TAMPEREEN TEKNILLINEN YLIOPISTO
TAMPERE UNIVERSITY OF TECHNOLOGY

NONA ONNELA

DETERMINING THE OPTIMAL DISTRIBUTION CENTER LOCATION

Master of Science Thesis

Examiner: Prof. Jarkko Rantala.
Examiner and topic approved by the Faculty Council of the Faculty of Business and Built Environment on the 4th of February 2015.

ABSTRACT

NONA ONNELA: Determining the Optimal Distribution Center Location
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The main research question of this thesis was: What is the optimal location for Kalmar's European Distribution Center when quantitative and qualitative factors are considered? The aim was to investigate whether or not the current location is optimal and if not, what would be a better location. In order to do that, relevant factors behind the location decision also needed to be determined.

This thesis is a combination of case study and action oriented study. It combines both, qualitative and quantitative methods. In the first phase, theoretical background was created for the subsequent empirical phase. It was done by using scientific literature as source material. The aim was to cover the most important themes of warehousing and location decisions in respect of the case company's situation. The empirical part started with the description of Kalmar's current supply chain. Then, challenges with the current distribution center location were determined through interviews and observations. Quantitative data of shipments and their destinations was used in center of gravity calculations. The actual location of the center of gravity created a base for searching for a candidate service provider and determining the relevant factors. The factors taken into account were cultural and logistical. After that, the service providers' competences were evaluated. Prices were taken into account as well. The results were then combined with the AHP method.

The result of the center of gravity analysis was a point in the western part of Germany. After closer scrutiny, there occurred to be three possible new service providers within a reasonable distance from the center of gravity. However, the current EDC location was also considered a possible option, and thus there were four candidates. Two of them were in Germany, one in the Netherlands and one (the current) in France. Culturally and logistically the current location was considered the worst and the locations in Germany the best. The service provider in Germany, Mönchengladbach, was seen as the best option also by its competences. Consequently, the most essential result of this thesis is that the optimal location for Kalmar's EDC would be in Mönchengladbach. However, changing the location there is not the recommended action of this thesis. Relocating has numerous possible complications and thus its implications and costs should be scrutinized more closely before any decision to change the location.

TIIVISTELMÄ

NONA ONNELA: Varaston optimaalisen sijainnin määrittäminen
Tampereen teknillinen yliopisto
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Tuotantotalouden diplomi-insinöörin tutkinto-ohjelma
Pääaine: Tuotannonohjaus ja logistiikka + Kuljetusjärjestelmät
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Avainsanat: Varaston sijainti, gravitaatiomalli, AHP, varaosaliiketoiminta, globaali toimitusketju, 3PL

Tämän diplomityön päätutkimuskysymys oli: Mikä on optimaalinen sijainti Kalmarin Services-yksikön Euroopan keskusvarastolle, kun sekä määrälliset että laadulliset tekijät otetaan huomioon? Tarkoituksena oli tutkia, onko nykyinen sijainti optimaalinen ja jos ei, mikä olisi parempi sijainti. Jotta optimaalinen sijainti saatiin selville, täytyi myös määritellä tärkeimmät siihen vaikuttavat tekijät.

Tämä diplomityö toteutettiin tapaustutkimuksen ja toiminta-analyyttisen tutkimuksen yhdistelmänä, jossa käytettiin sekä laadullisia että määrällisiä tutkimusmenetelmiä. Diplomityön alkuosassa luotiin teoreettinen tausta empiiriselle tarkastelulle. Teoreettinen osio toteutettiin käyttämällä aineistona tieteellistä kirjallisuutta ja artikkeleita. Tarkoituksena oli käsitellä käytännön ongelman kannalta tärkeimmät varastoinnin ja sijaintipäätösten teoriat. Työn empiirinen osuus aloitettiin Kalmarin nykyisen toimitusketjun kuvailulla. Tämän jälkeen määriteltiin nykyisen EDC:n sijainnin ongelmakohdat havainnoinnin ja haastattelujen keinoin. Määrällistä, lähetyksistä kertovaa dataa hyödynnettiin gravitaatiomallin mukaisissa laskelmissa. Laskemista saatua painopistettä ja sitä ympäröivää erikseen määriteltyä aluetta käytettiin sitten pohjana mahdollisten palveluntarjoajien kartoitukselle ja tärkeimpien sijaintitekijöiden määrittelylle. Tekijät, jotka päädyttiin huomioimaan, olivat kulttuuriset ja logistiset tekijät. Tämän jälkeen arvioitiin palveluntarjoajien ominaisuuksia, kyvykkyyttä ja hintoja. Lopuksi tulokset yhdistettiin AHP-menetelmää käyttäen, jotta saatiin selvitettyä kaikki tekijät huomioon ottava optimaalinen sijainti.

Gravitaatiolaskelmien tuloksena saatiin piste, joka sijaitsee Saksassa lähellä länsirajaa. Tarkemman tarkastelun jälkeen huomattiin, että järkevän matkan etäisyydellä uutta mahdollista palveluntarjoajaa. Myös nykyinen EDC osui tarkastelualueelle, ja se otettiinkin mukaan vertailuun, joten yhteensä vaihtoehtoja oli neljä. Kaksi palveluntarjoajista sijaitsi Saksassa, yksi Hollannissa ja yksi (nykyinen) Ranskassa. Nykyistä sijaintia pidettiin sekä kulttuurisesti että logistisesti heikoimpana. Vastaavasti Saksa oli näiltä ominaisuuksilta vahvin. Palveluntarjoajista parhaana pidettiin Mönchengladbachissa Saksassa sijaitsevaa tarjoajaa. Tämän diplomityön tuloksena olikin, että optimaalinen sijainti Kalmarin Services-yksikön Euroopan keskusvarastolle olisi Mönchengladbach. Tämä ei kuitenkaan ollut sama, kuin työssä esitetty toimintasuositus, sillä sijainnin muuttamisella olisi paljon negatiivisia vaikutuksia joita pitäisi tutkia vielä tarkemmin.

PREFACE

This Master of Science thesis was made at Kalmar Services during eight months, between September 2014 and April 2015. Writing this thesis was a challenging but also a very inspiring project, which is a great conclusion to my studies.

First, I would like to thank Professor Jarkko Rantala for his guidance during this process and for examining this thesis. Many people have helped and supported me also at Kalmar. I want to express my sincere gratitude especially to Logistics Manager Seppo Haapala for providing the topic and necessary information and also for mentoring me during the process. I would also like to thank Logistics Engineer Toni Uskola for his contribution to my work.

I am deeply grateful to ThD Jenni Spännäri, who has given me priceless pieces of advice on writing a thesis but whose comments also made me laugh. I also wish to express my appreciation to Susanna Yrjänäinen for her help with my English.

Finally, I would like to thank my friends and family who have always had faith in me. My heartfelt thanks go to Lauri, who has supported me and promised that there will be champagne at our shared graduation party.

Tampere, 15th April 2015

Nona Onnela

SISÄLLYSLUETTELO

ABBREVIATIONS AND NOTATION

3PL	Third party logistics
AHP	Analytical hierarchy process. A method for decision making
CoG	Center of gravity
DC	Distribution center
EDC	European Distribution Center
ERP	Enterprise resource planning
KPI	Key performance Indicator
SKU	Stock-keeping unit

1. INTRODUCTION

In global competition, organizations have to continuously search for new ways to lower costs, improve customer satisfaction, and increase profitability. Logistical operations, and especially warehousing, have traditionally been an opportune field for cost savings. Yet, savings should not be sought for at the cost of service level. A better option is to look for alternatives which avail both parties; customers and the organization serving these customers.

1.1 Motivation

Effective supply chain management is often an efficient way to increase profitability. Warehouse or distribution center location decisions are one part of the supply chain management. Functional distribution center locations can decrease organizations' transportation costs and cut down inbound and outbound lead times. Lead time shortenings, consequently, make inventory control easier and thus most likely increase service level (Gallmann and Belvedere 2010).

When making a location decision, there are lots of other factors than just lead time and cost reductions that should be considered. The surrounding environment which consists of society, culture and infrastructure among other things, has a remarkable significance to the functionality of the location (Skjøtt-Larsen et al. 2007, p. 402). For example, cultural differences may make interaction and communication difficult. Also, if the infrastructure around the distribution center location is weak, ostensibly short distances may be more time consuming than longer distances in an area with a strong infrastructure. These factors may have an effect not only on the easiness of the operating but widely on the costs and service level.

The nature of spare parts business adds its own characteristics to warehousing and thus also to location decisions. The volatile demand of spare parts increases the need for effective operations (Huiskonen 2001) and fluid relationships. Functional relationships are another important factor when the warehousing has been outsourced to a third party (Jespersen and Skjøtt-Larsen 2005, pp. 150-151). Possible outsourcing partners also occasionally create something of a basis for the location decision. If an organization has decided to outsource its warehousing functions, it has to consider the locations of the service providers in the location selection.

1.2 Case company

The case company of this thesis is Kalmar which is a global cargo handling solutions provider. Kalmar is a part of Cargotec Corporation, which has also two other business areas: MacGregor and Hiab. Cargotec provides a wide range of load handling equipment for end-to-end cargo handling solutions. MacGregor offers products and services for the maritime transportation and offshore industries while the equipment of Hiab is used in on-road transport and delivery. Kalmar's equipment is used in the cargo handling solutions and services in ports, terminals, distribution centers and industrial applications. (Cargotec 2013)

Cargotec Corporation was formed in 2005 after the demerger of Kone Corporation. Nowadays Cargotec operates in more than 100 countries and employs approximately 11 000 people. In 2013 Cargotec's sales totaled 3.2 billion Euros. (Cargotec 2013) Figure 1.1 shows the development of Cargotec's total sales and profit margins between the years 2008 and 2013.

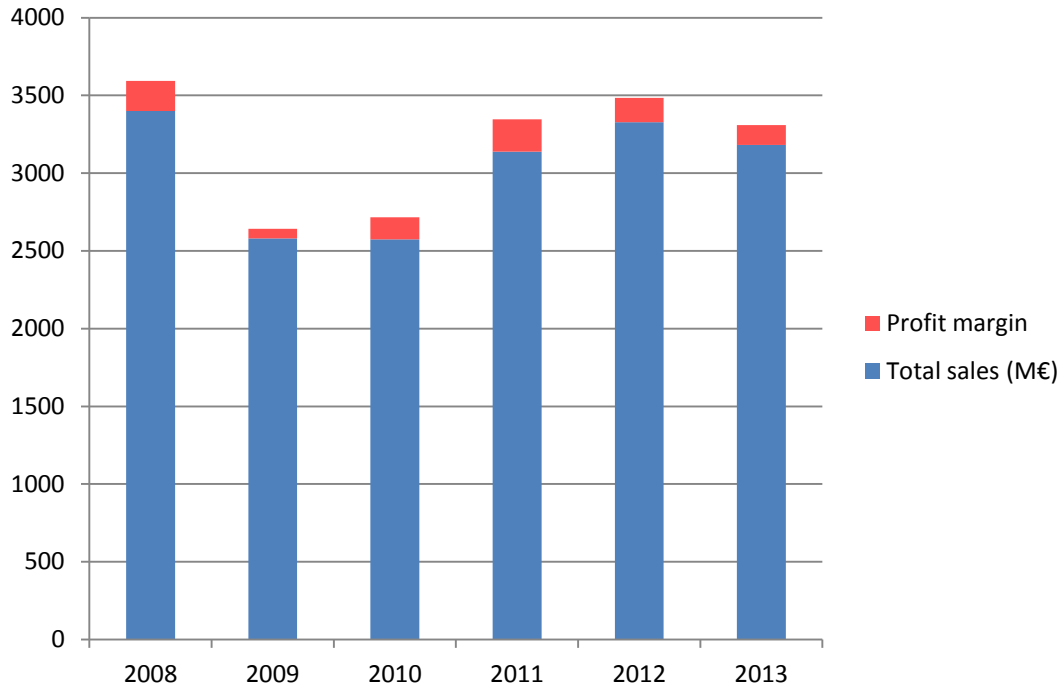

Figure 1.1. *Cargotec's total sales and profit margins between the years 2008 and 2013. (Adapted from Cargotec 2010 and Cargotec 2013.)*

Kalmar is the market leader in its field, which consists of cargo handling equipment, port automation and services. In 2013 its sales totaled 1 550 million Euros while the operating profit was 4.1 percent. Kalmar's business has spread out in 33 countries with approximately 5 000 employees. (Cargotec 2013)

Kalmar's selection includes container and cargo handling equipment such as straddle and shuttle carriers, reach stackers, empty container handlers, terminal tractors and fork-lift trucks. Spreaders, dry bulk handling systems, terminal automation and integration solutions and Navis terminal operating systems are included in Kalmar solutions as well. Kalmar also has an automation product and service offering which covers both equipment and process automation. That equipment is, for example, automated stacking cranes and automated straddle carriers. (Cargotec 2013)

Automation business is seen as one of the greatest growth potential in Kalmar and has been named as the number one cornerstone in Kalmar's strategy (Cargotec 2014). Figure 1.2. presents all the strategic cornerstones.

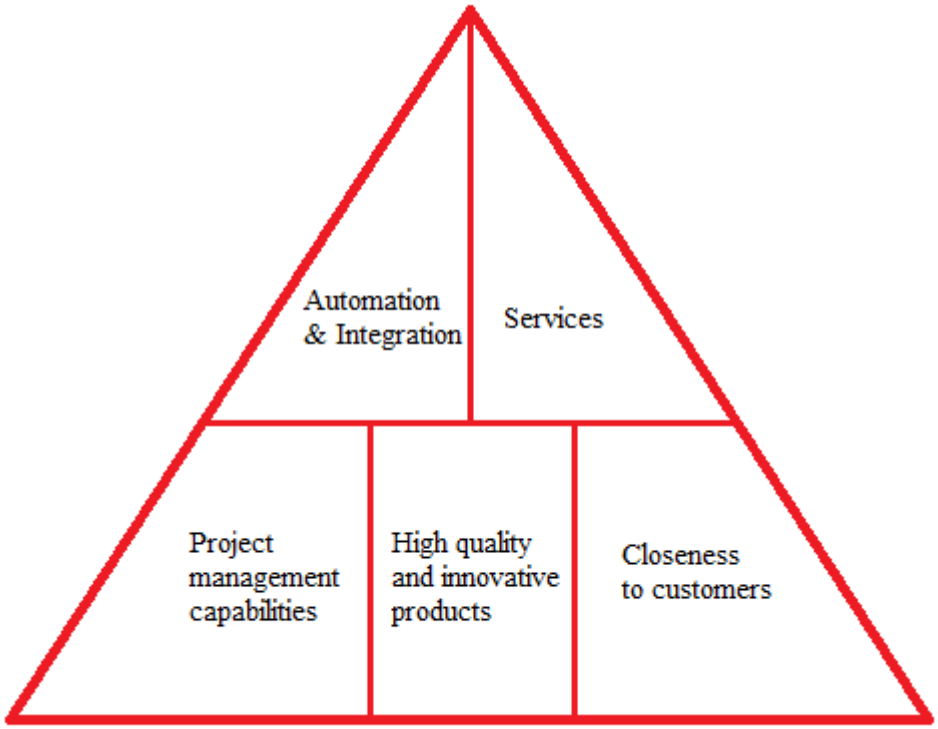

Figure 1.2. *Cornerstones of Kalmar's strategy. (Adapted from Cargotec 2014)*

As can be seen in figure 1.2, services are a very important part of Kalmar's offering. In 2013, 25 percent of Kalmar's sales came from service business. One reason for the growth of service business is the fact that outsourcing has become more common. Kalmar Services division covers maintenance, crane services, parts and logistics and sales of pre-owned equipment. Kalmar has the most extensive service network in the world. (Cargotec 2013) Figure 1.3 presents the share of service business in Kalmar's sales between years 2011 and 2013.

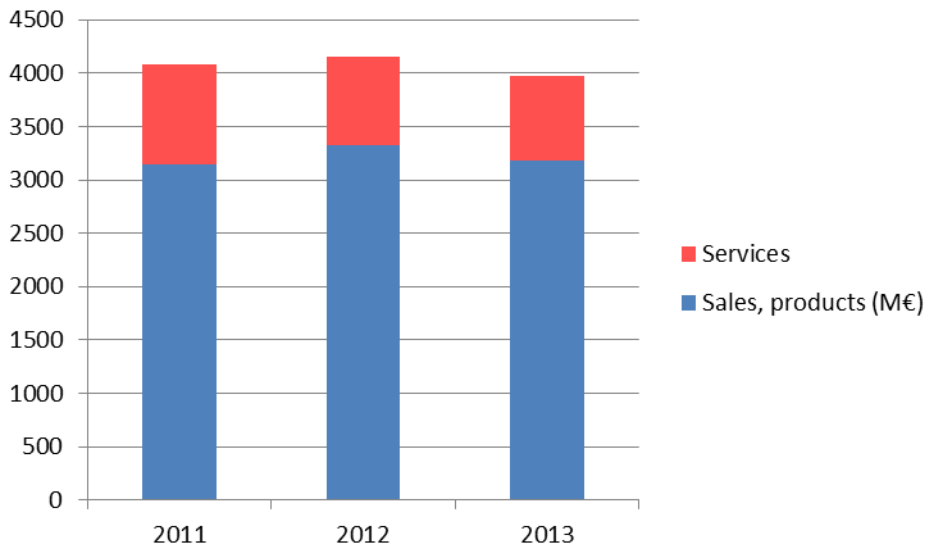

Figure 1.3. *Services, % of total sales. (Cargotec 2013)*

In Services division, there is Parts and Logistics business line which is responsible for spare parts sourcing, sales support and the logistics operations between suppliers and customers. Kalmar's spare part portfolio includes a wide range of different parts such as electrical items, servicing kits, major components and wear parts.

1.3 Research problem, objectives and restrictions

The main purpose of this study is to determine the optimal location for Kalmar spare parts' European Distribution Center (EDC). The expression "optimal" in this case means a combination of quantitative and qualitative factors. The primal quantitative factor used is the amount of ton kilometers between the distribution center and the customers. Qualitative factors include political, cultural and logistical attributes which affect the quality and the effectiveness of warehousing operations. Thus, the research problem of this thesis is:

- There is no certainty whether the current EDC location is optimal or not.

Consequently, the research question is:

- **What is the optimal location for the EDC when both quantitative and qualitative factors are considered?**

In order to answer the main research question, it is divided into sub questions as follows:

- Which method should be used when calculating ton-kilometers?
- Which other qualitative factors should be included?
- What are the main challenges for the current EDC location?

- What kind of attributes should be considered when evaluating the qualitative factors?
- How should the different factors be weighted?
- Which decision making method should be used in order to solve the location problem?

The scope of the research is the delivery part of Kalmar's supply chain. The optimal distribution center location is determined based only on external and internal customer locations. Thus, supplier locations do not have weight in this research. Also, when qualitative factors are evaluated, the main focus is on service level improvements and not on procurement functions. The main reason for these restrictions is that the supply part was considered not to have as significant importance as the delivery part when making a location decision. In addition, including all the parties would not have been possible in the time frame of this thesis. Figure 1.4 presents the scope of the thesis and the parties that are included in the determination of the optimal location.

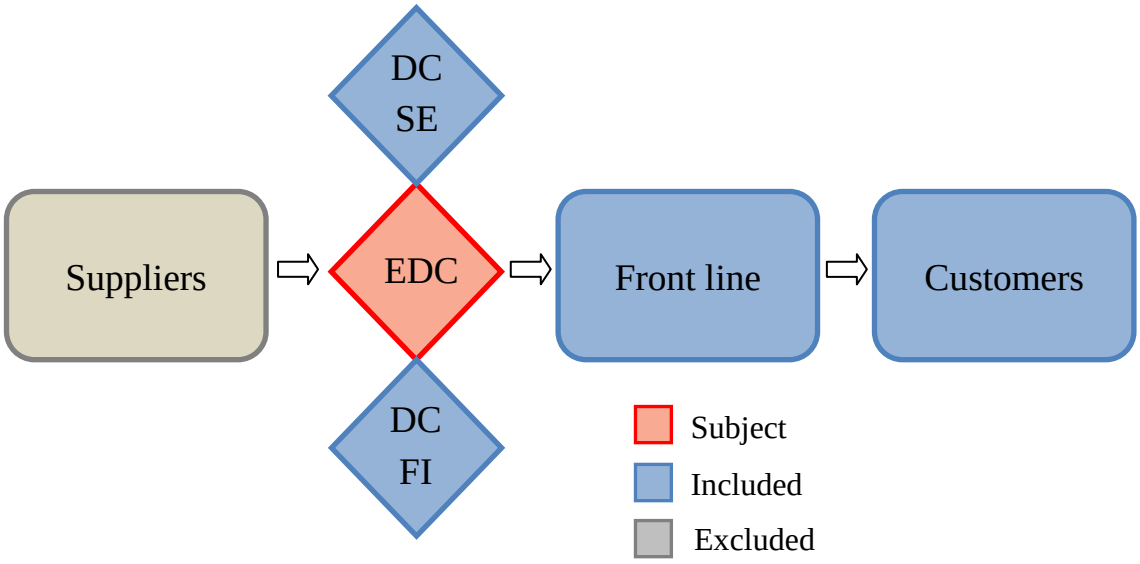

Figure 1.4. *The scope of this thesis in respect with the simplified supply chain of Kalmar Services*

As figure 1.4 presents, the simplified version of the supply chain of Kalmar Services consists of suppliers, distribution centers, front line and customers. The main subject of this research is Kalmar's European Distribution Center. The scope distribution center is located in France. Locations of the two other distribution centers are not considered, but their influence on the location of the EDC is noted. Thus, the factors which have impact on the location decision are customers, front line and other distribution centers.

