous	Basic tools for electrical installation and laptop.	
28	anonymous	Hand tools	
29	anonymous	Handtool box, battery impact gun, deflection indicator, multimeters	
30	anonymous	Hand tools	
31	anonymous	A set of general tools. And then additionally tools needed for the task at hand.	
32	anonymous	Fluke and tools for electrical work.	
33	anonymous	Hand tools	
34	anonymous	Electrical instruments and sensor mounting/cabling related tools	
35	anonymous	Hand tools and some 50SG/DF special tools	

Appendix 3. Question 9 in the questionnaire in Appendix 1

9. What do you think is the biggest problem in the tool management process?

23 Svar

ID ↑	Namn	Svar	Språk
1	anonymous	Biggest issue is if luggages are lost at the airport. That´s why short changes of flights should be avoided.	
2	anonymous	The assortment of available tools, there are plenty of tools, although some have mismatching/unproperly definition, i.e. it can occasionally be difficult to find and bring the needed tools to a jobsite.	
3	anonymous	Awry body wants to use them but no one wants to spend money to maintain the once we have. Nobody wants to spend money to make new once, even if it could save company lots of working hours.	
4	anonymous	The cost and time to send the tools before the job and also we always the ticket flights domestic/international with only one baggage instead of two for the tools	
5	anonymous	Heavy tools difficult to send by cargo due to urgent jobs	
6	anonymous	insufficient equipment for all personnel involved in field service. lack of special equipment suitable for the job which forces technicians to invest time in alternative solutions, modifying and building tools for the specific job. even in case of extreme necessity, even if the same tool is far cheaper compared to official channels, it is absurd that the purchase of that specific equipment of excellent quality and Brend leader in the sector, is unpermitted .	
7	anonymous	Bags with tools are more often lost at aiports than not.	
		Knowing what the situation is on the site with tools. Also the condition and potential calibration needed in order to perform a safe and	

8	anonymous	Knowing what the situation is on the site with tools. Also the condition and potential calibration needed in order to perform a safe and foremost the quality, ie not knowing if it site tools are maintained or calibrated in order to fulfil Wärtsilä quality standards. Another problem (from tool storage point of view) is that there's not many "premade" sets made for example bigger overhauls or reoccurring jobs. For example W31 high pressure fuel pumps or 34SG major overhaul sets, to mention two. These are "collected" each time and it's quite time consuming. Would be beneficial to have "normal jobs" with premade sets.	
9	anonymous	basic every day tools and supplies are not always found in our tools store, takes a lot of time to drive around to collect then from different stores.	
10	anonymous	Many times the tools are not certificate calibration update	
11	anonymous	No one place where you can find correct tools for the job. Example using just maintenance manual tool numbers now there is old numbers new numbers paaf numbers and all kind of numbers. Sometimes there is many different numbers for special tools and someone somewhere knows where those tools maybe are or where last time seen.	
12	anonymous	Inexperience and limited understanding of the tools, their correct use and maintenance. Very limited visibility of what is available, and where. Often inter company rates are prohibitively expensive	
13	anonymous	Hard to replace measurement devices when returning for calibration	

14	anonymous	customer assumes all needed tools are in the "normal wärtsilä toolcase". this does not include for example: torx (any), panduit gun, reducers, any electrical tools basically. Also usually "special" tools e.g for lifting start air valve or prechamber are "suppose to be here somewhere" but there is no order to it so it always takes an hour to find anything	
15	anonymous	When you send tools it usually take more time than your traveling time and you never know when they arrive.	
16	anonymous	Bigger tools are little bit harder to carry with, but this is not a problem in my job	
17	anonymous	Too comblicated !!!!	
18	anonymous	No tool store keeper. Tool store i spread out arrounf the hub. No ETRA at old factory any more.	
19	anonymous	We dont have enough special hand tools in our own storage.	