1.4 Research approach and methods

The research approach of this thesis is the action oriented approach. The action oriented approach aims to understand the target problem. Subjects are typically phenomena in the internal performance of an organization. The action oriented research approach is based on antipositivistic research philosophy, which means that the relationship between the target and the researcher is dense. (Olkkonen 1994, p. 74; Das 2014) According to (Eriksson and Kovalainen 2008, pp. 193-194) he action oriented approach is especially suitable if the research question is about describing series of actions over certain time and in a certain group, organization or other community.

The action oriented research approach combines theory, history and practice around the phenomenon in order to reach objectives. Thus, problems characteristically consist of actual historical data, previous theories and people with their expectations and practices. (Olkkonen 1994, p. 74) Figure 1.5 presents this point of view in the action oriented approach.

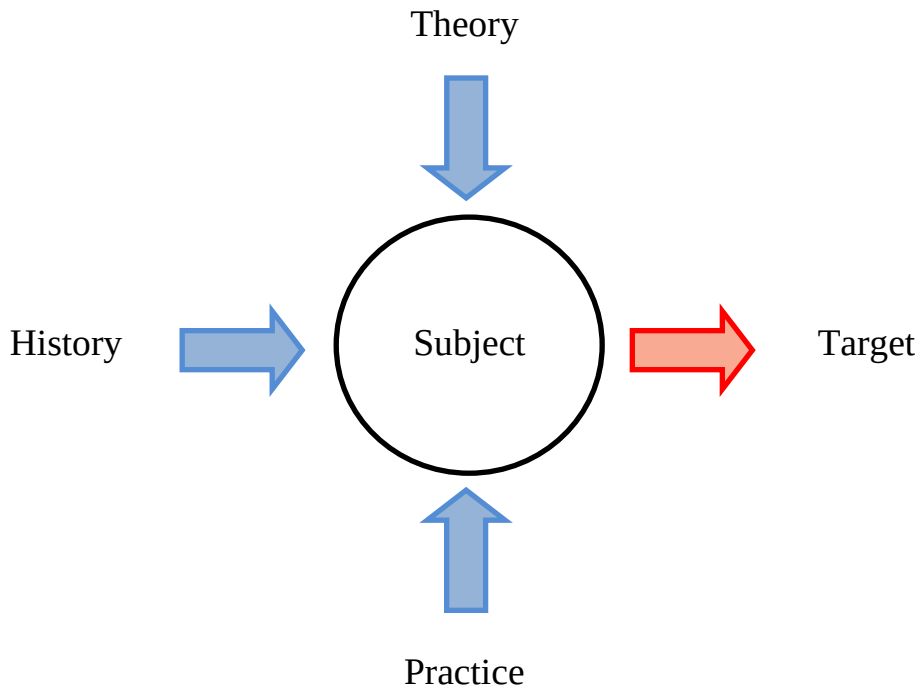

Figure 1.5. *Precept of an action oriented research approach (adapted from Olkkonen 1994, p. 75).*

The approach of a case study is also utilized in this research. Yin (2009, p. 19) states that a case study is an empirical inquiry which considers contemporary and real-life phenomena. A case study is highly dependent on the context and thus provides findings that generate insight into how the phenomenon actually occurs within a given situation. A case study is a suitable approach for answering questions that start with how, who or

why and provides relatively full understanding of the nature and the complexity of the complete phenomenon. The case study approach also enables the integration of qualitative and quantitative methods. (Farquhar 2012, pp. 8-9) Eriksson and Kovalainen (2008, p. 116) explain the popularity of case study approach in business research by its capability to present complex business and management issues in an accessible and easily understandable format.

This thesis is divided into theoretical and empirical study. The theoretical part is based on previous theories that are relevant to answering the research questions. The theoretical research has been done based on scientific literature and journals. The empirical methods that have been used are internal and external interviews, participant and descriptive observation, and gathering and analyzing statistical data. Thus, this thesis combines qualitative and quantitative methods. According to Saunders et al. (2009, p. 151), quantitative methods are mainly data collection and analysis techniques which generate or use numerical data. Qualitative methods, on the contrary, generate non-numerical information (Saunders et al. 2009, p 151).

Combining both, qualitative and quantitative research method is called as *mixed methods research* (Hesse-Biber 2010 p. 3). According to Cameron and Molina-Azorin (2014) it is a coherent approach for business and management research especially when a researcher "tries to innovate, add value or gain greater insights into increasingly complex business and management phenomena and discipline based inquiry."

Saunders et al. (2009, p. 318) state that interviews may help gather valid, reliable and relevant data. Qualitative interviews are based on conversation, as the main idea is researcher asking questions and listening, and respondents answering (Warren 2001, p. 83). Interviews in this thesis are done in order to determine the current situation with its benefits and challenges. Also, qualities of the candidate locations are studied through interviewing personnel in the relevant organizations. Interviews in this thesis are semi-structured. It means that there is a prepared outline of topics, issues or themes, but also a possibility to vary questions in each interview (Eriksson and Kovalainen 2008, p. 80). Overall seven persons were interviewed for this study between December 2014 and February 2015. The total number of the interviews was eleven, because some of the persons were interviewed couple of times.

Quantitative data analysis is used to make raw data useful for the study. Business and management researches most likely include some numerical data that helps answer the research questions. Quantitative analysis techniques range from creating tables to using statistics, to comparisons and conclusions made based on the data. (Saunders et al. 2009, p. 414) This research uses statistical data in order to determine the center of gravity location. Statistical data is also used as the basis of some qualitative comparisons.

Participant observation is used to describe "what is going on", particularly in social situations. It is a relevant method especially when the researcher is working in the target organization. Consequently, the closeness to the situation may also cause significant observer bias. The term descriptive observation describes observing a physical setting. (Saunders et al. 2009, pp. 296-299) In this thesis, participant observation is used to describe the current situation and systems. Eriksson and Kovalainen (2008, p. 86) see participant observation as one of the most demanding ways of collecting empirical materials. This is explained with the fact that in order to assure that the observations are of the natural phenomenon, the researcher needs to become accepted as part of the culture, which may take even years. In this thesis, becoming a part of the case company did not take any extra time, because the company was already familiar from the researcher's previous work history.

1.5 Structure

As the figure 1.6 indicates, the following two chapters provide theoretical background for the study. Both those chapters are based solely on literature reviewing. The second chapter introduces the basics of strategic warehousing and spare part business. The aim there is to point out the main functions of warehousing and the differences between a warehouse and a distribution center. Outsourcing of the warehousing functions and specialties of the inventory control of spare parts are discussed as well.

Location decision theories are introduced in chapter three. Both, qualitative and quantitative factors are considered in order to determine all significant inducements behind a location choice. The qualitative factors that are taken into account in this chapter are mainly cultural, political and logistical. This chapter also represents a decision making model that is suitable for combining qualitative and quantitative factors in location decisions.

The fourth chapter presents the current situation in the case company. It describes the whole supply chain of Kalmar's spare parts, from a supplier to a customer. However, the main focus is on the current distribution centers and their locations, and especially in the EDC location. Also the qualities and challenges of the current EDC location are determined in chapter four. These qualities determine the baseline especially for the further scrutiny of the location factors.

Research materials and methods are represented in the chapter five. The first subchapter concentrates on data that is used in analyzing current product flows. Then, the second subchapter describes the use of center of gravity method on the chosen data. Also, qualitative methods and targets of interviews are represented in the fifth chapter. The utilization of the Analytical Hierarchy Process (AHP) method is also explained.

The sixth chapter concentrates on the results that have been achieved through the data analysis, interviews, theoretical background and statistics. Those results are also finally combined in this chapter and it leads to the final result of this thesis. Consequently, also the reasons behind the final result are explained more closely. In this chapter the AHP method is widely utilized in order to get the final results.

The last chapter presents the conclusions of this thesis. First, the main results of the optimal distribution center location are summarized. Then the whole study and its relevancy are assessed in respect of the original objectives and research questions. The relevancy of the utilized research methods is speculated, too. Finally, some recommendations for further studies are given.

2. STRATEGIC WAREHOUSING AND SPARE PART BUSINESS

Warehousing is an important part of a modern supply chain. Its role depends strongly on the business type. For an organization that sells physical products, warehousing is rarely a key competence (Walker 2010). This fact and a need for cost reductions lead often to the outsourcing of warehousing operations. This chapter presents the theoretical background for strategic warehousing, outsourcing warehousing operations, and warehousing in spare part business. These topics are needed to be covered because they create a good base for the understanding of case company's business and current situation.

2.1 Warehousing functions

The main purpose of warehousing is to ensure the fluent product flow from the vendor to the customer. This is intended to be done as cost effectively as possible. The aim is to benefit both, the customer and the delivering party. Thus, successful warehousing may give direct cost savings but also indirect profits through risen customer satisfaction.

2.1.1 Balancing supply and demand

Ackerman (1997, p. 14) presents two typical situations, where warehousing is needed to balance supply and demand. The first situation occurs if demand fluctuates strongly, for example, along with season changes. In this kind of a situation, it may be impossible to produce or procure a sufficient amount just in time, in which case preparation to demand by warehousing products is reasonable. This is a typical situation for season dependent products, on whose sale for example Christmas has a huge impact.

The second example presented by Ackerman (1997, p. 14) is a situation where demand is stable but supply for some reason is cyclical. This kind of a situation occurs, for example, in an organization that shuts down its processes for the holiday season. In that case, the make to stock method is reasonable (Ackerman, 1997, p. 14). Another restriction for supply could be the growing season, during which a sufficient amount of products should be produced for the rest of the year (Ballou, 2004, p. 471).

Even if supply and / or demand were not dependent on seasons, they are almost never completely synchronized. Producing or procuring a product only for actual demand would in most cases make it extremely time taking to deliver. Consequently, organizations need to prepare for upcoming demand through stocking items. The exact level of

preparation needed depends much on the business field and the items delivered. (Ackerman, 1997, p. 14)

Stocking also helps risk management. Risks caused by a sudden and unforeseeable fluctuation of demand or supply become smaller as extra items are held in stock. For example, a strike in manufacturing may cause an inability to fulfill demand without stocked items. On the other hand, stocking also causes risks. If demand suddenly decreases, for example, because of the bankruptcy of a customer, stocked items may get out of date or they have to be sold at a lower price than planned. (Ballou 2004, p. 471)

2.1.2 Maintaining service level

Maintaining service level and balancing supply and demand are technically just two sides of the same issue. In practice, a customer experiences short response times as a high level of service. Thus, the availability of products is one of the most significant parameters when the logistics service level is assessed (Gallmann and Belvedere 2010). Furthermore, the given delivery time and its accuracy are important factors in customer satisfaction (Lutz et al. 2003). Sometimes the willingness to increase customer satisfaction is the major reason for warehousing (Ackerman 1997, p. 15). Especially in business fields with strong competition, a delay in availability may cause the loss of a customer, as the customer can choose a competitive product (Greis 1994).

A low service level causes costs that can be seen as costs of shortage. These costs appear when it is impossible to fulfill the demand. For example, back order deliveries with higher transportation costs are caused by insufficiency (Lehmuskoski 1982, p. 109). Huq et al. (2010) mention also monetary good-will gestures like discounts. These gestures are often shown when the customer does not get the product in the promised time. Consequently, the service level does not only affect customer satisfaction, but also costs and gross return.

Previous studies have mainly focused on pointing out what is the requisite inventory level in order to reach the desired service level. Recently, the relevant research question has been how is it possible to increase service level without increasing inventories. This kind of an approach demands that the whole supply chain is scrutinized in order to improve the fluency of the product and the information flow. Therefore, service level is not dependant only on inventories and warehousing functions. Moreover, it is important to consider warehousing as a part of the whole supply chain. (Gallmann and Belvedere 2010)

2.1.3 Reducing unit costs and adding value

Warehousing is often considered as the ”necessary evil”. By contrast, Ross (2004, p. 537) considers it as a possible competitive advantage and a value adding operation. One

of the reasons that ”justifies” the costs caused by warehousing is that through warehousing, it is possible to simultaneously decrease costs elsewhere (Ballou 2004, p. 470). Warehousing may help to reduce unit costs through the economy of scale. This economy of scale can be utilized not only in transportation but also in procurement and manufacturing. Thus, warehousing enables bigger lot sizes. (Ackerman 1997, p. 14)

The purchase prices of some items vary strongly in different points in time. For example, oil is that kind of a product. If an organization procures these kinds of products, it can benefit strongly if it can purchase them to stock while they are at their cheapest. This kind of a procedure helps to avoid purchasing when the prices increase. (Ballou 2004, p. 471)

If an organization is multi-sourcing its products, it is often more economical to consolidate the products to one shipment instead of sending them separately. It can also increase the service level as it most likely is easier for the customer to receive only one shipment. Also, if one product consists of many different items, a warehouse is often the combining party. (Stordy 2007) The same idea works also inversely; Items may arrive as mass shipments but are divided into smaller deliveries according to customers’ needs (Ballou 2004, pp. 473-474).

Manufacturing organizations’ warehousing supports the manufacturing operations as well. Not only will mass production most likely save manufacturing costs but for some products, like wine, warehousing may be one step of the manufacturing process. These kinds of products need to be stocked before selling them, so in other words, warehousing is a value add to the products. Other value adding warehousing processes are, for example, special packaging or customized labels. (Ballou 2004, p. 472) In addition, for example late customization, which may be a standard part of the manufacturing process, is in many cases executed in the warehouse. Also making product mixes for special events or seasons is possibly done in the warehouse. (Stordy 2007)

2.1.4 Specialties of a distribution centre

Higginson and Bookbinder (2005, p. 68) define a distribution center (DC) as a specific type of a warehouse. So does Ballou (2004, p. 250) who uses also the term *distribution warehouse* in order to determine this special type of a warehouse. The main difference between a traditional warehouse and a distribution center is that in a DC, the storage of goods is limited or non-existent. Thereby, the DCs focus on product flow rather than on stocking (Higginson and Bookbinder 2005, p. 68). Dawe (1995) adds that while warehouses store all their products, distribution centers hold only a minimum inventory concentrating on items with a high demand.

Bancroft (1991) emphasizes the role of a DC as a value adding part of the supply chain. He explains that traditional warehousing does nothing to add value to the product

stored. Actually, in some cases a long storage time may even have a decreasing impact on value. Dawe (1995), also, is along the same lines as he explains that while warehousing adds value only through packing and labeling, a distribution center should have more ways to it. He mentions final assembly operations as an example of a value adding activity that could be done in a DC.

Higginson and Bookbinder (2005, pp. 71-79) determine the six main functions of a distribution center as follows:

- make-bulk or / and break-bulk consolidation center
- cross-dock
- transshipment facility
- assembly facility
- product-fulfillment center
- depot for returned goods

Higginson and Bookbinder (2005, p. 80) emphasize that most DCs have simultaneously more than one of these functions. For example, consolidation and assembly operations have already been mentioned as warehouse functions by other writers (Ballou 2004, pp. 473-474; Stordy 2007). That among other things proves that in real life, it is often difficult to determine exactly whether the facility is a warehouse or a distribution centre. Most of the times, facilities are somewhere between a traditional warehouse and a DC.

2.2 Strategic warehousing

Rushton et al. (2014, p. 263) estimate that 20 – 30 percent of the logistics costs of an organization are caused by warehousing. Thus, it also forms a significant share of the total costs and affects strongly the finance of an organization. Because warehousing nonetheless provides many remarkable benefits, too, it is very important to pay attention to optimal inventory levels.

2.2.1 Optimizing service level and costs

The capital that has been invested in the products in stock causes income losses that can be evaluated by comparing its returns to returns of another possible investment of the same size. This evaluation is usually made based on the general interest rate. (Abbasi 2011)

The products in stock cause service costs like, for example, taxes, insurance payments and also personnel costs that are caused by people working in a warehouse and among warehousing functions. Warehousing risk costs include costs caused by larcenies and the dating of products, among other things. Previously mentioned shortage cost (Lehmuskoski 1982, p. 109) is also a risk cost. Obviously, warehousing space and

building have their price, too, which depends strongly on the size and the location of the building. (Abbasi 2011)

Generally, organizations try to keep their inventory levels as low as possible in order to cut down the amount of the capital invested in the products in stock and also to reduce other warehousing costs. Usually, demand forecasts are utilized so that the inventory levels meet with the real demand at the best possible accuracy. However, correctness of the forecasts is never perfect. In addition, order lead times to the stock may vary strongly, which means that a product is not in stock even if it was planned so. (Jeffery et al. 2008)

Baker (2008) considers external integration, such as close customer or supplier co-operation, as a part of an effective supply chain. Thus, he states that, for example, just co-operation with a customer is a practice which helps to achieve a situation where demand is well-predictable. Good predictability results in optimal inventory levels and effective responding to the actual demand. Close co-operation with suppliers, in contrast, may lead to shorter and more reliable lead times. Also Murphy and Wood (2008, p. 95) estimate that accomplishing the service level that satisfies customers requires listening to customer opinions and expectations for the lead times of different products.

Ballou (2004, pp. 314-315) also sees co-operation as a good method in order to create more accurate demand forecasts. He suggests that co-operation should be done not only outside but also inside the organization between different departments. Professionals with different backgrounds give their own skills and experience to the forecasts. Also Gallmann and Belvedere (2010) emphasize the significance of accurate demand forecasts. Correctly established forecasts may reduce the need for high inventory levels and thus lower the warehousing costs. However, if the demand is very unstable, forecasting may be almost impossible. In that case, it may be more reasonable to put effort into the flexibility of the supply chain instead of forecasting. (Ballou 2004, p. 317)

On the other hand, the satisfactory service level is not an absolute value, and thus it depends on the expectations of the customers. That is why the adequate service level can be determined by comparing the organization’s own processes to the similar processes of the competitors. This kind of benchmarking gives important information about the field of competition. There may not be a point in having an excellent service level if all the competitors are notably weaker in that area anyhow. (Murphy and Wood 2008, p. 95)

Jeffery et al. (2008) claim that an optimal inventory level strongly depends on the product type. Fisher (1997) agrees with that. He states that the supply chain of functional products does not have to react to demand as rapidly as in the case of innovative products. Thus, the stock level of innovative products should be higher. Also, for example, the life cycle of a product affects the required stock level (Greis 1994). The phase of the

life cycle should be noted as well (Greis 1994). If an organization has a monopoly on a product that is crucial for the customer, high service level is not necessary. On the other hand, if there are lots of substitutive products in the market, high service level may even be the only selection criterion. (Murphy and Wood 2008, p. 95)

Customer service responsiveness is not an unequivocal concept. Satisfaction with a certain service level may vary among customers even if the order fulfillment rate was similar for all of them. Customers may have individual needs and appreciate different qualities. Consequently, measuring service level should be done by taking into account many different factors in total order cycle and also by paying attention to the individual needs of each customer. (Lee and Billington 1992)

Gallmann and Belvedere (2010) present a theory that not only the inventory level control but also the operative management of distribution centers affects strongly the received service level. The high number of SKUs increases the need of effective operating. It means that service level depends also, for example, on the layout and the personnel's competence.

2.2.2 Following the main strategy

Ross (2004, p. 550) claims that distribution centers and warehouses should be considered as parts of the organizations main strategy and not as separate units. Thus, for example, marketing and manufacturing strategies should be strongly linked with the logistics strategy and further with service level goals. In practice, it means that the service level target, defined by the marketing strategy, should be considered when making purchase or manufacturing orders.

In order to determine the needed service level that corresponds with the strategy, an organization has to be able to understand its current situation as accurately as possible. Also, an organization must have an objective image of the role of its distribution centers in the supply chain. Thus, warehousing should execute its tasks effectively in the supply chain. When the roles are clear, it is possible to make coherent conclusions about the future and the changes needed in the service level. (Aiello 2007)

Lapide (2013) states that as warehousing has become more and more important, it is time to set the warehouse goals in line with corporate wide strategy. He claims that traditionally, warehousing objectives have focused being productive, fast, cheap and accurate but now it is time to supplement these goals with value-oriented objectives. He emphasizes the focus among three types of operational performance objectives: efficiency, asset utilization, and customer response. Figure 2.1 represents the triangle of these warehousing objectives.

Figure 2.1. *Dependence between warehousing objectives and business goals (Adapted from Lapide 2013)*

As figure 2.1 indicates, operational warehousing decisions should be in line with the corporate-wide objectives. Those goals are achievable, if the whole supply chain team works in unison in order to balance all three sectors of the warehousing performance triangle. (Lapide 2013)

Also Ballou (1997) describes a logistics strategy as a triangle which consists of a location strategy, a warehousing strategy and a transportation strategy. More closely, inventory strategy includes decisions about inventory level, deployment of inventories and control methods. Transport strategy consists of decisions about modes of transportation, carrier routing and scheduling and shipment size and consolidation. Location strategy then, covers decisions about locations, number and sizes of facilities, like warehouses and DCs, assignments of stocking points and outsourcing. Implementation of these three strategies impacts on the quality of customer service. However, the contents of each partial strategy depend strongly on the organization and its business and situation. Figure 2.2 represents these partial strategies and their common objective in customer service.

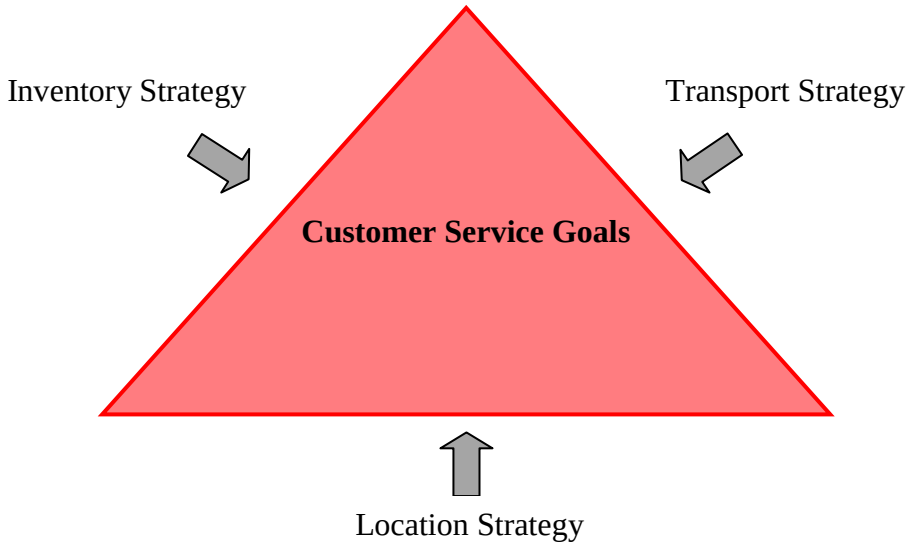

Figure 2.2. *The triangle of logistics strategy (Adapted from Ballou 1997)*

As it can be seen in figure 2.2, this view, too, considers warehousing as a part of an entirety and not as a separate field. Each sector of the logistics strategy has its impacts on the service level, profitability and thus on the main strategy. (Ballou 1997)

2.3 Outsourcing the warehousing functions

As a result of tightening competition, organizations often decide in their main strategies to concentrate their core competencies. Make or buy decisions received an important role in the area of logistics and as a part of organizations' competitive strategy in early 90's (Bardi and Tracey, 1991). Consequently, warehousing has become the most frequently outsourced logistics activity (Moberg and Speh 2004). According to Reeves et al. (2014), companies have three alternative options for their outsourcing strategy:

1. Develop and provide logistical services internally (insourcing).
2. Procure the services from a third party logistics firm
3. Hybrid approach where some of the services are provided in-house and others are outsourced

If a company has decided to outsource its warehousing functions, it is typical that it chooses the third option partly outsourcing and partly insourcing its services. Relph and Parker (2014) have divided this kind of a hybrid approach into three levels. The first level comprises only basic warehousing services. At the second level, there are some value added activities like labeling. The third level then is near to the complete sourcing. In that option, the third-party logistics (3PL) provider takes care of, for example,

the inventory management. Figure 2.3 represents the levels of outsourcing and the factors that should be considered when determining the optimal level of outsourcing.

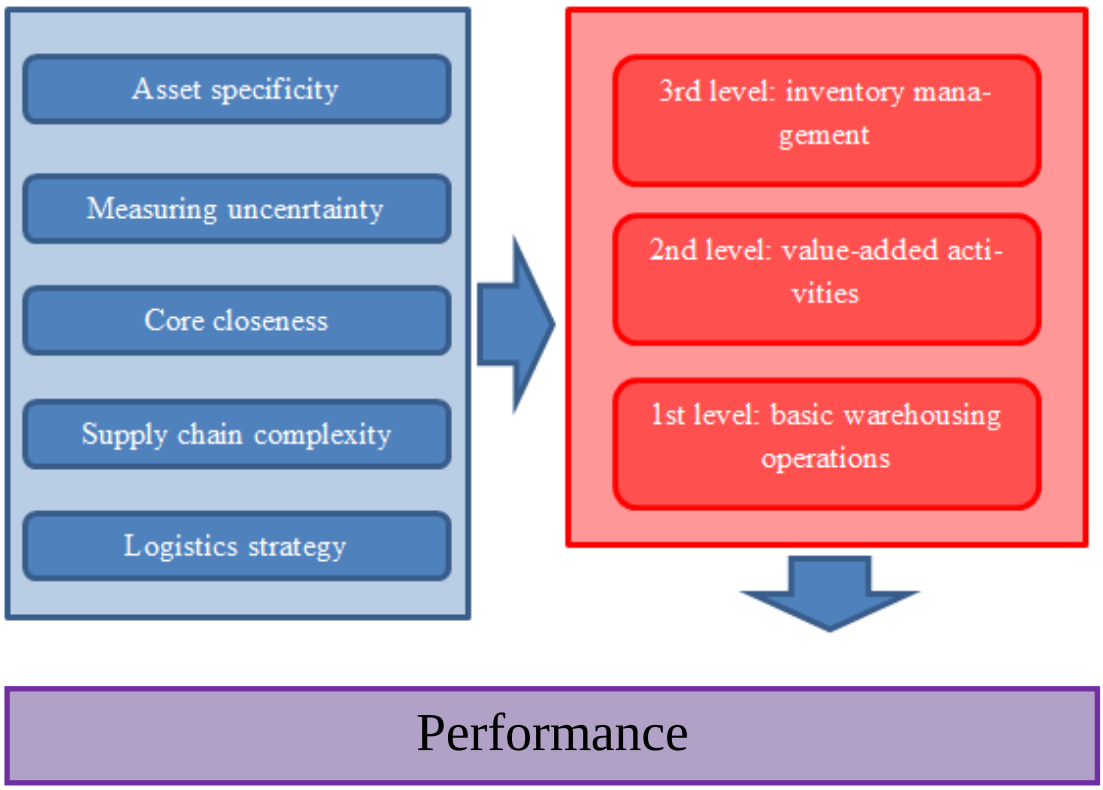

Figure 2.3. *Factors behind the selected level of outsourcing and the dependence to performance (Adapted from Relph and Parker 2014)*

As the figure 2.3 indicates, various qualities affect the selected level of outsourcing. The selected level of the outsourcing then affects further to the whole performance of the warehousing. Relph and Parker (2014) state that there are three major reasons to drive the desire of an organization to outsource part or all of its functionality. These three reasons are cost, strategy and politics. Razzaque and Sheng (1998) agree that along with concentration on core competencies, there are many other motives for outsourcing warehousing functions. Bardi and Tracey (1991) add that labor cost savings are often the most important driver for outsourcing.

Third-party logistics providers are capable of producing the same operations at lower costs as those operations are their core competence. Consequently, they have strong expertise, gained from working with other clients, which can help improve customer service. Furthermore, in global logistics, an external operator may have a better understanding of its region of operation. (Razzaque and Sheng, 1998) Willingness to reduce capital investment is a driving force for outsourcing warehousing functions. By outsourcing those activities, an organization avoids investments in area and buildings. In addition, it does not have to acquire assets like warehousing equipment and software. (Bardi and Tracey, 1991)

Presently, outsourcing is increasingly extending across international borders and is as relevant today as in the past (Reeves et al. 2014). Mello et al. (2008) state that internationalization has increased the demand for outsourcing. They claim that the use of third-party logistics support for global supply chain execution actually creates competitive advantages in a global supply chain.

Outsourcing warehousing functions has its problems, too. Bardi and Tracey (1991) state that loss of control is the greatest obstacle for outsourcing. Along the loss of control comes often the loss of touch with important information. However, the observations of Bardi and Tracey (1991) indicate that the loss of control should not be considered as a real obstacle if outsourcing is otherwise a reasonable option. Still, many outsourcing problems like poor communication and unsatisfactory availability of information implicate a weak partnership. Strong relationships are a consequence of close, long-term co-operation. Through strong partnerships it is possible to achieve the whole competitive advantage that outsourcing enables (Razzaque and Sheng 1998). Mello et al (2008) emphasize the role of confidence-building, too. They state that it is not only the performance of 3PL providers but also personal feelings towards providers that create a feeling of mutual confidence.

Ansari and Modarress (2010) have listed the biggest challenges in logistics outsourcing. One of the problems is that the 3PL provider may be incapable of meeting the customer's specific logistics requirements. Some businesses, for example, have very specific requirements for warehousing equipment and systems. Secondly, technology may nowadays cause incompatibility problems if, for example, the information systems of the service provider and the customer cannot be integrated. Thirdly, Ansari and Modarress (2010) present the concern of the 3PL failing to meet the customer's future growth needs. The fourth challenge listed by them is the familiar lack of control, discussed earlier in this chapter.

The selection of a warehouse operator is an important decision which may have remarkable impacts on the performance of the organization. If an organization outsources its warehouses, location decisions often include also a decision of a warehouse operator. Maltz (1995) emphasizes the importance of a proper supplier selection procedure. By the proper procedure, the organization is able to choose the best suitable partner for it. The first aspect that should be considered is why to outsource. This means determining the main objectives of outsourcing. After that it is easier to evaluate different service providers.

Also Jespersen and Skjøtt-Larsen (2005, pp. 150-151) state that behind every co-operative partnership there is a careful analysis of alternative partners. They notify that there is a risk of a lock-in with the wrong partner and in order to avoid it, it is crucial to take into account all the aspects that may have an impact on the partnership. This kind

of an analysis should be done for both, short-term and long-term aspects and it should include an assessment of the benefits, drawbacks, possibilities and threats.

The first step of the provider evaluation process is to truly understand the characteristics and capabilities of third-party logistics providers (Razzaque and Sheng 1998). Maltz (1994) claims that the quality of services is more important than low prices. Korpela et al. (2007) have scrutinized the quality and service capabilities of 3PL providers. They have created a warehouse operator service capability evaluation model which includes reliability and flexibility factors. The criteria of this model are presented in figure 2.3.

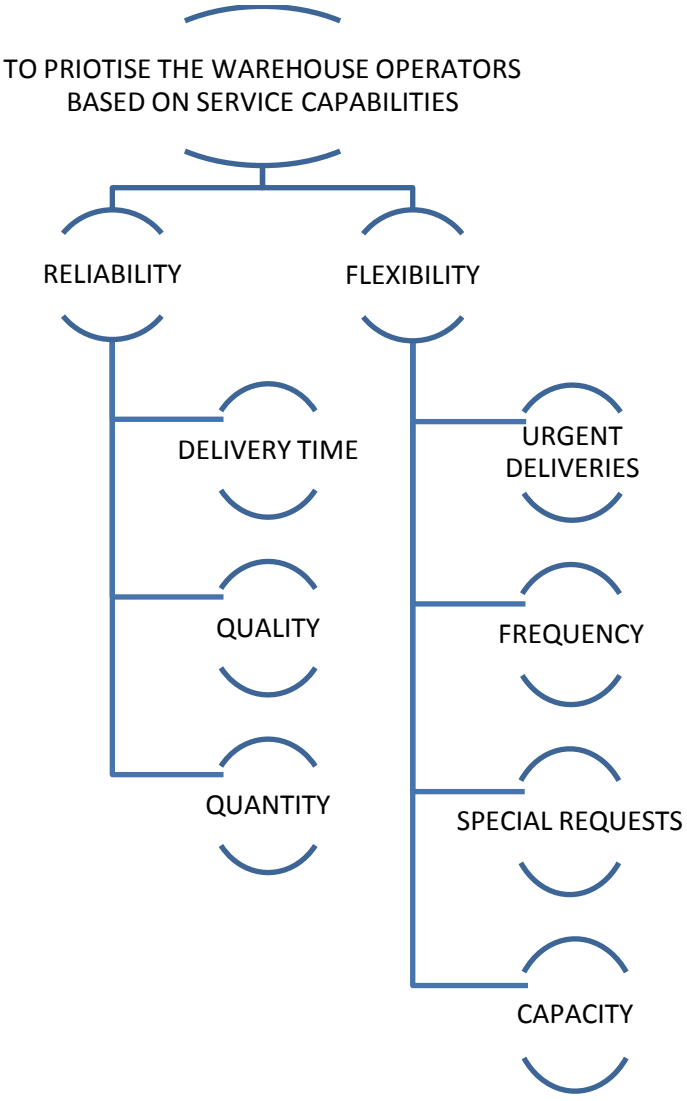

Figure 2.3. *Evaluation criteria for warehouse operator selection (Korpela et al. 2007)*

As figure 2.3 represents, two main factors for prioritizing warehouse operators' service capabilities are reliability and flexibility. Reliability includes factors like delivery time, quality and quantity. The factors impacting on flexibility are capability to fulfill urgent deliveries and special requests but also frequency and capacity. Moberg and Speh (2004) have found similar factors but have not done the similar division than Korpela et

al. (2007) have. They claim that the top four selection criteria are responsiveness to service requirements, quality of management, track record of ethical importance and ability to provide value-added services.

2.4 The role of warehousing in spare parts business

It is important to know the specialties of spare parts business in order to understand the special features of storing spare parts. Spare parts inventory management differs from traditional inventory management in many special requirements and characteristics (Wang 2012). The goal of spare parts management is to minimize the total cost of inventory holding, stock-outs, and ordering (Lawrenson 1986).

Spare parts, which are also known as service parts or spares, are needed when technical installations fail. They are also used in planned maintenance (Fortuin and Martin 1999). Kennedy et al. (2002) notify that spare parts are never final products to be sold to a customer. They determine that the function of spare parts is to assist in keeping equipment in an operating condition. Thus, the spare parts business can be seen as service business (Wood et al 2002, p. 396). Spare parts themselves can be divided into two different categories: repairable and non-repairable (or consumable) (Fortuin and Martin 1999). Repairable parts can be switched to new ones while the faulty ones are fixed for reutilization. Non-repairable parts cannot be overhauled, so the faulty ones are just to be disposed. Gopalakrishnan and Banerji (2004, p. 232) emphasize that even though spare parts may look small and be much cheaper than the machine or the raw material, they have a crucial role in maintaining, ensuring and reinforcing the reliability of any equipment. The spare part business itself has three main phases: procurement, warehousing and sales (Suomala et al. 2002).

Suomala et al. (2002) find two groups of spare part orders: normal and emergency. A normal order is placed for planned maintenance routines. However, it is quite typical that customers need emergency parts outside normally planned maintenance schedules. That is often why a spare parts inventory is held. An inventory is also often divided by its criticality. It means consideration of the consequences to the customer if an item is needed and not available (Botter and Fortuin 2000).

Huiskonen (2001) claims that the demand for spare parts may be extremely volatile and thereby it is difficult to forecast. Also Boone et al. (2008) find the inaccuracy of service parts forecasts a great challenge. They even claim that "the old adage that the forecast is always wrong is certainly applicable to service parts". The weak predictability of the demand results from the fact that equipment or part failures are sporadic. However, as in any other inventory management issue, capital is tied up to maintain high inventories of spare parts. The results from that are high costs and consumption of investment capital, which could be used in more profitable ways (Roda et al. 2014).

Gopalakrishnan and Banerji (2004, pp. 232-233) state that spare parts are often uneconomical to manufacture. In addition, the demand of spare parts is often very small whereas the product variety is large. All that makes spare parts inventory management a complex and an important area of logistics strategy.

Customer service level decisions are often in an important position in spare parts inventory management. Because a simple component failure situation may cause remarkable losses for the customer, stock out situations are even more harmful for service level than in normal business (Minner 2011, p. 160). Furthermore, lead times for spare parts may be long and it is hard to give accurate lead time information for customers (Boone et al. 2008).

One challenging task in spare parts management is minimizing parts obsolescence (Boone et al. 2008). Also Suomala et al. (2002) pay attention to the life cycle consideration of the items. The reason is that in firms manufacturing industrial equipment, the life cycles of the products may be decades. That generates a problem: where to find spare parts for the equipment manufactured, for example, 30 years ago. Boone et al. (2008) as well consider the part obsolescence as one of the greatest risks in the spare part business. They mention that with rapid changes in product introduction and design, there is a huge challenge to minimize investments in parts subject to obsolescence while keeping up the strategic level of customer service.

3. OPTIMAL DISTRIBUTION CENTER LOCATION

Location decisions are a crucial part of an efficient supply chain planning. Other warehousing decisions, concerning, for example, transportation or inventory, can often be changed in a short notice whereas decisions about location are less flexible. Changing a facility location is typically a challenging and arduous project which consumes both material and immaterial resources. As location changes cannot be made frequently, they should be planned meticulously by experts. (Daskin et al. 2005) According to Stevenson (2011, p. 340), there are four steps in making a location decision. Those steps, also followed in this thesis, are as follows:

1. Decide on the criteria that will be used to evaluate location alternatives
2. Identify criteria that are important
3. Develop location alternatives
4. Evaluate the alternatives and make a selection

This chapter introduces various criteria which are often utilized in location selection. Also, an evaluation model for the criteria is represented. These theories are then used later as a base for the empirical part of this thesis.

3.1 Logistics strategy and warehouse location

As in all other warehousing decisions, location decision should be made at lower costs but also to reach the service level goals. Chopra and Meindl (2007, p.124) give an example that a model of many local facilities may reduce transportation costs and lead times but at the same time also increase warehousing costs and make the system unclear. Ballou (2004, p. 550) points out that the location strategy, consisting of location decisions and network design, is an important means to reach customer service goals. He discusses facility location as the “bones” of the supply chain meaning that facility location is the basis for other logistics management decisions.

Huiskonen (2001) finds four elements in logistics system design. Those elements are network structure, supply chain relationships, coordination control and strategy/policies/processes. The figure 3.1 demonstrates how these strategic goals are related to a network structure and supply chain relations.

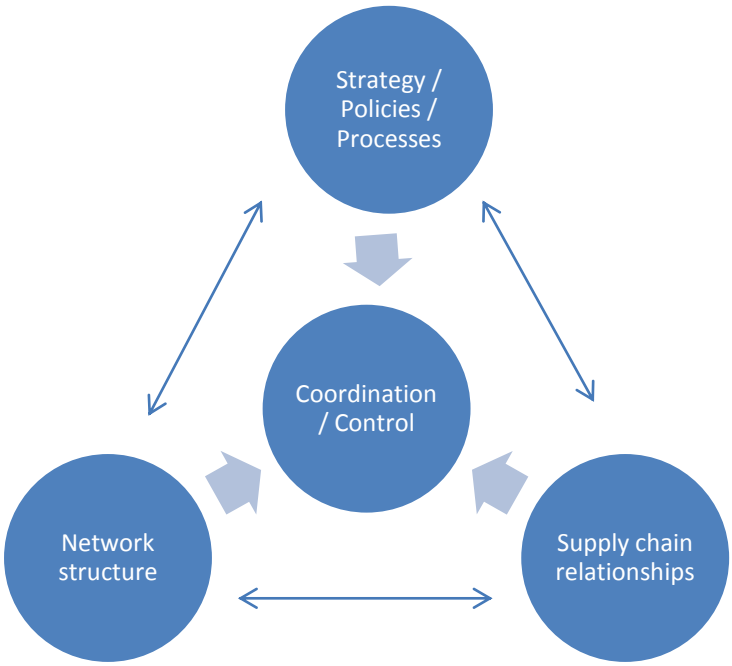

Figure 3.1. *Elements of a logistic system design (Huiskonen 2001)*

As figure 3.1 indicates logistic system is a complex system, of which parts are not only linked to each other via coordination and control but also affect each other directly. Network structure decisions include the number of inventory echelons and locations used in the system. Consequently, location decisions are an important part of the network design. (Huiskonen 2001)

3.1.1 Cost savings

When it comes to warehouse location decisions, economical factors often dominate (Ballou 2004, p. 551). Maybe the most obvious cost saving opportunity in relocating a warehouse is to lower inbound and outbound transportation costs. Transportation costs depend often quite linearly on distances between warehouses and customers or plants / suppliers. Transport cost minimization was discussed already in 1929 by Weber (1929, pp. 41-42). He uses a simple ton-kilometer optimization to determine the optimal facility location and to minimize the total travel distance between the site and a set of customers.

Shorter distances mean lower transportation costs almost without exception. Krajewski et al. (2007, p. 432) uses the term load-distance method to describe the method which can be used to select a location that minimizes the distances that loads travel. The load-distance method is a mathematical model used to evaluate optional locations based on proximity factors. The meaning of a load depends on the case industry and it may be, for example, shipments from the suppliers or to the customers. Distance can also be replaced with time, if it is reasonable.

Krajewski et al. (2007, p. 432) explains how the load-distance method can be used to calculate a load-distance score of a certain location. The organization seeks to minimize its load-distance score by choosing the location which leads to the shortest distances. The formula for load-distance score is

$$ld = \sum_i l_i d_i \quad (1)$$

where

ld = load-distance score
l_i = load of a certain location
d_i = distance to the location

The goal is to find one acceptable facility location which minimizes the score. However, there are many other factors that should be considered in order to reduce costs.

Mentzer (2008) presents three basic economic factors in location decisions: land, labor and capital. A dense land-area makes building a new warehouse more expensive as the site prices are higher than in looser areas. Even in public warehouse cases, high density most likely raises the prices. Labor costs depend closely on the income level of the area. Sometimes there is a possibility for great savings in labor costs when the location is moved to a neighboring country. The economic factor of capital means that there are occasionally economic incentives to companies that decide to set up a facility in a certain location. This may mean, for example, tax degradations or low-interest development loans.

Huang et al. (2012) pay attention to the opportunity of getting lower supplier prices by locating the warehouse correctly. They claim that not considering the supplier prices when locating a warehouse is a significant omission. In that theory, the optimal locations gravitate towards locations of the suppliers offering lower prices. However, if the price variability is high, the optimal location moves towards the demand's center of gravity. In those cases, it is beneficial for the organization to keep the location near that center of gravity and pay less attention to the supplier prices and supplier locations.

Melachrinoudis and Min (2007) point out that warehouse consolidation may provide cost savings due to the economics of scale. They prove that redesigning the warehouse network can help an organization to save transportation, inventory and warehousing costs. Fewer warehouses cause lower handling costs and also decrease transportation costs due to the increase in opportunities for large-volume shipments. However, consolidation, despite of its cost saving opportunities, lengthens lead times therefore deteriorating customer services.