20	anonymous	After the ETRA Tool shop closed in Wärtsiläs old factory, acquiring tools consumables, PPE takes a lot longer, since no normal Tool shop (ETRA, WURTH, ...)keeps much of anything in their stock. This is not only a problem for WFI-FS, also noticed at STH, where the work is stopped sometimes because of missing tools, with long waiting times, since the needed tools are ordered through WeBuy. When the task/project at hand is planned long in advance, this is no issue. But when the work starts at short notice, acquiring needed tools is a challenge. Many times the only option is to order through unconventional channels. Ebay, Amazon, courier delivery of tools from the main warehouse of example ETRA. To me is seems like it would be a lot cheaper/convenient to open an ETRA store in STH, just like we had before in the old factory. Also the employees of that particular tool store had expert knowledge of what is needed for Wärtsilä.	
21	anonymous	Hard to exactly know what tools we have in the tool store.	
22	anonymous	Carrying enough tools to the site.	
23	anonymous	In my case there is no tool management process, I have my own tool set	

Appendix 4. List of all random samples

Random sample 1

Service contract: **9090028212**

Job location: **Sydney, Australia**

Total excess baggage on flight costs on the service contract: **1221,18 €**

Number of excess baggage on flight tickets: **2**

1 031,39	EUR
189,79	EUR

Random sample 2

Service contract: **9090028117**

Job location: **Seattle, USA**

Total excess baggage on flight costs on the service contract: **3612,95 €**

Number of excess baggage on flight tickets: **18**

970,71	EUR
400,00	EUR
400,00	EUR
250,00	EUR
181,43	EUR
153,51	EUR
153,51	EUR
153,51	EUR
153,51	EUR
122,60	EUR
114,80	EUR
110,00	EUR
110,00	EUR
110,00	EUR
90,72	EUR
84,07	EUR
34,11	EUR
20,47	EUR

Random sample 3

Order nr: **11262155**

Job location: **At sea / Colombo, Sri Lanka**

Total excess baggage on flight costs on the order: **906,95 €**

Number of excess baggage on flight tickets: **1**

Random sample 4

Service contract: **9090022535**

Job location: **Melbourne, Australia & New Zealand**

Total excess baggage on flight costs on the order: **1384,22 €**

Number of excess baggage on flight tickets: **7**

810,00	EUR
290,98	EUR
110,00	EUR
60,00	EUR
60,00	EUR
26,62	EUR
26,62	EUR

Random sample 5

Order nr: **11274831**

Job location: **Port Moresby, Papua new Guinea (outside of Australia)**

Total excess baggage on flight costs on the order: **1116,21 €**

Number of excess baggage on flight tickets: **2**

607,57	EUR
508,64	EUR

Random sample 6

Order nr: **8725086**

Job location: **Dresden Reick, Germany**

Total excess baggage on flight costs on the order: **720 €**

Number of excess baggage on flight tickets: **2**

600,00	EUR
120,00	EUR

Random sample 7

Order nr: **11185088**

Job location: **Balamban, Philippines**

Total excess baggage on flight costs on the order: **2154,26 €**

Number of excess baggage on flight tickets: **14**

459,44	EUR
405,50	EUR
300,20	EUR
174,38	EUR
159,42	EUR
159,42	EUR
156,23	EUR
123,09	EUR
87,27	EUR
43,35	EUR
26,89	EUR
23,39	EUR
17,99	EUR
17,69	EUR

Random sample 8

Order nr: **11245695**

Job location: **Izimit, Turkey**

Total excess baggage on flight costs on the order: **929,42 €**

Number of excess baggage on flight tickets: **8**

458,56	EUR
180,00	EUR
109,09	EUR
88,00	EUR
54,55	EUR
37,39	EUR
0,93	EUR
0,90	EUR

Random sample 9

Order nr: **11223167**

Job location: **Dakar, Senegal**

Total excess baggage on flight costs on the order: **648,89 €**

Number of excess baggage on flight tickets: **2**

440,00	EUR
208,89	EUR

Random sample 10

Order nr: **9000019055**

Job location: **Miami, USA**

Total excess baggage on flight costs on the order: **970,56 €**

Number of excess baggage on flight tickets: **8**

430,00	EUR
278,24	EUR
180,00	EUR
54,55	EUR
8,46	EUR
8,20	EUR
5,64	EUR
5,47	EUR