3.1.2 Service level

Korpela et al. (2001) claim that the main problem in the traditional approaches to supply chain design is that they underrate the role of customer service. The focus is typically on the deliverer's point of view. Thus, the scope should be expanded from the traditional approaches to a more customer oriented direction. Ho and Perl (1995) agree with that opinion. They explain that customer service and cost savings are rather two sides of the same case, not separate goals. Therefore, customer service level should be considered as an element of the location objective. Ballou (2005, p. 653) claims, though, that customer service level improvements and the resulting revenues do not have a reliable relationship. He states that they should be considered rather as an adjustable constraint which can be changed in order to see the effect on total costs. In any case, service level is an important factor when the location decisions are made.

Chopra and Meindl (2007, p. 124) claim good location decisions can improve the responsiveness of the whole supply chain. In contrast, a poor location can make it impossible to achieve the desired service level. To achieve high responsiveness, the warehouse should be as near the customer as possible. Although there are often numerous customers and it is impossible to have a warehouse near every one of them. That is why an optimal location should be found. Also Boone et al. (2008) describe the distribution decision as crucial to providing the necessary flexibility to meet customer demands and to achieve the desired levels of customer service.

An organization has often many kinds of customers: some of them value, for example, short lead times more than the others. It should also be considered when finding the optimal location (Chopra and Meindl 2007, pp. 115-116). Also Korpela et al. (2001) emphasize differences among customers and their effect on supply chain design. Therefore, customers' preferences for customer service should be analyzed carefully. Ashayeri and Rongen (1997) add that a functional warehouse location should be seen as a part of value-added logistics where an effective supply chain increases the value that the customer experiences.

To enable the improvements in service level, an organization should figure out the current state of its services. This can be done through simple questionnaires or interviews where customers' expectations and satisfaction are investigated. It is also useful to get to know the levels of service of the competitors. (Ballou 2004, pp. 652-653)

When making, for example, location decisions, strategic importance of each customer should be determined (Korpela et al. 2001). Baumol and Wolfe (1958) explain that sometimes location decisions have a direct influence on demand. Alizadeh (2009, pp. 488-489) notifies that in profit-maximizing purposes it is not always the best option to satisfy the need of all the customers. She claims that in competitive situations, it may be

more profitable to lose some of the customers to the competitors, at least if the cost of maintaining these customers is unbearably high.

3.2 Distance functions in location planning

When the costs are calculated based on the distances, like in the load-distance method, it is important to consider how the distances are measured. In real world, distances are almost always some kind of approximations. Mwemezi and Huang (2011) present two distance measures which are popular among location planners when measuring distance on a plane. The first measure, rectilinear distance means a distance which is measured along orthogonal paths. The mathematical formula for rectilinear distance is

$$d_r = |x_a - x_{\ b}| + |y_a - y_b| \quad (2)$$

where

d_r = the rectilinear distance
x_a = x coordinate of point A
y_a = y coordinate of point A
$x_{\ b}$ = x coordinate of point B
y_b = y coordinate of point

Rectilinear distances are useful for example in metropolitan areas, where travel takes place along streets which are usually orthogonal (Kuo and White). Figure 3.2 presents the main idea of the rectilinear distance measure.

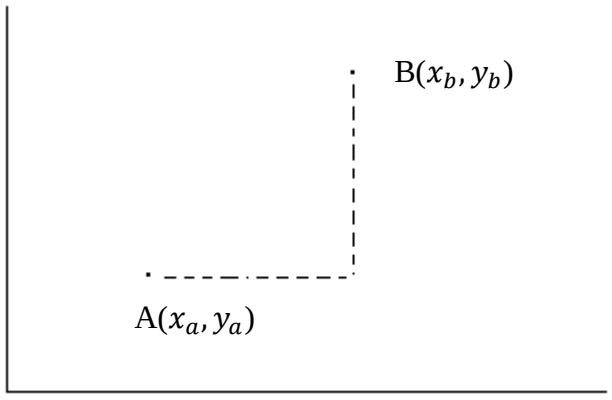

Figure 3.2. *Rectilinear distance between points A and B (Adapted from Mwemezi and Huang 2011)*

The second distance measure, the Euclidean distance is a straight distance between two points. It assumes that it is possible to travel directly from point A to point B. This Eu-

clidean distance measure is useful for example in air traffic, where distances are almost straight. The mathematical formula for the Euclidean distance is

$$d_e = \sqrt{(x_a - x_{\ b})^2 + (y_a - y_b)^2} \quad (3)$$

where

d_e = Euclidean distance,
x_a = x coordinate of point A
y_a = y coordinate of point A
$x_{\ b}$ = x coordinate of point B
y_b = y coordinate of point B

Figure 3.3 presents the main idea of the Euclidean distance measure

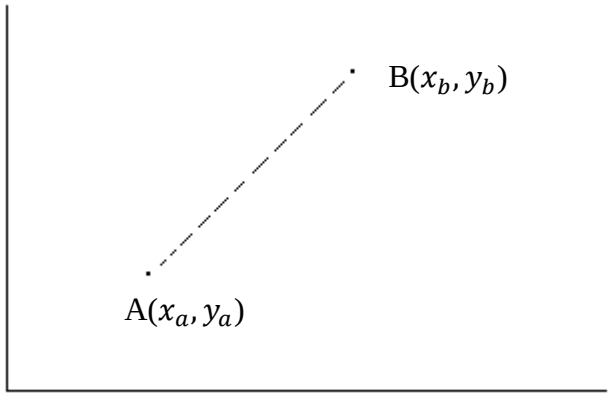

Figure 3.3. *The Euclidean distance between points A and B. (Adapted from Mwemezi and Huang 2011).*

The previously mentioned distance measures are thus suitable when estimating distances on a plane. However, the Earth has the shape of a sphere. Basic geographic coordinate system is linear on plane but in reality, especially the length of a degree of longitude depends strongly on the latitude. Near the geographical poles of the Earth the length of a degree of longitude is significantly smaller than on equatorial locations.

Mwemezi and Huang (2011) notify that by using spherical trigonometry, it is possible to get more realistic distance measures. They explain that the shortest possible distance between two points on the Earth's surface lies always along the arc of the great circle between these two points. In comparison, when the Euclidean distance is the length of a straight line between two points, in spherical geometry, great circle paths are used instead of straight lines. The mathematical formula, according to Mwemezi and Huang (2011), for great circle distance in spherical geometry is

$$d_s = \alpha r \quad (4)$$

where

d_s = Great circle distance between two points

α = central angle measure
r = radius of the Earth

Figure 3.4 demonstrates the great circle distance between points A and B.

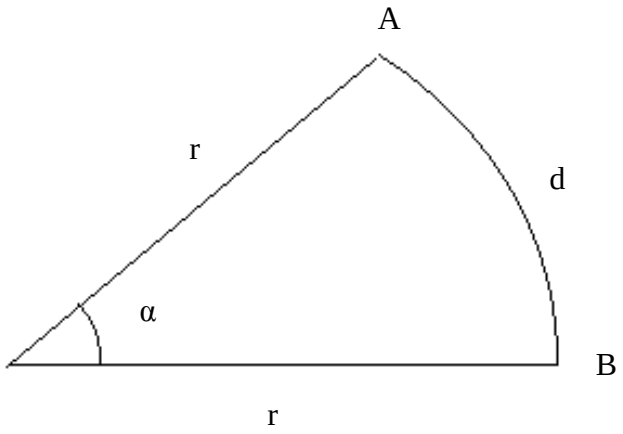

Figure 3.4. *Great circle distance on the sphere (adapted from Mwemezi and Huang 2011)*

Mwemezi and Huang (2011) explain that the spherical nature of the Earth we live in creates a need for spherical distance modeling. They also recommend applying spherical trigonometry to facility location planning because it provides more realistic distance estimations for real life problems.

When approximating long distances, for example, globally, the Euclidean measure is often more reasonable than the rectilinear measure. However, in real life and especially in road transportation, travelling along straight lines is not possible. Ballou et al. (2002) introduce the circuity factor as a solution to this problem. It is a multiplier which gives estimates for actual road distances. Circuity factors vary in different areas and their value is relative, for example, to road network density and obstacles like mountains and lakes. If the circuity factor's value was 1, the distance would be absolutely straight. In the calculations of Ballou et al. (2002), 1.12 is, however, the lowest found value belonging to Belarus. Comparably, the highest value is 2.10, belonging to Egypt. For Europe as a whole, they give the circuity factor value of 1.46.

3.3 Center of gravity method

When locating a facility or facilities, there are lots of different methods to choose from. The Center of Gravity approach is a method used for locating a single facility (Murphy and Wood 2008, p. 204). Krajewski et al. (2007, p. 433) present the Center of Gravity method as a refined version of the load-distance method which was introduced earlier in

this thesis. It can be used to find the optimal location coordinates for a facility. Like the main function of a load-distance method, it minimizes the distance that loads travel but also gives the x and y coordinates for the location. The formula used in the center of gravity calculations are as follows:

$$x^* = \frac{\sum_i l_i x_i}{\sum_i l_i} \quad (5)$$

$$y^* = \frac{\sum_i l_i y_i}{\sum_i l_i} \quad (6)$$

where

x^* = actual longitude coordinate for the optimal location
y^* = actual longitude coordinate for the optimal location
l_i = load of each location
x_i = x coordinate of the loand point
y_i = y coordinate of the load point.

Murphy and Wood (2008, p. 204) use the term weighted center of gravity for this method presented by Krajewski et al. (2007) as the approach pays attention also to the volumes and not only the locations.

Krajewski et al. (2007, p. 433) see the Center of Gravity method as a good starting point when evaluating locations in the target area. However, they explain that the location obtained by the center of gravity method is not generally the optimal one. Neither Murphy nor Wood (2008, p. 205) consider the weighted center of gravity approach as a sophisticated method. They call for recognition of real life considerations such as taxes, volume discounts and the fact that transport rates are not linear with distances.

Ballou (2004, pp. 555-556) considers the transportation rate a variable of the center of gravity method. This recognition is meant to diminish the difference between the method and the real world. When using the same denotations as Krajewski et al. (2007, p. 433) use, Ballou's (2004, p. 556) the formula are as follows:

$$x^* = \frac{\sum_i l_i R_i x_i / d_i}{\sum_i l_i R_i / d_i} \quad (7)$$

$$y^* = \frac{\sum_i l_i R_i y_i / d_i}{\sum_i l_i R_i / d_i} \quad (8)$$

where

x^* = x coordinate of the located facility
y^* = y coordinate of the located facility

l_i = total load at point i
R_i = transportation rate to point i,
d_i = distance to point i from the facility to be located
x_i = x coordinate of point i
y_i = y coordinate of point i

However, as stated already in chapter 3.2, the spherical shape of the Earth affects the distance functions. The situation is the same with the traditional center of gravity method: it is suitable on a plane but does not take into account the curvature of the Earth. In practice, the size of the target area has a great effect on the functionality of the traditional method. If the area is large, it should not be considered as a plane. Mwemezi and Huang (2011) state that the Center of Gravity method can still be used but it needs some modifications.

The main difference between the normal and the spherical center of gravity method is that in the spherical method, latitudes and longitudes are not simple coordinates but directions from the center of the sphere. The first step with this method is to express latitudes and longitudes, minutes and seconds as decimal values. The second step is to convert West Longitudes and South Latitudes as negative values. Also, degree values should be expressed in radians. After that, finding the correct center of gravity is a time-taking iterative process which almost necessarily requires the usage of a special optimization program. (Mwemezi and Huang 2011)

Without any special program, the spherical shape of the Earth is possible to take into account by using three dimensional Cartesian coordinates (Clynch 2006). In order to do that, the degree values of coordinates should be expressed in radians. Then Cartesian coordinates (x, y, z) can be named for each coordinate point by the following formulae:

$$x = \cos(lat) * \cos(lon) \quad (9)$$

$$y = \cos(lat) * \sin(lon) \quad (10)$$

$$z = \sin(lat) \quad (11),$$

where

lat = latitude point in radians
lon = longitude point in radians

Figure 3.5. presents the basic idea of three dimensional Cartesian coordinates for the Earth.

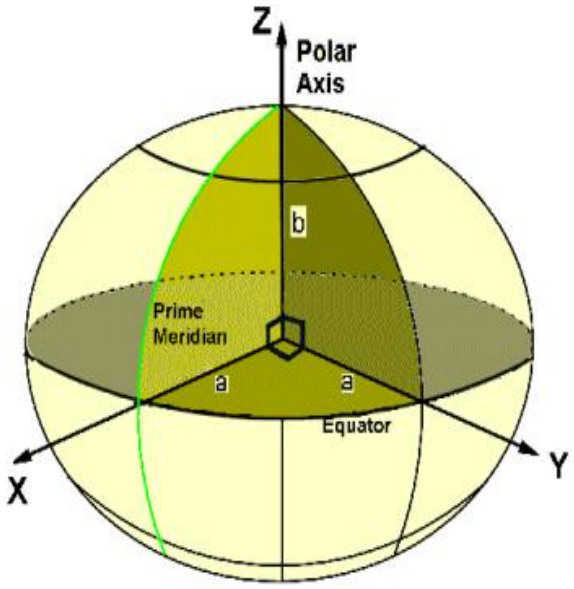

Figure 3.5. *Basic idea of the three dimensional Cartesian coordinate system for the Earth (Clynch 2006)*

As can be seen in the figure 5.5 coordinate points may now be inside the Earth's surface. Now, the new center of gravity can be calculated from the bare of these points and their weights. The result is consequently a point in three-dimensional space and thus not a relevant result.

Three dimensional coordinates can be extrapolated with an arctangent function in order to get a point on the surface of the Earth. That point should then be converted from radians to degrees. This method does not give the absolute center of gravity but it is the best approximation that is possible to give without a program. However, it is far more exact than the normal center of gravity method which does not take into account the spherical shape of the Earth.

3.4 Location decisions in the global supply chain

There are many other factors than just transportation and inventory related costs that have a remarkable impact on a global supply chain's performance. A global supply chain faces a diverse set of environmental and structural conditions whose importance should not be underestimated in supply chain planning, such as in location decisions (Skjøtt-Larsen et al. 2007, p. 402). Environmental conditions include, for example, political and cultural factors as the structural conditions focus rather on the effectiveness of the physical product flow. Two following subchapters cover the environmental conditions and the third explains the structural qualities of logistics. However, when making a location decision in global supply chain, it is also important to notice the possible complications that may be caused by the relocating operation. That is the situation al-

most always, when the facility already exists somewhere, and the location needs to be changed. Complications caused by relocating are covered in the fourth subchapter.

3.4.1 Political and societal factors

There are three main aspects to politics in a global supply chain and thus further to location decisions. The first aspect is national or regional protectionism, benefited mostly by emerging markets, which may cause, for example, high import tariffs in order to restrict international trade. The second aspect is trade liberalization through the World Trade Organization. The WTO is an agreement of eliminating discrimination and other barriers in trade and thus liberalizes trade and investments. Thirdly, there are regional unifications which develop regional trade. The EU is the strongest existing regional agreement as it removes barriers to the free movement of labor, capital, products and services. (Skjøtt-Larsen et al. 2007, p. 403)

In a global supply chain, there are also political and economical risks. Political or economical instability may cause crises that are hazardous for a global supply chain (Banham 2014). Consequently, local stability is a factor that has to be considered in the location decision. The political and economical situation of countries in Western Europe is relatively stable (European Commission 2014).

One potential way to prepare for political risks is to add organization's agility. A complex supply chain decreases agility and thus exposures the supply chain for risks. Every country border the supply chain crosses adds complexity. However, as evident, the ideal situation is not either to not involve in international operations. Consequently, the important thing there is to keep international supply chains as simple as possible in reasonable limits. (Prater et al. 2001)

Also society and societal factors such as social welfare have an impact on the supply chain. It is an important thing to notice, especially when the aim is to follow organizations' common rules, values and the main strategy (Stock 2002). Skjøtt-Larsen et al. (2007, pp. 405-406) add that social issues, like human rights protection, are an important part of global supply chain management. Also, the quantity of midweek holidays and working days depends on a country's habits and may have an impact on the effectiveness of logistical operations. (Murphy and Wood 2008, p. 201)

3.4.2 Cultural factors

The primary system of thinking, feeling, behaving and values forms the primary layer of a social culture. Above that, there is a layer of professional and organizational culture. Social cultures are stabile and change slowly whereas organizational cultures are quite adaptable and changeable with the group. (O'Hara-Devreaux and Johansen 1994, pp. 233-234) Both of these layers of cultures have an influence on a supply chain in several

ways. Different cultures have, for example, different attitudes towards institutions, contractual practices, education and labor. (Skjøtt-Larsen et al. 2007, p. 403)

Hofstede (1980) uses the expression 'culture' about nations only and the expression 'subculture' for smaller groups with common traits. Also, this approach considers subculture strongly dependent on national culture. Cultural differences are often clearer in institutional behavior than in individual behavior. Correspondingly, the concept of organizational culture, according to McAfee et al. (2002), "refers to the personality of a firm, i. e. what makes the organization unique in the eyes of insiders and outsiders".

Ueltschy et al. (2007) consider understanding and appreciating cultural differences as the most important challenge in a global supply chain. They state that in intercultural relationships, trust has an important role. Trust should be generated through good communication and, for example, face-to-face meetings. However, Kanter and Corn claim that the role of a national culture if often exaggerated. They add that many problems that seem to be caused by cultural differences often, on closer examination, turn out rather to have a structural cause.

The Hofstede Centre (2015) has found six factors that affect a culture most. These factors are as follows

- Power distance
- Individualism
- Masculinity
- Uncertainty Avoidance
- Long Term Orientation
- Indulgence

Power distance deals with the fact that all individuals in societies are not equal. In other words, it expresses the attitude of the culture towards these inequalities amongst its members. The level of individualism consists of the degree of interdependence a society maintains among its members. For example, in extremely individualist society, people look after only themselves and their direct family but not any others. Masculinity deals with competition, achievement and success. In a masculine society success is defined by the winner. Uncertainty avoidance means the way that society deals with the uncertain future. The main question is whether to try to control the future or to just let it happen. Long term orientation describes how a society maintains links to its past while dealing with changes of the present. The final factor, indulgence, means the degree of controlling desires and impulses. These six categories create also a base for the business culture. Thus, difficulties with different business cultures in a global partnership stems from the differences in these categories. (The Hofstede Centre 2015)

Because of the possible difficulties caused by different cultures (or business cultures) cultural differences should be taken into account when engaging in intercultural busi-

ness relationships. Thus, cultural factors should also be considered when determining a new location for a facility. Consequently, from the point of view of this study it is important to determine the main differences between the cultures inside the EU area.

The European Commission (2014) states that cultural differences have a direct impact on the profitability of the business, even inside the EU area. Being aware of the main differences helps to communicate and interact smoothly over country borders. Communication which is always a key to a successful partnership has an even more important role when it comes to international relationships. The study divides Europe into four different cultural groups: Northern Europe, Southern Europe, Eastern Europe and Western Europe. All of these four groups have their own special cultural features that affect the business culture. For example, the business culture in Western Europe is formal and punctual. The work force there is relatively highly educated and documentation and formalities are preferred over personal relationships in business.

3.4.3 Logistical performance

If the logistical capability of a country is poor, logistical operations will be unpredictable, slow and possibly expensive. In this kind of a country, a lot of attention must be paid to the supply chain coordination. Consequently, controlling lead-time and cost as well as flexibility, is demanding. Reciprocally, improved logistical capacities in a country enable easier coordination of a supply chain. The high logistical capability of a country allows supply chain partners to focus on other efforts than just coordination and ensuring on-time delivery. Thus, logistical performance has an effect, for example, on relationships and innovation in a supply chain. (Wiengarten et al. 2014)

Kinra and Kotzab (2008) analyze the performance of physical flows in four different fields. These fields are the quality of road transportation, the quality of rail transportation, the quality of air transportation and the quality of water transportation. These factors together form the quality of the physical infrastructure of a country. Information flows are also a significant part of the whole logistics infrastructure. These flows consist of text communication, telephone penetration and Internet penetration (Kinra and Kotzab 2008).

The World Bank Group (2015) is publishing The Logistics Performance Index (LPI), which evaluates the logistical performance of trade in the global economy. It claims that logistics performance is strongly related to the reliability of supply chains. Another remarkable aspect is the predictability of service delivery for producers and exporters. The six main factors are considered when analyzing the International LPI. Those factors are as follows:

- **Customs:** The efficiency of customs and border clearance
- **Infrastructure:** The quality of trade and transport infrastructure

- **Ease of arranging shipments:** The ease of arranging competitively priced shipments
- **Quality of logistics services:** The competence and quality of logistics services – trucking, forwarding, and customs brokerage
- **Tracking and tracing:** The ability to track and trace consignments
- **Timeliness:** The frequency with which shipments reach consignees within scheduled or expected delivery times

From the basis of performance in these fields, countries have been divided into four categories. The highest category is *logistics friendly countries* which consists mostly of high income countries. Almost all the EU countries are included in this category. (The World Bank Group 2015). Figure 3.6 represents the ten EU countries with best Logistics Performance Index scores.

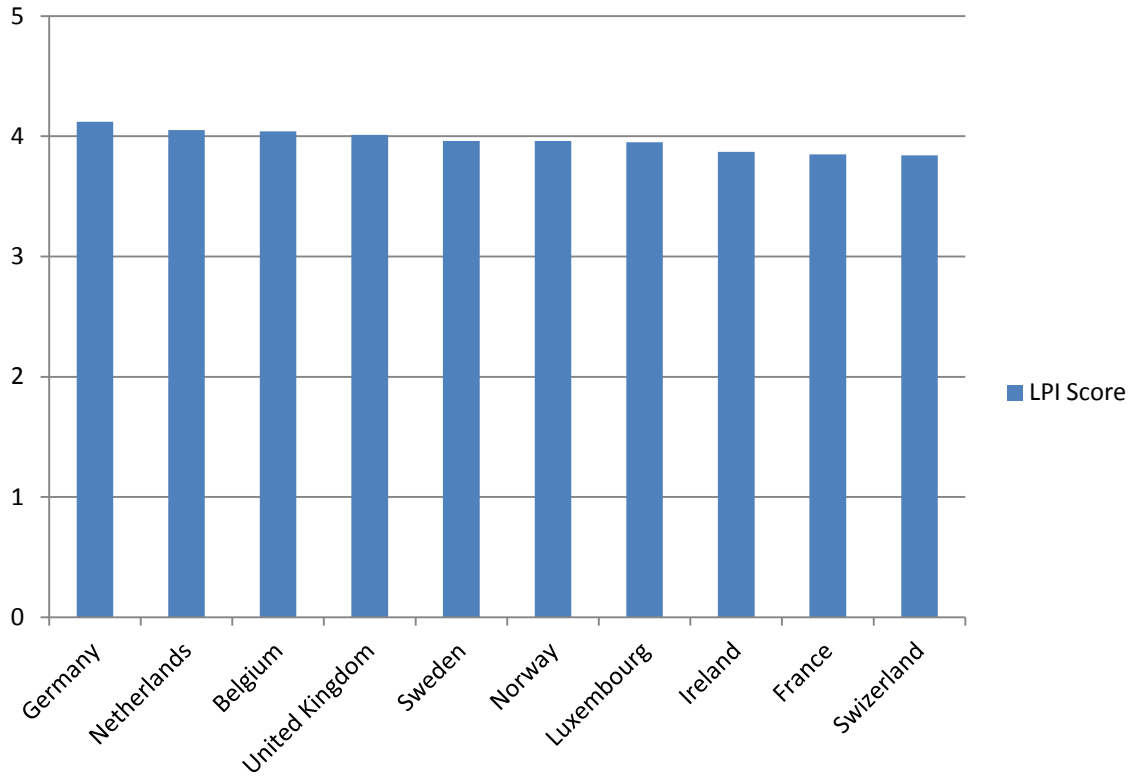

Figure 3.6. *Ten EU countries with best LPI scores*

As can be seen in figure 3.6, differences between these countries with the highest scores are quite insignificant. For a perspective, the lowest score among the EU countries is Montenegro's 2.88 (ranked as 67th best country by its LPI score in the World). The lowest score in the World is Somalia's 1.77. (The World Bank Group 2014).

Skjøtt-Larsen et al. (2007, p. 403) mention also the level of education as a part of logistical infrastructure. They add that especially when working with high technology, education of the work force has a major effect on the performance. It impacts also on the

language skills of the employees. In global supply chain English skills are often valued as a base for fluent co-operation.

3.4.4 Relocation complications

Warehouse relocation occurs when an organization could receive better results by changing the location of its warehouse. However, relocation may cause many problems and thus repeal the benefits of it (Murphy and Wood 2008, p. 206). For an organization which uses 3PL services for its warehousing, it is, however, much easier to relocate or change the number of its warehouses (Baumol and Wolfe, 1958).

Relocating a warehouse is often a time-sensitive and a highly expensive project. If an organization has not outsourced its warehousing processes, relocating costs consist most likely of the construction costs of a new facility (Owen and Daskin 1998) whereas relocation of an outsourced warehouse causes mostly transportation costs when the inventory is moved to the new location. In both cases, the location decision should be considered a long-term investment (Owen and Daskin 1998).

For customer service level, the relocation of a warehouse may cause temporary degradation. Out of service days are a common effect of relocating. Also, a customer has to get the new contact information and, for example, the new hours of service. In order to make the change as smooth as possible, customer communications are in a significant role. All customers should be informed in advance of the move so that they have enough time to get ready for it. Also, if there are changes in service charges or standards, they should be explained to the customers. (Ackerman 1997, pp. 87-88)

Opasanon and Lersanti (2013) have found five major areas of operating where relocating causes the biggest problems. These issues of concern are as follows:

- Network design
- Vehicle routing and scheduling
- Inventory management
- Internal processes
- Developing a set of key performance indicators (KPIs)

The whole supply network undergoes major changes when one facility is relocated. For example, service coverage overlaps may occur in the new network. Thus, comprehensive network design in synchrony with all network members is vital. When a facility location is changed, vehicle routing and scheduling change as well. Even if the organization uses a 3PL provider for transportation, contracts have to be reformed. (Opasanon and Lersanti 2013)

Inventory management is another logistics activity that is impacted by the change of facility location. For example, layout or capacity of the new distribution center may

have an effect on selecting an optimum level of inventory. Consequently, a new facility may also affect internal processes like receiving, picking and shipping. Because the overall performance of logistics activities may be directly impacted by the location of the new DC, a set of logistics KPIs is vital for enhancing the overall logistics system upon relocation. However, the KPIs are not necessarily the same as in the previous location. Thus, KPIs should be determined carefully, in order to enrich the quality of service provided to the customers. (Opasanon and Lersanti 2013)

3.5 Analytic Hierarchy Process in location decisions

Location decisions consist of qualitative and quantitative factors that have different importance. The Analytic Hierarchy Process (AHP), developed by Saaty (1987), enables assessing, prioritizing, ranking, and evaluating decision choices and different factors behind them. It is a technique which combines mathematics and psychology in order to organize and analyze complex decisions (Saaty and Katz 2012, p. 3).

The first step in the AHP is to structure the hierarchy of the problems. In the top level is the main goal of the whole decision making process. The second level consists of the criteria which contribute to the goal, and the different candidates are in the bottom level. (Saaty 1990)

Guanghua and Zhanjiang (2010) emphasize the importance of profound understanding of the problem and claim that making sure that the overall objective and the scope of decisions are clear should be done before dividing the problem into hierarchies. In order to clarify the goal, extensive information collecting is needed. They also emphasize the role of strategic thinking, strategies and a variety of constraints in order to achieve the objective. Thus, the main strategy should be kept in mind also when utilizing the AHP method.

The second step is to arrange the elements in the second level into a matrix and elicit judgments about the relative importance of the criteria. The fundamental scale goes from 1 to 9. The value of 1 means equal importance between the criteria. Value of 3 is for moderate importance, 5 for essential or strong importance, 7 for very strong importance and 9 for extreme importance. Also intermediate values of 2, 4, 6 and 8 are usable, if compromise is needed. Using the scale and choosing the correct value for each criterion, is in most cases based on subjective opinions of importance. The same scale is used also when comparing candidate qualities against each other. Then it is not about the importance but the superiority of the candidates. The scale used in making the judgments is presented in table 3.1.

Table 3.1. *The fundamental scale used in the AHP (Adapted from Saaty (1990) and Saaty and Katz (2012, p. 6)*

Intensity	Definition	Explanation
1	Equal	Two objectives contribute equally to the objective
3	Moderate	Experience and judgment slightly favor one activity over another
5	Essential or strong	Experience and judgment strongly favor one activity over another
7	Very strong	An activity is favored very strongly over another and its dominance is demonstrated in practice
9	Extreme	The evidence favoring one activity is of the highest possible order of affirmation
2,4,6,8	Intermediate values	When compromise is needed

The scale presented in table 3.1 is used in pairwise comparisons of the criteria. The basic idea is to compare two elements at a time. For example, if element x has number 3 assigned to it when compared with element y, then y has the reciprocal value of 1/3 when compared with x. Possible candidates are then compared also in pairs under each criteria. The aim is to judge how much better one candidate is than the other, satisfying each criterion in level 2. (Saaty 1990)

The pairwise comparisons are put into matrixes whose sizes are equal to the amount of candidates or the factors compared. Then, a priority vector is calculated for each factor as a measurement of their relative strengths. Mathematically, priorities are the values in the matrix's principal right eigenvector. These values can be calculated by hand or by using specialized AHP software. Basically, the idea is to calculate the product of each row by multiplying its elements with each other. Then, the n^{th} root of the product is calculated. The final step is to normalize roots so that their sum is equal to 1. The results, then, are the priorities of each factor or candidate. (Villanen 2013)

The third step is to establish the composite priorities for the candidates. Local priorities are laid out with respect to each criterion in a matrix and multiplied each column of vectors by the priority of the corresponding criterion and the added across each row. Actually drawing a figure of the hierarchies makes often it easier to understand the structure and dependencies between candidates and criterion. (Saaty 1990) Figure 3.7 represents the hierarchical structure of the AHP method.

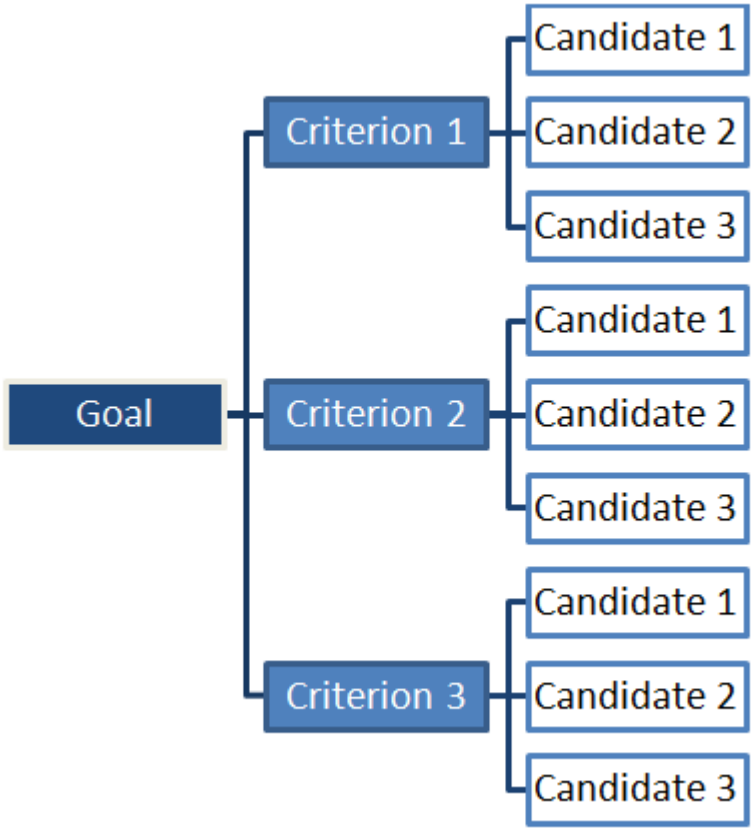

Figure 3.7. *Hierarchical structure of the AHP method*

As the figure 3.7 indicates, by using AHP method the problem is divided into clear phases. The first phase is to determine the final goal. Secondly, criteria are determined and compared. Then the candidates are also compared against each other.

Pairwise comparisons and priority judgments are basically made based on, for example, discussions and debates. Thus, they are not actual facts but carefully considered opinions (Villanen 2013). That is why they are not always perfectly accurate or logical. In order to ensure the consistency of comparisons, an inconsistency check should be done for the matrixes. The inconsistency is approximated with the Consistency Ratio (CR), which is on an acceptable level when its value is 0.1 or less. In order to get the consistency ratio, the consistency index of the matrix should be calculated first. The formula for the consistency index (CI) is as follows

$$CI = \frac{\lambda_{max} - n}{n - 1} \quad (11)$$

where

λ_{max} = the biggest eigenvalue of the matrix
n = size of the matrix

The consistency index is, then, divided by a coherent value of Random Index (RI) which is an average random consistency index derived from a sample of randomly generated reciprocal matrices using the scale 1/9, 1/8,…,8, 9 (Villanen 2013). Saaty and Vargas (2012, p. 9) provide complete Random Index for different sized matrixes. Table 3.2 represents the values for RI for matrixes of size between 1 and 10.

Table 3.2. *Random Consistency Index for matrixes of different size (Saaty and Vargas 2012, p.9)*

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.52	0.89	1.11	1.25	1.35	1.40	1.45	1.49

In order to get the final consistency ratio, the correct RI value is chosen from the table and the Consistency Index is then divided with it. The formula for that is simply as follows:

$$CR = \frac{CI}{RI} \quad (12)$$

where

CR = consistency ratio,
CI = consistency index
RI = random consistency index

The Analytic Hierarchy Process is a suitable application for many different fields like economics, politics and technology (Saaty and Katz 2012). Min and Melachrinoudis (1999) use the AHP in the relocation decision of a hybrid manufacturing / distribution facility. For the location, they have determined six criteria which are site characteristics, cost, traffic access, market opportunity, quality of living and local incentives. In their study, the AHP approach was found a suitable method for location decisions as it is capable of handling multiple conflicting objectives (Min and Melachrinoudis 1999). Wang (2014) reminds that when evaluating logistics systems through any method, customer satisfaction should always be kept in mind. He adds that the AHP method is very suitable also for that kind of scrutiny.

Wei and Jiangsheng (2010) consider the AHP as a valid method for evaluating logistics service providers. Also Yang and Lee (1997) state that pairwise comparison makes it possible to evaluate candidate characteristics and qualitative factors consistently in location decisions. They notify that it is this special capacity that makes the AHP method very practical in location planning. Korpela et al. (2007) have also pointed out that the AHP methodology is suitable for warehouse operator selection.

The AHP method has also been criticized for the fact that it gives quite subjective results (Roháčová and Marková 2009). However, no decision making method is hardly ever completely objective. In addition, Daim et al. (2013) have noticed that independent logistics experts give remarkably similar priority scores to 3PL provider's qualities. It indicates that the Analytic Hierarchy Process gives relatively reliable results.

4. CURRENT SITUATION AT KALMAR

This chapter introduces the current supply chain of Kalmar spare parts. It presents the structure of the whole supply chain from supplier to customer. The main focus is on the distribution centers, especially on the European Distribution Center, and its role in the supply chain. The data for this chapter was collected mainly by interviewing the personnel of Kalmar Central Operations and observing, but also some internal documents were used to get a wider picture of the current situation. The final subchapter represents the challenges faced in the current EDC location. It creates an important base for the upcoming analysis and interviews. Thus, that part includes information that is gathered from various persons in order to get as wide picture as possible.

4.1 Supply chain in Kalmar Parts and logistics

The supply chain of Kalmar Services consists basically of four levels: suppliers, distribution centers, front line and customers. Items come from external suppliers to Kalmar's distribution centers. These DCs store items, consolidate shipments and in the case of the European Distribution Center, book transportation, too. From distribution centers, items are typically forwarded to front line, which consists of regional sales offices, but in some cases also directly to the customers. Occasionally, items can be delivered from the supplier directly to front line or the customer.

4.1.1 Suppliers

Most of the Kalmar spare part suppliers are selected when parts are purchased for new machines. This is the main procedure especially in the main component procurement. Minor parts are usually purchased from the origin source. In addition, new, substituting suppliers are searched continuously in order to find lower prices, shorter lead times or more reliable operators. Lead times from the supplier vary strongly between different product categories.

Kalmar Central Operations has suppliers globally, albeit they are strongly concentrated in Europe. Two dominating countries are Finland and Sweden whose purchase volumes stand at over 62 percent of the total volume. The amount of suppliers is approximately eight hundred of which approximately 550 are active at this moment.

From suppliers, the items are transported to distribution centers. The supplier's location does not have an influence on the distribution center used. It is, though, an important factor when evaluating suppliers. Short distances to distribution centers are logistically

beneficial. In some cases (for example, in urgent deliveries of big components), items may be shipped directly to the customer from the supplier. These kinds of situations, however, are highly rare.

The future of the supplier base looks fairly stable. Some new suppliers come along and some previous suppliers are to be substituted. All in all, there are no major changes expected in the supplier base.

4.1.2 Sales offices and customers

Kalmar has front line sales offices and end customers on all continents. However, the significance of the customers in Europe is relatively high. Kalmar has sales offices in the following European countries: Albania, Austria, Belgium, Denmark, Finland, France, Germany, Italy, Norway, Russia, Spain, Sweden, the Netherlands, and the United Kingdom. Some of the sales offices are responsible for providing services for their neighboring countries as well. Thus, the service network in Europe is highly extensive. Figure 4.1 represents the most significant European destinations and their relative volumes of shipments that were dispatched from the EDC between January and October of 2014.

Figure 4.1. *The most significant destinations and their relative volumes in Europe*

As figure 4.1 represents, the biggest concentration is in the Netherlands. It can be explained with the fact that in the Netherlands, there are significant harbors and customers in them. The volume concentrations in Tampere and Stockholm result mainly from the shipments between the distribution centers.

Most of the sales happen through the front lines, but also direct sales to the end customer have a remarkable role for Kalmar Central Operations. A delivery chain often has even more levels than these two. Kalmar Central Operations also sells spare parts for dealers and agents that sell the products further to end customers. Figure 4.2 represents Kalmar's delivery chain and all the possible delivery options.

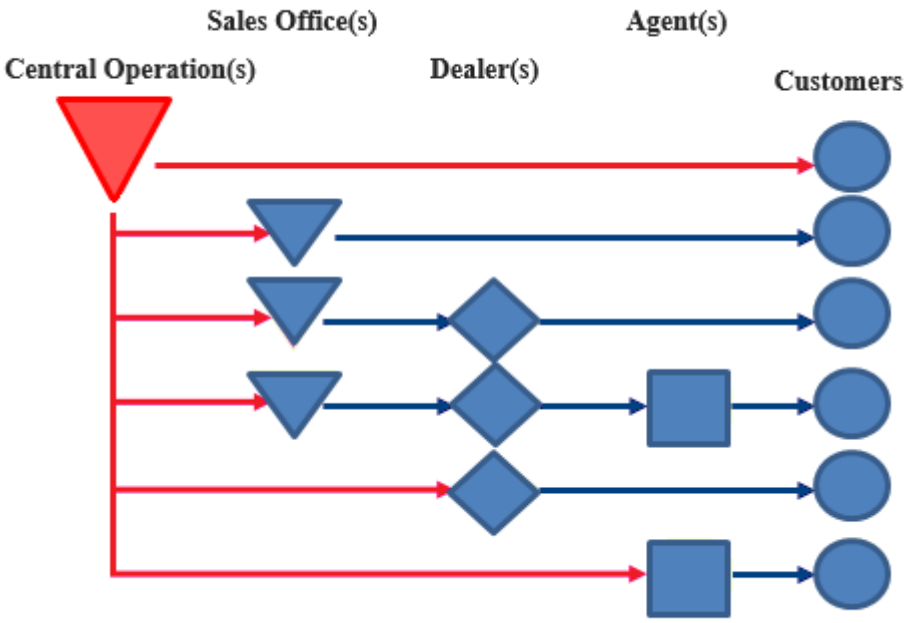

Figure 4.2. *The delivery chain of Kalmar spare parts (Kalmar Industries 2000)*

As figure 4.2 represents, products are not always delivered directly to the final customer from the front line. Front line delivers products also to dealing parties or agents. Also, Central Operations sell parts directly to dealers and agents. The sale volume of Europe is approximately 30 percent of the total sales volume. The future of the customer base seems relatively stable. However, a trend where container operations focus on the few biggest companies has occurred lately. The same trend has been perceptible also with industrial customers, but that development has been slower.

4.1.3 Modes of transportation

The mode of transportation used in the deliveries of Kalmar Central Operations depends basically on three things: destination location, weight of the shipment and priority of the delivery. Priority means most likely the urgency of the shipment. Choosing the trans-

portation mode for inbound shipments has mainly the same principles. Four transportation modes used in outbound deliveries are courier shipments, road freight, air freight and sea freight.

Courier shipments are used in intra-European transportations but also globally. They are suitable for relatively small and light packages. Courier shipments are the fastest mode of transportation and consequently used for urgent deliveries. Road freight is another mode of transportation which is used in deliveries in Europe. Trucks can carry big shipments at a relatively low cost. It depends on the distance and the geography between the distribution center and the destination whether road transportation is fast or not. For example, in Central Europe, truck transportation does not take much time. On the contrary shipments from Finland to Central Europe are not that fast. This is why road transportation is not used outside Europe.

Air freight is a coherent way of transportation when the shipment is too big to be a courier shipment but it also is expedited by the customer. They are used only globally. Another global transportation mode is sea freight, which is used when the schedule is not so tight or when the shipped item is significantly large. Table 4.1 represents all the transportation modes and their ranges of use.

Table 4.1. *Modes of transportation and their ranges of use*

Mode of transportation	Global shipments	Shipments inside Europe
Courier	x	x
Road freight		x
Sea freight	x	
Air freight	x	

The terms of delivery depend on the customer, sales order and the mode of transportation. Shipments are mainly organized and paid by Kalmar Central Operations but there are also EXW (Ex Works) cases that are completely taken over by the customer. The term of delivery for inbound shipments is, in most cases, FCA (Free Carrier).

4.1.4 Distribution centers

Kalmar Services has three distribution centers in the Europe and Middle East (EMEA) region. The distribution center which serves customers in Finland and Russia is located in Tampere, Finland. The Nordic Distribution Center delivers products mainly to Sweden and Norway and it is located in Stockholm, Sweden. The European Distribution

Center is located in Metz, France and it serves all the other countries. These region terms apply in general but are sometimes not followed, for instance, because of urgent orders. The main aim of the whole warehousing process is to fulfill the availability gap between suppliers and customers. As suppliers provide the availability of about 40 percent, Kalmar aims to provide the availability of 96 percent. Figure 4.3 presents the current locations of all three distribution centers.

Figure 4.3. *Locations of distribution centers*

Kalmar has outsourced its operational warehousing. Distribution centers in France and Sweden are operated by the same 3PL provider. The distribution center in Finland is also operated by a 3PL company. The European Distribution Center is distinctively the largest distribution center in volume. The distribution center in Finland has the volume about 1 / 10 of the EDC's volume and the distribution center in Sweden about 2 / 10 of the EDC's volume.

Warehouse operators are responsible for the daily operations. When parts arrive at the distribution centers, they are first received by the warehouse personnel. Parts which have no sales order waiting are taken into stock and shelved. If parts have a sales order, they are possibly re-packed and then moved to the shipping process. As the operational functions of warehousing are outsourced, Kalmar Central Operations takes care of the strategic decisions. These strategic functions include inventory management, logistics management, sales support and purchasing of the parts. Figure 4.4 represents all the European locations that the EDC was serving between January and October 2014.

Figure 4.4. *European destinations of shipments sent from EDC*

As the figure 4.4 indicates, Central Europe and the United Kingdom have the highest densities of shipments. On the contrary, density in peripheral regions is remarkably low.

4.2 Qualities of the current EDC location

The current location of the European Distribution Center has been decided in 2000. The choice was made partly because Hiab already had its distribution center in Flevy. Thus, it provided a familiar ground to Kalmar's new distribution center. Also, the location was seen as strategically reasonable considering the customer locations and the other distribution center locations. Logistical factors of the location were considered beneficial as well. In that time, there were not that many warehousing service providers so that, too, explains why the choice was quite simple. The current provider also had experience with similar businesses.

Now, about fifteen years later, there is no accuracy whether the location is optimal or not considering the customer locations. The customer base is not exactly the same as back then and the sales volumes have changed, too. Some operational complications have also occurred in the co-operation with the current warehousing company. Those complications are problematic for the reason that they do not only cause the indirect costs but also lower the service level.

Perhaps one of the biggest problems in the current situation is related to cultural differences. Interacting with the warehousing company and its personnel is occasionally difficult. In practice, it means that, for example, operations with some special requirements are not carried out as desired. On the contrary, daily operations with no special needs are dealt with nearly faultlessly.

The current warehousing company is very hierarchical. Even small decisions need an approval from the higher level. It slows down processes and consequently makes it harder to make changes. Thus, the current situation is not very flexible. However, the situation has got slightly better over time. Still, greater changes in operating take too much time. That is considered as a very significant drawback in the current situation.

Other cultural complications occur in responsibility issues. The interviewed personnel at Kalmar Central Operations call for sense of responsibility and also for the ability to admit the commitment in fault situations. Although the areas of responsibility are relatively clear, there are problems almost without exception if someone has made a mistake. The culture of obstinacy in the 3PL organization is not seen as a positive quality.

Communication is another challenging sector in co-operation with the current 3PL provider. Receiving information about changes is not certain. Information problems are, however, mainly related to smaller changes like holidays. Also, response times are often unbearably long which is, perhaps, due to the insufficient amount of employees. Weak language skills in English have caused some complications, too.

Politically, there are no drawbacks in the current location. The strongest political factor is the European Union which means that the political circumstances are quite similar to all the other EU countries. The society is relatively stable and there is also a high level of safety. Strikes have not disturbed the operating but midweek holidays stop the operations more often than in Finland. The only significant drawback is the high level of bureaucracy. Communication with the public authorities is complicated and slow. Despite the EU, some regulations are different than in Finland. It makes document confirmation processes both expensive and time-taking.

Logistically, the current EDC location is very convenient. The number of transportation companies that operate in the area is high. Thus, there are many options for the transportation service providers for Kalmar. Airports, harbors and hubs of transportation companies are all relatively close to the current location. It means that there are no extra costs caused by long transportation distances between the hubs and the EDC. However, some delivery delays have occurred because of roadwork in the summer.

Previous opinions were gathered from the Kalmar parts and logistics team. For a wider picture, the opinion of the spare part sales was also asked. The sales team does not communicate directly with the distribution centers but indirectly via the logistics team. Thus, all problems are not visible to it. In the sales team's opinion, the most significant

problem was that when there are complications in the shipments (for example, wrong items, wrong quantities or delivery delays), problem investigating and solving is taking a lot of time and effort. However, the quality of warehousing operations was considered as satisfactory, despite the challenges and the resources wasted in problem situations. The current location, with respect to customer locations, was seen considered nearly as the best possible option.

Also, the opinion of the purchase team was asked through an interview. Issues that came up in that interview were very similar than previously mentioned challenges. Long response times in exceptional situations were mentioned as the biggest problem. Low educational level of employees followed with poor English skills were considered as main reasons behind this problem. The location was not seen as ideal with respect to supplier locations but, however, future development would most likely make it more optimal also in this point of view.

5. RESEARCH MATERIALS AND METHODS

The structure of this chapter follows Stevenson's (2010, p. 340) determination for the location decision, mentioned previously in chapter 3. The first step in choosing what kind of methods to use was to determine all the factors that wanted to be included in the location decision. The location of customers in Europe was considered as the most important factor since the location of the European Distribution Center has the biggest impact on the lead times and transportation costs inside Europe. Also, the fact that the location of the EDC should stay inside the EU area was predetermined. After considering these factors, there were only four possible countries in which the distribution center could be located. Because of that, some qualitative factors like climate were excluded; the candidates clearly had no significant differences in them. Consequently, the qualitative factors behind the decision were political, cultural and logistical. Also, the performance of the candidate service providers was evaluated. Consequently, all the factors scrutinized were as follows:

- Customer locations in Europe
- Cultural factors
- Logistical factors
- Political and societal factors
- Competences and prices of the service providers

5.1 Data analysis

The ERP (enterprise resource planning) system of Kalmar, SAP, provided the statistical data for the basis of a quantitative analysis. The data used for the analysis covered all the shipments sent from the European Distribution Center. The statistics included information about the mode of transportation, the transportation company, the date, shipment measurements (weight and volume weight), the destination country, the address and the terms of delivery. The data was imported from the ERP system to a spreadsheet program where it could be processed.

In the scope of the examination were the shipments dispatched during the ten first months of the year 2014. This period was considered long enough to give a picture of the actual shipment distribution. Then, the terms of delivery were scrutinized and only the shipments paid by Kalmar Central Operations were included. Thus, the shipments paid by customers or front lines were not included in the analysis, even though the possible new location would affect the costs of those deliveries. However, those effects were approximated to be quite insignificant and were thus restricted from the analysis.

Global shipments were excluded from the analysis which was made for European internal road and courier shipments only. This restriction was made because in global deliveries, the distribution center location has no remarkable significance. It is caused by the fact that the transportation costs between the DC and, for example, an airport or a harbor, are relatively small when taking into account the whole transportation cost. In addition, the lead times are not strongly dependent on the DC location, either, when the distance is long enough. It was decided that distances to airports and harbors used in global deliveries would be taken into account in the qualitative analysis of the logistical performance of the location, but not in the data analysis phase.

After a careful consideration with Kalmar Central Operations, the volumes of Northern Europe (Sweden, Norway, and Finland) and Russia were decided to be excluded. The main reason was that ideally Nordic volumes would be dispatched from Nordic distribution centers. Countries included in the analysis were thus Austria, Belgium, Bulgaria, Switzerland, Czech, Cyprus, Germany, Denmark, Estonia, Spain, France, the United Kingdom, Greece, Croatia, Ireland, Iceland, Italy, Lithuania, Latvia, Malta, the Netherlands, Poland, Portugal, Romania, Slovenia, Slovakia and Ukraine. Other European countries (except the previously mentioned Norway, Sweden, Finland and Russia) were not excluded consciously; there just were no shipments sent to them during the period of analyzing.

After the data was filtered, it was arranged after the postal codes of the destination. Some postal codes were not correct in the data because zero digits from the beginning of the codes were removed by the spreadsheet program. Thus, all the codes had to be verified to match with the actual destination city. Also, some places had similar postal codes, which led to a careful verifying. Then, all the volumes with similar destinations were summed. After summing, all secondary data was filtered from the table to make it clearer.

However, some other versions of the table were also utilized in order to make comparisons. The center of gravity was finally calculated also with the volumes of Northern Europe and Russia just to see the difference between it and the previously mentioned solution with restrictions. In addition, the center of gravity was also calculated from the base of volume weights in order to compare it to the weight based solution.

The final version of the table included only the postal code, the city name and the summed shipment measurements (weight and volume weight). That structure made it possible to create a map in the spreadsheet program, based on the locations and the weights. After summing the weights, it could be seen that the EDC had dispatched shipment to X different destinations during the time period in scope. Figure 5.1 represents that map, i.e. the summed shipment weights of the destinations in Europe.

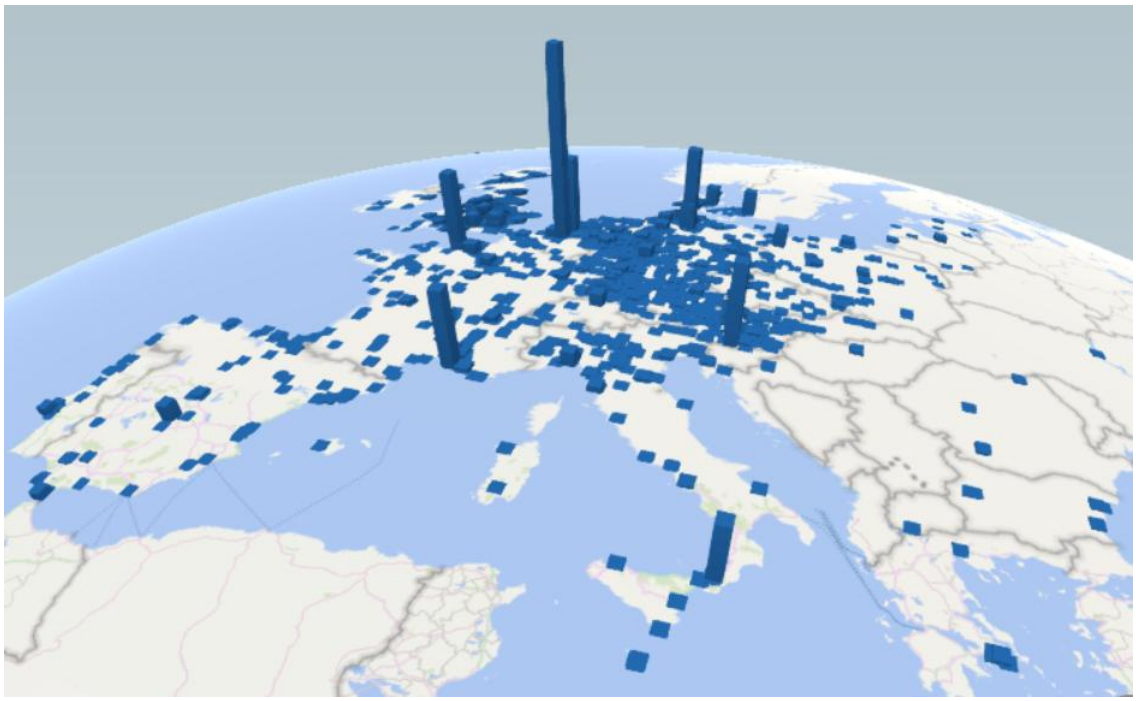

Figure 5.1. *Summed weights in the scope area*

As can be seen in the figure 5.1, there are a couple of very significant separate concentrations in the area. Also, there is an area, mainly situated in Germany, where there is a huge amount of destinations with relatively small volumes. The seven highest volumes in the scope area were near Antwerp (Belgium), Klagenfurt (Austria), Marseille (France), Rotterdam (the Netherlands), Hamburg (Germany), Gioia Tauro (Italy) and Le Havre (France).

5.1.1 Center of Gravity method

After the data was put in order, the Center of Gravity method was used to find the actual center of gravity based on the shipment volumes. As the scope area (almost the whole Europe) is excessively wide, the traditional Center of Gravity method of the formulae 5 and 6 (presented in chapter 3.3) was not seen as a proper approach for the problem. Instead, the spherical CoG method of formulae 9, 10 and 11 was utilized because of the fact that it is more suitable for wide areas as it takes into account the spherical shape of the Earth. Ballou's (2004, p. 556) addition (presented in formulae 7 and 8) about transportation prices was excluded from the analysis because of the fact that the actual transportation prices depend strongly on the departure point of the shipments. Thus, using the current transportation prices would not have given accurate approximations.

The use of circuity factors was considered but then rejected because, as stated in the subchapter 3.2, Ballou et al. (2002) provide circuity factors only for some of the European countries. Using circuity factors only for some distances would lead to incomplete results. Using the approximated average value for the European circuity factor would not give any reliable results, either.

The method selected was thus the spherical Center of Gravity method. To make the use of that method possible, the destination addresses were converted to actual latitude and longitude points. Because of the utilization of the spherical CoG method, it was necessary to express latitude and longitude minutes and seconds as decimal values. The second step was to convert West Longitudes and South Latitudes as negative values. This was made with a special converter by entering the postal codes and the cities into it. The converter then gave the coordinates which were then shifted to the excel table next to the corresponding volume.

After coordinate degrees were determined for all the destination locations, the next step was to convert them into radians. This was made simply by multiplying the degrees with pi and then dividing the result with 180. This was repeated with all the locations. After this, all the locations had both, latitude and longitude expressed in radians. The latitude and longitude coordinates in radians are then expressed in three dimensional Cartesian coordinates, following the formulae 9, 10 and 11.

With the Cartesian coordinates, it was possible to calculate the three dimensional center of gravity. It was basically done as follows: every X was multiplied with the corresponding weight. Then the results of these multiplications were summed and divided by the total weight. This was made for the Y and Z values also. The result, the center of gravity, then was a point somewhere inside the Earth.

However as obvious, a point inside the Earth is not a realistic location for a distribution center. That is why the result was extrapolated with basic trigonometric functions (the arctangent function) in order to get a point on the surface of the Earth. The received point was in radians, so it was then also converted to degrees by multiplying with 180 and the dividing with pi. The result was the actual center of gravity on the surface of the Earth.

In summary, the steps of utilizing the spherical center of gravity were as follows:

1. Converting addresses to latitudes and longitudes
2. Converting minutes and seconds to decimal values
3. Converting West Longitudes and South Latitudes to negative values
4. Converting degrees to radians
5. Expressing coordinates in three dimensional Cartesian coordinates after formulae 9, 10 and 11.
6. Calculating centers of gravity for each coordinates after the formulae 5 and 6
7. Extrapolating result point onto the surface of the Earth
8. Converting radians to degrees

Same process was repeated with volume weights in order to compare results and see if there is a significant difference in them. Also, results with different area restrictions

were calculated in order to determine the impact of volumes of certain countries like Finland and Sweden.

5.2 Evaluating service providers

After determining the center of gravity, the next step was to scan for possible service providers near the optimal point. Candidate searching was implemented simply by browsing web sites of various service providers, and also lists like "Top 100 3PL providers 2014" (Inbound Logistics 2014) and "A&A'sTop 50 Global Third-Party Logistics Provider (3PL) List" (Armstrong & Associates Inc. 2015).

As Kalmar Central Operations has outsourced its warehousing functions, this is an inevitable action in order to determine the optimal location. When searching for possible candidates, the first criterion was that the service provider should have an existing facility. Kalmar CO had no interest in participating in the construction of a new warehousing facility. Also, the candidate organizations should have experience of working with partners with similar businesses as Kalmar.

When the possible candidates were gathered, requests for quotation were sent to them by Central Operations in order to map out their interest and qualities. The request reviewed the facilities and equipment, the prices for different functions, the opening hours and standard collection time and the ERP system. Also, a possible schedule was inquired of them. Based on the replies, a couple of service providers were chosen for a closer scrutiny. Couple of service providers invited Kalmar CO employees to meet them and check their facilities. After that, those Kalmar’s employees were interviewed for the better view about qualities of those 3PL providers.

5.3 Qualitative location analysis

The Center of Gravity method and the locations of the candidate 3PL providers are used as a basis for the location analysis. The potential service provider locations determined that the relevant qualitative factors evaluated are cultural and logistical. Political factors were not seen as important because of the fact that all the candidates had a very similar political situation. However, the logistical factors include some political factors, too, because, for instance, the level of bureaucracy affects also the logistical performance. As mentioned earlier in this chapter, there was no point in comparing, for example, climatic factors or social welfare issues, as the candidate locations were too similar in these properties.

An important part of the qualitative analysis was to describe the current situation with its challenges and strengths. Consequently, the qualities determined in the subchapter 4.2 create a good starting point for the analysis. The same features were decided to be considered when evaluating the candidate service providers. As the information for the

subchapter 4.2 was collected mainly by interviewing the relevant employees, it was considered an appropriate method for collecting comparative info. The main idea was to ask similar questions to those that were asked for determining the current situation. The businesses of the selected organizations were quite close to Kalmar's spare part business in their type. It was also important to get interviewees from the organizations that have outsourced warehouses in the candidate countries.

5.3.1 Company X

The first selected organization was Company X which does not want its name to be mentioned. It is a business unit of a global engineering organization. It offers a wide range of heavy equipment for industry. Company X's logistics organization, which is a part of its service division, provides logistics services for the product lines. This logistics organization takes care of the warehousing of spare parts. Its European spare part distribution center is located in Eindhoven, the Netherlands.

The warehousing operations of the distribution center have been outsourced to a global 3PL organization. Company X and that 3PL organization do not operate in a common ERP but the ERP system of the 3PL organization is connected to Company X's ERP. The contract period with the service provider organization is a couple of years at a time. The contract determines the key performance indicators (KPIs) that are monitored. The followed factors are, for example, the reliability of deliveries and the amount of faulty deliveries. The service provider reports every day the result of the primal indicator. In addition, the performance is controlled in weekly meetings and in business reviews monthly.

Two interviewed employees of Company X were the Distribution Services Manager, (Europe, Middle East and CIS) and the Manager in Lifetime Support Services. The Distribution Service Manager is a person responsible for the current operations and the Manager in Lifetime Support Services was responsible for the location decision in the first place but does not participate remarkably in the current operating. Thus, the interview questions were not similar for these two people.

Consequently, interviews were not executed simultaneously. The Distribution Services Manager (Interviewee 1) was asked questions about the current situation and performance. On the contrary, questions asked from the Manager in Lifetime Support Services (Interviewee 2) were mainly about the factors that should be considered when making a location decision. The interview 1 was executed by email because the Interviewee 1 is working abroad but the interviewee 2 was interviewed personally.

5.3.2 MacGregor

MacGregor, which is a part of Cargotec Corporation, offers integrated cargo flow solutions for maritime transportation and offshore industries. It is a global company with facilities near ports worldwide. Its offering includes products like hatch covers and self-unloading systems for ships and products like subsea load handing solutions an anchor handling systems for the offshore industry.

Services are very important area of business for MacGregor. MacGregor's service network consists of more than 70 service centers in major ports around the globe. Its service portfolio covers a wide range of service products on board, offshore and onshore. The aim is to provide services throughout the complete life cycle of its products.

The EDC of MacGregor's spare part unit has been located in Hamburg, Germany since 2004. The warehousing operations have been outsourced to a 3PL provider that takes care of basic warehousing, picking and packing and warehouse management. The contract period with the service provider is three years. Its ERP system and ERP of MacGregor, SAP, are linked with electronic interfaces. Although the interviewee is German and the EDC is located in Hamburg, the operating language between MacGregor and the 3PL provider is English.

The person who was interviewed works as a Materials Manager in the Global Lifetime Support in MacGregor Germany. The questions asked in the interview were mostly about the current cultural, political and logistical situation and the performance of the 3PL provider. Also background questions were asked in order to find out the level of comparability of the results. The main focus was on the qualities that were considered problematic in the Kalmar's current situation. However, interview also surveyed if there were some other challenges. The aim was not to get stuck on the obvious questions. This interview was executed by email. Also additional phone interview was considered, but after receiving emailed answers, there were seen no need for that.

5.4 Combining quantitative and qualitative results: Decision making with the analytic hierarchy process

After the factors were determined, they were arranged into the hierarchy of the AHP method. The main idea was to combine all the results received with the quantitative and qualitative methods presented previously in this chapter. The main idea behind choosing the AHP method was to simultaneously determine priorities for each factor and evaluate the different candidates.

The main factors used in the decision making were location, service provider's competences and price. Location factors were then divided into smaller sub factors which were logistical factors, closeness to the actual center of gravity and the cultural factors. The

reason for this kind of division was that for example cultural factors were considered relatively small if compared directly with price. However, together with other location dependent factors, they create a significant entity which has to be taken into account when determining the final location. Figure 5.2 represents the hierarchy of factors and candidates.

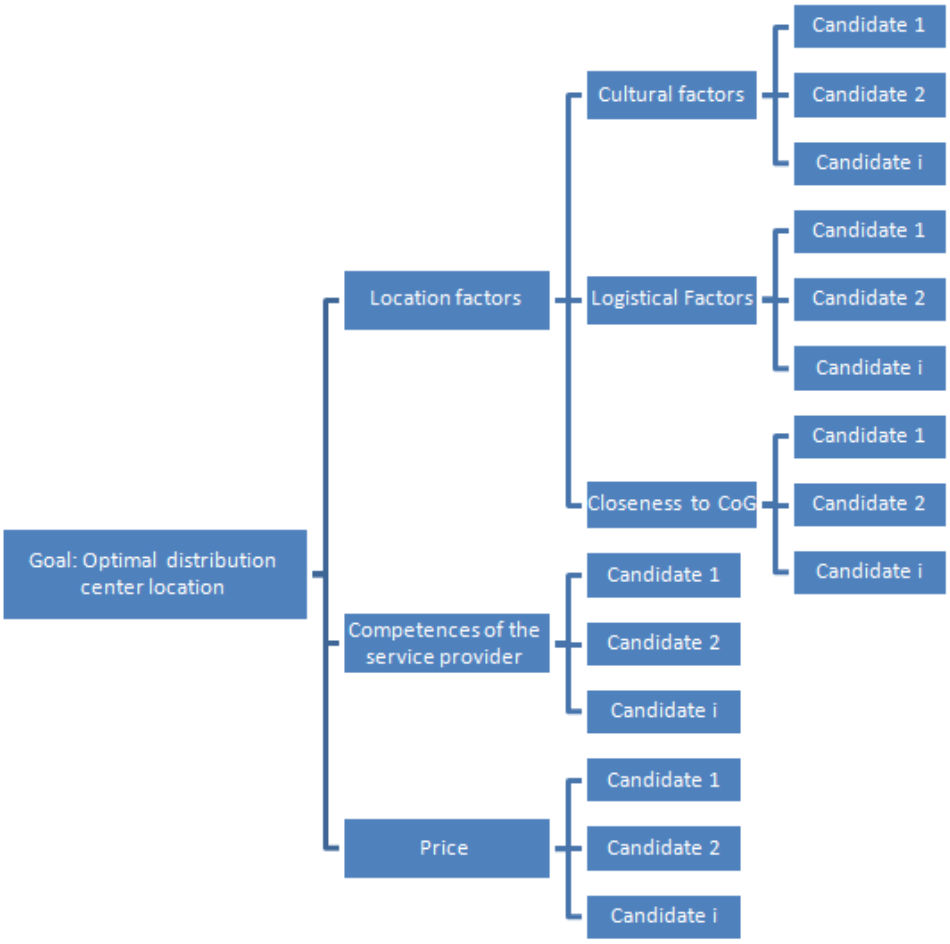

Figure 5.2. *Criteria behind the optimal distribution center location decision*

The next step was to approximate the priority of each factor with respect to their importance in reaching the goal. This was done by a series of pairwise comparison. This step required much discussion and was thus done in co-operation with Kalmar's professionals. The method was to interview two professionals simultaneously, so that they could debate about the priorities. The contents of each factor were explained to the interviewees and then also compared in pairs.

After the criteria were selected and the factors affecting each criterion were determined, the candidate qualities were evaluated in matrixes with pairwise comparison. After each pairwise comparison, an inconsistency inspection was executed in order to check that comparisons were made consistently. If there would have been an unacceptable incon-

sistency, comparisons would have been scrutinized more closely in order to find and change any illogical judgments.

Each candidate quality was multiplied with its importance and summed with its other multiplications. The same procedure was done also for the other two candidates. Then, these summaries were compared to each other in order to choose the candidate with the biggest summary. The result, then, was the optimal distribution center location based on a diverse set of qualitative and qualitative factors.

6. RESULTS AND DISCUSSION

The results in this chapter are presented in the order in which they were found. The first subchapter covers the calculations of the actual center of gravity. Also, the results based on the weights and volume weights are compared. The center of gravity and the chosen area around it create a basis for the qualitative results represented in the second subchapter. It collects together the qualities of a candidate location. Then, the results from both of these subchapters are combined in the final subchapter.

6.1 Center of Gravity

The centers of gravity, based on the weight of each coordinate are as follows:

$$x^* = \frac{\sum_{1764} w_{1764} x_{1764}}{\sum_{1764} w_{1764}} = \frac{530045.3\ kgrad}{828959.7\ kg} = 0.63941\ rad$$

$$y^* = \frac{\sum_{1764} w_{1764} y_{1764}}{\sum_{1764} w_{1764}} = \frac{64572.66\ kgrad}{828959.7\ kg} = 0.077896\ rad$$

$$z^* = \frac{\sum_{1764} w_{1764} z_{1764}}{\sum_{1764} w_{1764}} = \frac{627523.1\ kgrad}{828959.7\ kg} = 0.757001\ rad$$

This point (0.63941, 0.077896, 0.757001) is inside the Earth's surface. Then, after extrapolating the point to the surface, the x coordinate of the center of gravity is 0.865776 rad and the y coordinate is 0.121227 rad. By converting these values to degrees, the actual center of gravity coordinates are received. They are as follows:

$$\boldsymbol{x = latitude = 49.6053\ °}$$

$$\boldsymbol{y = longitude = 6.94582\ °}$$

This point (49.6053, 6.94582) or (49° 36' 19.0794" and 6° 56' 44.952") is located in the municipality of Nonnweiler in the district of Sankt Wendel, in Saarland, Germany. It is about 140 kilometers southwest from Frankfurt and 180 kilometers south from Dusseldorf.

There was an interest for the center of gravity location, too, if the volumes of the Nordic countries and Russia had been included in the analysis. Calculating that location gave the coordinates of point 51.76342 (lat) and 8.912398 (lon). This point is also located in Germany, near the city of Paderborn and it is thus northeast from the actual center of

gravity. The distance between these locations is about 400 kilometers. Figure 6.1 represents these points on the map.

Figure 6.1. *The centers of gravity: the point in southwest does not take Nordic volumes into account (map base from Google)*

Same calculations were made also based on the volume weights in order to see if there is a significant difference in results. The results of each coordinate were as follows:

$$x^* = \frac{\sum_{1764} v_{1764} x_{1764}}{\sum_{1764} w_{1764}} = \frac{357325.3\ kgrad}{558526.6\ kg} = 0.639764\ rad$$

$$y^* = \frac{\sum_{1764} v_{1764} y_{1764}}{\sum_{1764} w_{1764}} = \frac{44143.46\ kgrad}{558526.6\ kg} = 0.079036\ rad$$

$$z^* = \frac{\sum_{1764} v_{1764} z_{1764}}{\sum_{1764} w_{1764}} = \frac{422525.3\ kgrad}{558526.6\ kg} = 0.756500\ rad$$

After extrapolating and converting the values to degrees, the result was a point with coordinates of 49.56506 and 7.042555872. This point is located less than 10 kilometers away from the center of gravity based on the weights. 6.2 represents both centers of gravity. The result based on weights is marked with W and the result based on volume weights is marked with V.

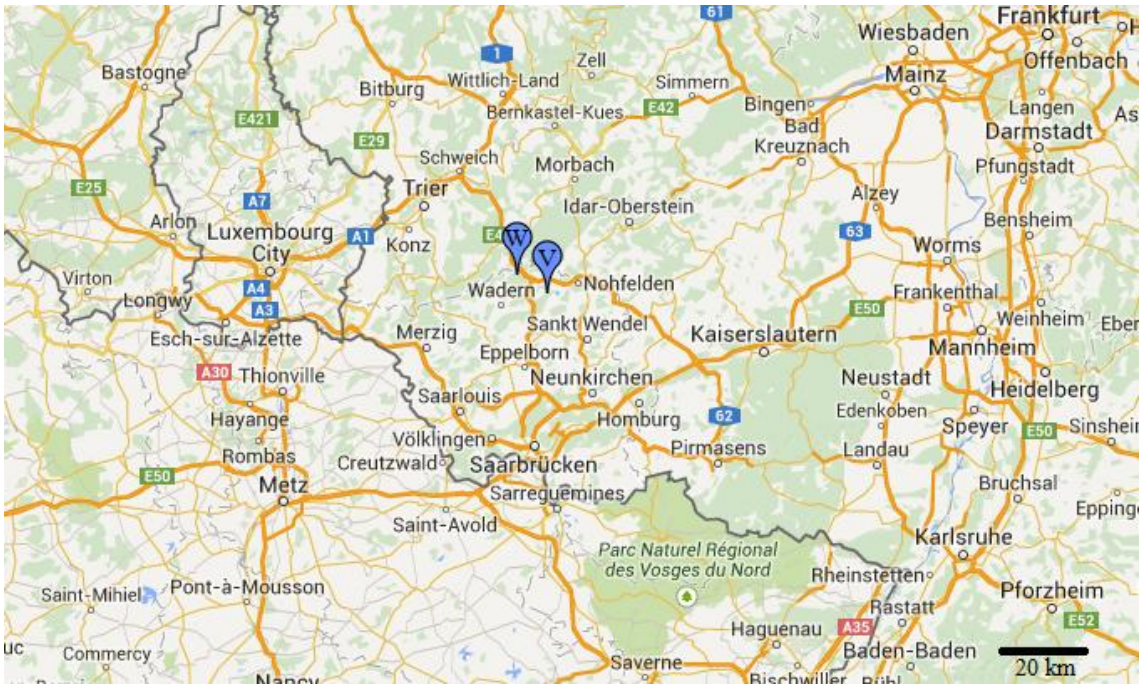

Figure 6.2. *Both centers of gravity (map base from Google)*

As figure 6.2 indicates, there is no remarkable difference between the results based on the weights and the volume weights. Thus, the decision was to consider the center of gravity based on the weights as the final result. This choice was made considering the fact that most of the time, freight costs are determined after weights and not so often after volume weights. However, it was reasonable to check the difference between the results because if there had been a significant difference, a more precise scrutiny would have been needed. Consequently, a more extensive analysis is made based on the point that was calculated on the weights.

The normal Center of Gravity Method that does not take into account the spherical shape of the Earth was also used in order to double check that the spherical method gives more optimal results in this case. With that method, the coordinates of the center of gravity would be 49.40919 (lat) and 6.929891 (lon). The difference between the spherical method and the normal method is thus quite insignificant in this case. This is because of the fact that the nonlinear nature of the Earth's coordinate system affects the most near the poles. As the Nordic countries were excluded from this analysis, taking the sphericity into account does not seem necessary. However, the scope area was still so large that the results are not identical. Thus, it is reasonable to consider the result that takes sphericity into account as the final one.

The next step was, as previously mentioned in chapter 5.2, to scan for possible service provides near the center of gravity. The aim was to avoid choosing a too narrow area for further scrutiny because it could have ruled out too many candidates. Consequently, the suitable area was specified to be a circle around the center of gravity with a radius of

200 kilometers. Figure 6.3. represents the area with a radius of 200 kilometers around the center of gravity.

Figure 6.3. *The selected area around the center of gravity (map base from Google)*

As can be seen in figure 6.3, the selected area includes parts of five countries: Germany, the Netherlands, France, Belgium and Luxembourg.

6.2 Candidate service providers

After scanning the service providers with the criteria presented in chapter 5.2, there were three potential companies in three different locations in addition to the current location. Two of the potential candidates were located in Germany and one in the Netherlands. One of the candidate locations is also the current distribution center location in France. More closely, the candidate locations were as follows:

- Mönchengladbach, North Rhine-Westphalia, **Germany**
- Ramstein-Miesenbach, Rhineland-Palatinate, **Germany**
- Born, Sittard-Geleen, **the Netherlands**
- Flevy, Lorraine, **France**

Consequently, further scrutiny will be done from the basis of these locations. Figure 6.4 represents these candidate locations on map.

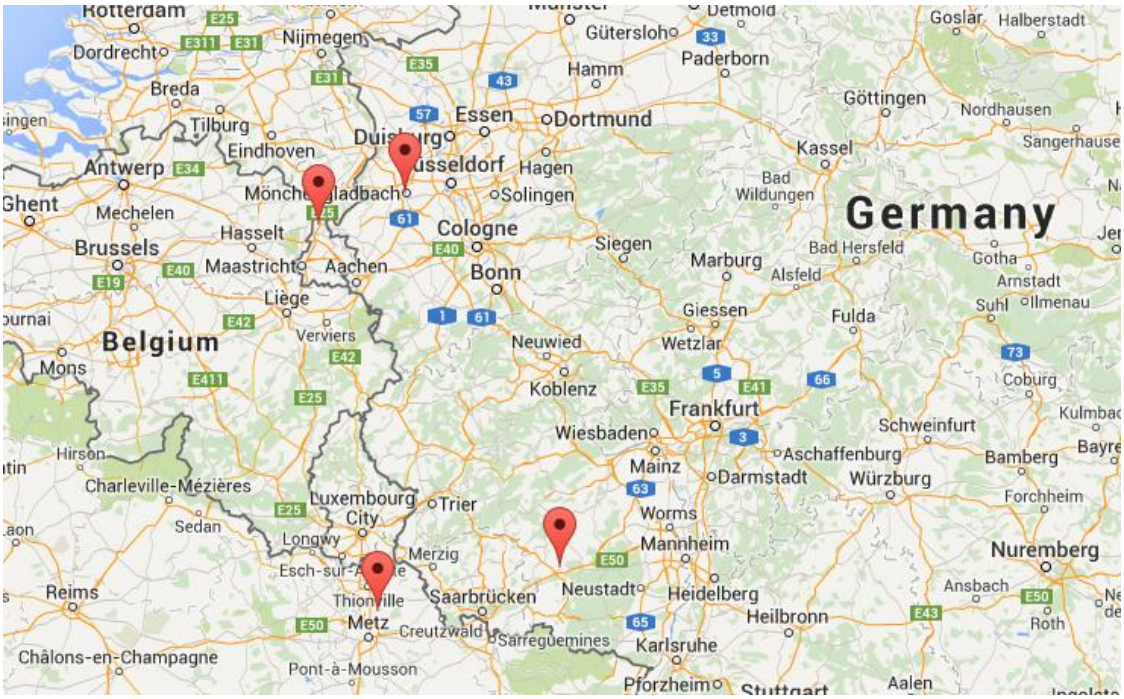

Figure 6.4. *Candidate locations (map base from Google)*

As figure 6.4 shows, the current location of the European Distribution Center in Metz is quite near to the actual center of gravity. Also, the candidate location in Ramstein-Miesenbach is near the CoG.

6.3 Qualities of the candidates and their locations

As previously mentioned, the location factors in this survey consist of cultural and logistical factors as political factors are excluded. It was decided that logistical factors include only the general situation of the country and not the more specific location of the service provider. For example, a short distance between the service provider and motorways was considered as a competence of the service provider and not as a logistical factor. Consequently, logistical qualities like loading places and equipment of a 3PL provider were included only in competences.

6.3.1 Cultural factors

The European Commission (2014) states that Germany, France and the Netherlands belong in the same cultural area of Western Europe. Thus, the cultural differences between these countries are minor ones. However, there still are some differences that come up especially when compared to Finnish culture. In Hofstede Centre's (2015) comparison, the Netherlands has the nearest score to Finland's. The difference between Finland and Germany is almost equal to the difference between Finland and France.

As pointed out in chapter 4 the current partner's strong hierarchy is considered a problem in Kalmar CO. Thus, the interviewees in Company X and MacGregor were asked about the hierarchies in their distribution center operators. The result was that hierarchies were not found problematic either in Germany or in the Netherlands. Hierarchy was considered mainly reasonable and the interviewees did not see it as a slowing element. This result is in keeping with Hoefstede Centre's (2015) comparison: the Netherlands and Germany score near Finland but France has significantly higher score in power distance, which means that French companies have normally one or two hierarchical levels more than comparable companies, for example, in Germany.

Changing practices and policies was considered a challenge in the current situation. It is hard to say whether it is caused by strong hierarchies, but based on the interviews, there does not seem to be similar problems in Germany or the Netherlands. Interviewee 1 told that making changes surely takes some time, but it is only reasonable. However, he added that when there are changes or problems in their 3PL provider's operations, communication does not work as well as wished. The same problem occurs in Kalmar's current situation. Only with the German service provider there did not appear to be any communication problems.

Based on the interviews, both Germany and the Netherlands seem to have a better culture of co-operating than France. Interviewee 2 emphasized that collaborating with the Dutch is easy and fluent. However, he added that negotiating monetary issues and areas of responsibility demands extreme exactness. Also, the interviewee found the biggest challenges in negotiations in the beginning of the co-operation. After the beginning, there did not seem to be any responsibility related issues like with Kalmar's current situation.

Insufficient skills in English were not considered a problem either in the Netherlands or in Germany. However, in France the situation is different. The European Commission (2014) notifies that in France, the English language does not have the status it has in the rest of the Western Europe. It is explained with the fact that in France, the French language is seen as a huge part of their culture and identity. Also, EF Education First Ltd. (2015) ranks France as remarkably weaker than the Netherlands or Germany in their English Proficiency Index. In this ranking, English skills are evaluated as very high in the Netherlands, high in Germany and only moderate in France.

6.3.2 Logistical factors

Logistically, the whole scope area around the center of gravity is quite ideal. It has big airports and harbors near it and the road network is excellent for the most part. Also, many logistics operators are working in that area and have their hubs nearby. In World Bank's Logistical Performance Index, Germany and the Netherlands rank as the first (Germany) and the second (the Netherlands) best countries. Their scores are really close

to each other. France has a slightly lower score and the rank of the thirteenth best country. Also, based on the interview (Behrens), Germany seems to be an excellent location in a logistics point of view. It is an ideal place for tendering because of the high number of logistics operators. There are numerous warehousing companies and freight forwarders and thus the prices are competitive. Moreover, other logistical costs are also on a reasonable level. Road traffic is mainly fluent and delays caused by traffic jams are rare. Only accidents in motorways may disturb deliveries occasionally. The export procedure is strict, but it does not cause any problems or extra bureaucracy if known and followed. All in all, interviewed person could not find any negative factors about the logistical situation in Germany.

The distribution center location in the Netherlands was also considered excellent based on logistical factors. The number of logistical operators is high so consequently, prices are reasonable. There are numerous service providers in warehousing and forwarding which creates a good basis for tendering. Bureaucracy is in a low level and the export process is easy to follow. Interviewee 2 could not see any better place for a distribution center than the Netherlands. However, interviewee 1 slightly disagreed. He saw risks like airport restrictions and traffic jams in the huge amount of transportation in the Netherlands.

6.3.3 Service provider competences

After evaluating cultural and logistical factors, the service providers were scrutinized more closely. In that scrutiny it occurred that the service provider in the Netherlands was far too expensive. The difference between its prices and other service providers' prices was significant. Thus, the service provider was considered an impossible option even though it could be a good candidate because of its other qualities. Consequently, it was seen unreasonable to keep it along with the other candidates in comparisons. Candidates, whose competences were compared, were therefore Ramstein-Miesenbach, Mönchengladbach and the current location in Flevy.

It is an indisputable fact that the current service provider has many advantages when compared to the other service providers because it has already gained experience with Kalmar. Co-operating with a familiar service provider has many beneficial aspects. Also, Interviewee 1 emphasized the importance of the service provider's experience from similar business. He stated that the lack of experience may cause many operative complications and misunderstandings.

In the case of not changing the DC location, there would not be any relocating complications like temporary service level declines or additional costs. Also, for example, information management systems are already connected and there are no requirements for additional investments. However, selecting the optimal location is a strategic decision which should be made considering strategic, long-term goals. Thus, this evaluation is

done at a rather general level, ignoring the advantages of the current service provider. Consequently, competences are compared like the situation was totally neutral and there was no common history with any of the service providers. In practice, the advantages should not be understated. Thus, they are reflected in the final recommendation for action. An interview with the professionals of Kalmar CO clarified that the qualities that were evaluated in general were as follows:

- Quality system
- Accessibility
- Pick-up hour by the freight company
- Processes
- Disciplines in warehouse
- References
- Attitude
- Understanding of process

Based on the factors listed above, the service provider in Mönchengladbach was considered the best option. It clearly has the best quality system and its warehouse was disciplined. Its automated warehousing processes and service oriented attitude were highly valued, too. The current service provider has the second best competences. It has, for example, better references and more functional pick-up hours than the service provider in Mönchengladbach. Attitude was seen as maybe the biggest problem in its competences. The service provider in Ramstein-Miesenbach was considered as the worst option by its competences.

The least expensive of the candidates is the one in Mönchengladbach. Despite the fact that there would be costs caused by, for example, transferring items to a new location, it was slightly cheaper than the current warehouse operator. However, this was the situation only from Kalmar's point of view. As previously mentioned in chapter 4, Hiab has its distribution center in Flevy, too, and it is operated by the same service provider as Kalmar's DC. For contractual reasons, this situation is economical for Cargotec and decentralizing distribution centers would cause it extra costs. However, this study was done for Kalmar and not for Cargotec and consequently, this contradiction was ignored. The contradiction is, however, taken into account in the final recommendation for action. The service provider in Ramstein-Miesenbach was the most expensive option in every aspect.

6.4 Combining the results

The first step of combining the results through the AHP method was to evaluate the importance of different factors. This evaluation was divided into two phases. In the first phase, the locations were compared in general in country level. The qualities compared in that phase were cultural factors, logistical factors and closeness to the center of gravi-

ty. These factors were combined into location factors in the next phase. The compared factors, then, in that second phase were location factors, service provider competences and price as determined already in the fifth chapter. In summary, the contents of these two phases were as follows:

- First phase: determining the quality of a location
    - Cultural factors
    - Logistical factors
    - Closeness to CoG

- Second phase: determining the optimal distribution center location
    - Location quality
    - Service provider
    - Price

Consequently, the result generated in the second phase is almost the final answer to the main research question. However, it does not take into account all the complications that relocating may cause. Those complications are then discussed in the recommendation for action.

6.5 The first phase: Determining qualities of the locations

The first step was to evaluate the significance for cultural factors, logistical factors and closeness to CoG which were the factors chosen into the first phase. The factors were collected into a 3x3 matrix and then evaluated with the fundamental scale used in the AHP method. It is important to notice that this comparison was already made keeping the qualities of possible candidates in mind. The candidates and their quite similar qualities had a remarkable impact on the prioritizing factor. For example, if there had been a possibility that one of the candidates would have been on the other side of the Earth, closeness to center of gravity may have been even more important that it was considered in this comparison.

When making comparisons, two main sectors that were kept in mind were service level and costs. As mentioned in the previous chapters, easiness of operating often reduces costs but also increases the service level and overall customer satisfaction. In other words, the aim was to speculate with the impacts of each factor in respect to the easiness and costs of own operating, but also customer service responsiveness and its impacts on customer satisfaction. Based on these facts the importance of cultural factors, logistical factors and closeness to the CoG were evaluated with the scale presented in the table 3.1. The result matrix is represented in table 6.1.

Table 6.1. *Evaluation of location factors*

	Cultural factors	Logistical factors	Closeness to CoG	Normalized weight
Cultural factors	1	1/3	1/5	0.105
Logistical factors	3	1	1/3	0.258
Closeness to the CoG	5	3	1	0.637

As can be seen in table 6.1, closeness to the center of gravity was considered the most important factor with the normalized weight of 63.7 %. It was slightly favored when compared to logistical factors and strongly favored when compared to cultural factors. Consequently, logistical factors were seen slightly more important than cultural factors. Inconsistency ratio of this matrix is 4.0% which means that the judgment is consistent enough.

The next step is to compare the candidates in these three categories. In these comparisons, all four candidates are named after their locations. The first comparison, which was about cultural factors, is represented in table 6.2. The codes for the candidate locations are as follows: DE_M for Mönchengladbach, DE_R for Ramstein-Miesenbach, NL for Born and FR for Flevy

Table 6.2. *Pairwise comparison of the candidates, based on cultural qualities.*

	DE_M	DE_R	NL	FR	Normalized priority
DE_M	1	1	1	5	0.313
DE_R	1	1	1	5	0.313
NL	1	1	1	5	0.313
FR	1/5	1/5	1/5	1	0.0625

As can be seen in table 6.2, both candidates in Germany were seen culturally as strong as the candidate in the Netherlands. However, for reasons that are explained in chapter

4.2, the candidate in France was considered much weaker than the other candidates. For example, strong hierarchies and weak English skills affected that result. Inconsistency ratio of this comparison is 0 % which means that it is perfectly consistent.

The second pairwise comparison based on candidate qualities was about logistical factors. Results of that comparison are represented in table 6.3.

Table 6.3. *Comparison of logistical qualities*

	DE_M	DE_R	NL	FR	Normalized priority
DE_M	1	1	3	5	0.394
DE_R	1	1	3	5	0.394
NL	1/3	1/3	1	3	0.152
FR	1/5	1/5	1/3	1	0.0599

As can be seen in table 6.3, the locations in Germany were considered logistically slightly better than the location in the Netherlands. The main reasons for that were the logistical risks that came out in the interviews. Those risks were about the huge amount of traffic and its possible impacts on the product flow.

All the other logistical qualities of Germany and the Netherlands were seen equally strong. France was seen as the worst option in this comparison. This was because of the facts that rose up in the interviews and also because France's scores in Logistics Performance Index are notably lower than the scores of Germany and the Netherlands. Inconsistency ratio of this comparison was 1.6 % which is clearly in an acceptable level.

Then, the last compared quality was closeness to the center of gravity. It was done simply by measuring the distances between each location and the center of gravity. This comparison is represented in table 6.4.

Table 6.4. *Comparison based on closeness to the CoG*

	DE_M	DE_R	NL	FR	Normalized priority
DE_M	1	1/3	1	1/3	0,125
DE_R	3	1	3	1	0,375
NL	1	1/3	1	1/3	0,125
FR	3	1	3	1	0,375

As can be seen in table 6.4, Mönchengladbach and Flevy are the nearest points to the center of gravity and thus slightly favored in comparison with the other two candidates. Inconsistency ratio of this comparison is 0 % and the comparison is thus perfectly consistent.

The next step was to calculate the products of each quality and priority for each candidate. Table 6.5 represents these calculations.

Table 6.5. *Qualities multiplied with priorities*

Criterion	Priority	Candidate	Quality	Priority * quality
Cultural factors	0.105	DE_M DE_R NL FR	0.313 0.313 0.313 0.0625	0.0329 0.0329 0.0329 0.00656
Logistical factors	0.258	DE_M DE_R NL FR	0.394 0.394 0.152 0.0599	0.102 0.102 0.0392 0.0155
Closeness to the CoG	0.637	DE_M DE_R NL FR	0.125 0.375 0.125 0.375	0.0796 0.239 0.0796 0.239

Table 6.5 was then used as a base for the final summing. Multiplications of each candidate were summed, and the result was the overall priority of the candidates. Table 6.6 represents these results.

Table 6.6. *Final location priorities of the candidates*

Candidate	Cultural factors	Logistical factors	Closeness to CoG	Final priority of the candidate (sum)
DE_M	0.0329	0.102	0.0796	0.215
DE_R	0.0329	0.102	0.239	0.374
NL	0.0329	0.0392	0.0796	0.152
FR	0.00656	0.0155	0.239	0.261

As table 6.6 indicates, the candidate in Ramstein-Miesenbach (DE_R) has the highest score and is thus the optimal location when considering only the location factors. The second highest score is for the current location in Flevy (FR), and the third highest score is for Mönchengladbach (DE_M). The location in Born is the worst option in this scrutiny.

6.5.1 The second phase: Determining the optimal distribution center location

As mentioned in subchapter 6.3.3, the service provider in the Netherlands was far too expensive. The difference between its prices and other service providers' prices was so significant that there was seen no reason to keep it along with the other candidates in comparisons. The candidates in the second phase were therefore Ramstein-Miesenbach, Mönchengladbach and the current location in Flevy.

The first step after redetermination of the candidates was to evaluate the significances of each factor chosen into the second phase. The factors were collected into a 3x3 matrix and then evaluated with the fundamental scale used in the AHP method like in the first phase. The result matrix is represented in the table. In this second phase, it is also important to notice that this comparison was already made keeping the candidates in mind. The candidates and their quite similar qualities had a huge impact on the prioritizing factor. Table 6.7 represents the result of evaluations of the significances of the factors.

Table 6.7. *Evaluation of the factors in the second phase*

	Location factors	3PL provider's competences	Price	Normalized weight
Location factors	1	1/5	1/3	0.105
3PL provider's competences	5	1	3	0.637
Price	3	1/3	1	0.258

As can be seen in table 6.7, competences of the service provider were considered as the most important factor with the normalized weight of 63.7 %. It was slightly favored when compared to price and strongly favored when compared to location factors. Consequently, price was seen slightly more important than location factors. Inconsistency ratio of this matrix is 4.0% which means that the judgment is consistent enough.

The next step was to compare candidates based on their competences, prices and locations. Evaluation of the locations was already done in the first phase. However, there were still four candidates in that phase. After the candidate in the Netherlands was dropped out, it was important to check evaluations and normalize them for three candidates. The sum of priorities of those candidates was 0.85, which has to be multiplied with 1.176 in order to get 1. Consequently, all priorities were also multiplied with 1.176. Table 6.8 represents the revised values of location qualities

Table 6.8. *Revised location priorities of the final group of three*

Flevy	Mönchengladbach	Ramstein-Miesenbach
0.307	0.253	0.440

Then, candidates were evaluated from the basis of their prices. This evaluation is presented in the table 6.9.

Table 6.9. *Pairwise comparisons of candidates based on prices*

	Flevy	Mönchengladbach	Ramstein-Miesenbach	Normalized weight
Flevy	1	1/2	3	0.320
Mönchengladbach	2	1	4	0.558
Ramstein-Miesenbach	1/3	¼	1	0.122

As table 6.9 indicates, Mönchengladbach is the most economic option, and Flevy the second best option based on prices. Ramstein-Miesenbach was considered clearly more expensive. Inconsistency ratio of this comparison is 0.02 % and the comparison is thus

almost perfectly consistent. The final evaluation was about the competences of the service providers. Table 6.10 represents this comparison

Table 6.10. *Evaluation of competences of the service providers*

	Flevy	Mönchengladbach	Ramstein-Miesenbach	Normalized weight
Flevy	1	1/2	2	0.297
Mönchengladbach	2	1	3	0.540
Ramstein-Miesenbach	1/2	1/3	1	0.163

As can be seen in table 6.10, the service provider in Mönchengladbach has the highest competences. Then, the current service provider is considered as the second best option and the service provider in Ramstein-Miesenbach as the worst option by its competences. Consistency ratio of this matrix is 0.01 and it is thus in an acceptable level.

The next step was to calculate the products of each quality and priority for each candidate. Table 6.11 represents these calculations.

Table 6.11. *Qualities multiplied with priorities*

Criterion	Priority	Candidate	Quality	Priority * quality
Location	0.105	DE_M DE_R FR	0.253 0.440 0.307	0.0266 0.0462 0.0322
Price	0.258	DE_M DE_R FR	0.558 0.122 0.320	0.144 0.0315 0.0826
Competences	0.637	DE_M DE_R FR	0.540 0.163 0.297	0.344 0.104 0.189

Table 6.11 was then used as a base for the final summing. Multiplications of each candidate were summed, and the result was the overall priority of the candidates. Table 6.12 represents these results.

Table 6.12. *Final priorities of the candidates*

Candidate	Location	Price	Competences	Final priority of the candidate (sum)
DE_M	0.0266	0.144	0.344	0.515
DE_R	0.0462	0.0315	0.104	0.182
FR	0.0322	0.0826	0.189	0.304

As table 6.12 indicates, the candidate in Mönchengladbach (DE_M) has the highest score and is thus the optimal location considering all the factors. The second highest score is for the current location in Flevy (FR), and the worst score is for Ramstein-Miesenbcah (DE_M). As can be seen in the table, Mönchengladbach has the highest scores in all other categories but location factors. Consequently, the final rank of the candidates is as follows:

1. Mönchengladbach
2. Flevy
3. Ramstein-Miesenbach

Based on the factors that have been considered in this study, Mönchengladbach is the optimal distribution center location for Kalmar's EDC. Thus, relocating the distribution center there would make operating easier and most likely cause service level improvements. However, this is only the situation in the long run, if all the relocating complications are excluded.

7. CONCLUSIONS

The main purpose of this thesis was to determine the optimal location for Kalmar's EDC. It was done through mathematical calculations of customer volumes, data analysis, and interviews. This chapter summarizes the main results and gives recommendation for action, based on the results. The results and the whole study are then assessed as well as the utilized methods are evaluated. Recommendations for further studies are also given.

7.1 Main results

Two most significant results of this thesis are as follows:

- Determination of the factors that should be taken into account when making a location decision
- Optimal distribution center location based on those factors

Based on theoretical literature, empirical interviews and observation, it was noticed that selecting a facility location is a complex decision that requires a huge amount of diverse information. Location selected only in respect of customer locations and volumes is most likely not the optimal location when considering qualitative features as well. However, volumes and destinations of deliveries create a good starting point for further scrutiny. Supplier locations and volumes are another quantitative factor that could be utilized in location decisions. However, they were excluded from this thesis as an advance restriction determined by the target company.

Qualitative location factors which should be considered when making a location decision are logistical, cultural and political. Also, when a company has outsourced its warehousing operations, competences and prices of candidate service providers cannot be ignored. Thus, an optimal distribution center location is a combination of optimizing product flows, evaluating the location and its logistical, cultural and political environment and selecting a suitable service provider.

When determining qualitative factors, it occurred that the starting point, which in this thesis was the center of gravity, has a huge impact on the relevancy of those factors. For example, political factors may have a remarkable role in some cases, but if the area around the starting point is politically homogenous, there is no sense of including them in the decision. This is a valid hypothesis also for other factors.

After the relevant factors were determined, the actual optimal distribution center location was concluded. The starting point for this was to calculate the center of gravity based on customer locations and volumes. As a result, the center of gravity occurred to be in Germany, at a point whose coordinates are 49.6053 and 6.94582. The distance between the center of gravity and the current DC location is less than 100 kilometers. Thus, it was clear that based on volumes, the current location is near optimal. However, when cultural and logistical factors were also considered, the location of the candidate service provider in Ramstein-Miesenbach, Germany was considered a better option. Then, after evaluating the service providers, this ranking changed. The final, and the most essential result of this thesis showed that the optimal location for Kalmar's EDC is Mönchengladbach, Germany.

7.2 Recommendation for action

The final result for the optimal DC location is determined only from the basis of the previously selected factors. Thus, it is not the same thing as recommendation for action. It is rather a starting point for further scrutiny. Firstly, relocation complications should be considered more closely. Stock transfer is a huge project with remarkable costs and operational complexities. Even if another location was clearly better when examined in a neutral view, the current location always has numerous benefits.

Not only the transfer process has its problems, but also co-operating with a new service provider would be challenging in the beginning of the relationship. Common experience was a feature that came up as a significant factor in this study. It is because learning common practices and policies takes a lot of time. This all would significantly weaken the service level and possibly not only cause costs, but also reduce customer satisfaction. Reduced customer satisfaction could then decrease incomes. Because the availability of products is vital especially in spare parts business, relocating the distribution center could even have quite fatal effects on the whole business.

When taking all complications and obscurities of relocation into account, it is clear that the result of this thesis should not be considered as a simple recommendation for action. Instead the final recommendation is to execute some additional scrutiny on Mönchengladbach, including, for example, investment calculations and schedule planning for the possible transfer. Relocation costs should be calculated more carefully, too. Also, closer evaluation of the service provider should be done. In addition, the view of the whole Cargotec corporation should be taken into account in this closer scrutiny as this thesis concentrates only on Kalmar's point of view.

After closer calculations and evaluations, if it is discovered that relocation is possible and seems to be profitable in the long run, Mönchengladbach should be selected as the location of Kalmar's EDC. In conclusion, the future location of Kalmar's EDC should

be either Flevy or Mönchengladbach and further investigation is needed in order to determine which one is the better option in the long run.

7.3 Assessment of the utilized methods

The Center of Gravity method was widely utilized in this thesis. It is a valid method for location planning if the results are interpreted correctly. The location of the actual center of gravity creates a good starting point for determining the optimal distribution center location but it should not be taken as the only factor behind the location decision. Also, selecting a suitable version of the CoG method should be done carefully when customer volumes are split all over the Earth. In this kind of situations, the spherical nature of the Earth must be taken into account. Thus, it is quite astonishing that only few sources seem to have noticed this fact.

In real world, a distribution center that is located in the center of gravity does not always mean the lowest transportation prices. Those prices are often based on competitive tendering process and are deeply dependent on the hub locations of transportation companies. In addition, the CoG method does not take geography or possible routes into account. Thus, even inside Europe, some distances are remarkably longer than direct Euclidean distances. Estimating the size of this kind of inaccuracies is nearly impossible without any location planning software. With special software it would be possible to determine a more realistic location for the center of gravity. Consequently, this study also would absolutely have profited from more advanced data analyzing systems. On the other hand, also the data analyzing systems are based on some formula and

Combining qualitative and quantitative results is also a part that should be viewed critically. The AHP method seemed to be an appropriate method for this thesis because its hierarchical approach makes it possible to combine qualitative and quantitative results in respect of professional opinions. However, the benefit of utilizing subjective opinions implicates the fact that also results are somewhat subjective. However, that is the situation with most of the decision making methods at least if the professional opinions are utilized. In this study, the AHP method provided a relevant approach for combining results. Even though now the results may be considered partly subjective, the lack of professional opinions would have caused less reliable results.

7.4 Assessment of the study

This thesis gives a solution to its research problem and answers the research questions. However, the results of this thesis should also be viewed critically. One of the main reasons is that the results are mainly based on the center of gravity location which does not, as stated previously, give perfectly accurate results. Because of this fact, the area with the radius of 200 km may be slightly incorrectly selected. On the other hand, this was a known fact already in the beginning of this study and has affected the selected

area's size. If the calculated CoG location was perfectly accurate, the selected area would have most likely been smaller.

The interviews are an important part of the qualitative study in this thesis. However, the results are based on only a few interviews and consequently, the amount of interviewees could have been higher. Also, one of the interviewees is German and that interview does not provide that much information about cultural differences. It may have been better if there were more Finnish interviewees giving their opinion about operating in Germany. However, suitable Finnish interviewees could not be found. Also, there is no accuracy whether all the interviewees are one of their kinds and do not represent a wider state.

This study provides relatively remarkable results and solution to the current situation which was also the main objective. Consequently, it does not take a stance on the impacts of possible future changes. Even though Kalmar's situation is considered stable, some "what if" -scenarios could have been made. Because of that, the results of this study are not undoubtedly valid in the future if there are remarkable changes in the customer base or volumes. Also, if, for example, political or logistical situation in Europe changes, there is no certainty that the Mönchengladbach is still the optimal location for Kalmar's EDC.

This study concentrates on one special case and thus the results are company and case-specific. That creates some limitations to theoretical implications of this study. However, this thesis provides with a model for location planning for companies with similar businesses in similar situations. This thesis has a quite extensive case description that should make comparing situations and their compatibility easier.

7.5 Recommendations for further studies

This study excludes suppliers and their locations. For future research, it would be an interesting research question to find out what should be the weight, if also supplier volumes were considered. There are no previous studies where the Center of Gravity method would have been utilized in order to calculate the center of gravity for supplier volumes. Thus, there is no opinion whether that method is suitable for that kind of situations. In addition, there are no studies where the distance between a distribution center and supplier locations was considered to have an effect on customer service responsiveness.

Another interesting area of research could be the impacts if the distribution center was relocated. As pointed out in sub chapter X, there is a lot of literature about relocating complications. However, there is a lack of studies about the proven benefits of relocating. Almost all of the previous researches concentrate on speculating possible benefits. Thus, there is no proof that relocating may actually be worthwhile in a real world situation. Also, the dependence between reducing ton-kilometers through relocating to the

CoG and the actual transportation costs could be one recommended theme for further studies.

This thesis is based on the European volumes only. A further study could cover also the global volumes. Including them would cause interesting questions about the suitable method, as it is quite clear that the CoG method would in that kind of case provide only with a rough approximation. Also, the “optimal” location determined could be, for example, in the middle of an ocean. Consequently, global volumes may cause a need for multi-location determination. Another possible solution could be transferring global volumes to their departure harbors or airports. If this kind of method was followed, some kind of a starting point would be still needed. How and with which volumes that should be done, is an interesting subject for further studies.

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APPENDIX A: INTERVIEW QUESTIONS / BEHRENS AND INTERVIEWEE 1

Background questions:

1) What is your position at MacGregor / Company X? What are your responsibilities?

2) What is the exact location of the EDC?

3) How long has the EDC been at that location? What were the reasons behind this location decision?

4) Have the warehousing functions been outsourced? To which 3PL organization?

5) Which functions are the responsibilities of the 3PL organization?

6) How long is the contract period?

7) Is there a common ERP system?

8) Is the operating language English?

Cultural factors:

1) How are the language skills of the 3PL organization?

2) Is there strong hierarchy in the 3PL organization? (For example, does even the smallest decision need a permit from the higher level?)

3) Are the responsibility areas of the 3PL organizations personnel clear?

4) Is it easy to change the 3PL organization's practices?

5) Does the 3PL organization inform about its changes? How are the communications with the organization in general?

6) Is it easy to operate with the 3PL organization? Which are the most proficient functions?

7) What are the most challenging tasks / features when operating with the 3PL organization?

8) Anything to add?

Political / societal factors:

1) Have there been strikes that have stopped / disturbed the operations?

3) Is there strong bureaucracy in Germany / the Netherlands? How does it turn out?

4) How are the safety issues in the DC area / 3PL organization? Have there been problems with, for example, thefts?

5) Anything to add?

Logistical factors:

1) Has the location of the DC set any limitations to selecting the transportation companies? Or has it created a good base for tendering?

2) Were there many potential 3PL providers in the area?

3) Are there any logistical extra costs caused by the location?

4) Have there been any delays in transportations caused by traffic jams?

5) Anything to add?

In summary:

1) Are you satisfied with the current location? If not, what would be a better location?

2) Which factors do you consider as the most significant in the location decisions?

3) Anything to add?

APPENDIX B: INTERVIEW QUESTIONS / INTERVIEWEE 2

Background questions:

1) What is your position at Company X? What are your responsibilities?

2) What are your responsibilities that are related to warehousing processes?

3) Have the warehousing functions been outsourced? To which 3PL organization?

4) Which functions are the responsibilities of the 3PL organization?

5) How long is the contract period?

6) Is there a common ERP system?

Location decision:

1) Was there a previous EDC?

2) Why was the EDC set up? And why in the Netherlands?

3) Was there any other candidate locations or companies?

4) Was the CoG analysis utilized?

5) What were the most critical reasons behind the selection?

6) Were any environmental, cultural, logistical or political factors considered?

7) What was the importance of different factors?

8) What should the factors and their importance be if making the location decision now?

Cultural factors:

1) How are the language skills of the 3PL organization?

2) Is there strong hierarchy in the 3PL organization? (For example, does even the smallest decision need a permit from the higher level?)

3) Are the responsibility areas of the 3PL organizations personnel clear?

4) Is it easy to change the 3PL organization's practices?

5) Does the 3PL organization inform about its changes? How are the communications with the organization in general?

6) Is it easy to operate with the 3PL organization? Which are the most proficient functions?

7) What are the most challenging tasks / features when operating with the 3PL organization?

8) Anything to add?

Political factors:

1) Have there been strikes that have stopped / disturbed the operations?

2) Is there strong bureaucracy in Germany / the Netherlands? How does it turn out?

3) How are the safety issues in the DC area / 3PL organization? Have there been problems with, for example, thefts?

4) Are there any taxation relation issues?

5) Anything to add?

Logistical factors:

1) Has the location of the DC set any limitations to selecting the transportation companies? Or has it created a good base for tendering?

2) Were there many potential 3PL providers in the area?

3) Are there any logistical extra costs caused by the location?

4) Have there been any delays in transportations caused by traffic jams?

5) Anything to add?

In summary:

1) Are you satisfied with the current location? If not, what would be a better location?

2) Which factors do you consider as the most significant in the location decisions?

3) Anything to add?

APPENDIX C: VOLUMES DELIVERED FROM EDC

Country	Latitude	Longitude	Weight
