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LOG950 Logistics

Possibilities for Cost Reduction in Spare Part Logistics: a Case Study for Hustadmarmor

Didrik Gilde

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Preface

This thesis is the end of the MSc program at Molde University College.

I would like to thank my supervisors Asmund Olstad and Geir A. Svenning for helpful guidance and good discussions throughout this thesis.

Gratitude's to Hustadmarmor for providing me this thesis and a special thanks to Ralf Nedrebø for his help providing data.

Molde University College has been a milestone in my life and I will therefore thank both faculty staff and fellow students for five great and challenging years.

May 2014
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Abstract

This research presents findings in purchasing issues related to the transportation of spare parts for a local company in Møre og Romsdal, Norway, called Hustadmarmor.

The goal for this research was to explore if there was any possibilities to reduce transportation cost for spare parts in to Hustadmarmor. The research itself turned towards more advanced calculations to reveal the possibilities for cost reduction in the supply chain of spare parts.

Calculations on demand from some suppliers have been done and new key parameters such as order quantity, safety stock and reorder point have been optimized to see if there are positive changes related to new and improved parameters.

The possibilities for vendor managed inventory and consignment stock have also been slightly investigated and discussed to look at the positive effects it might have.

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1. Company Introduction

1.1 History

Hustadmarmor (HM) was founded in 1948 by Kjell Steinsvik, former editor of the local newspaper Romsdals Budstikke. The company was then named Hustad Bruk with subsidiary companies named Hustadjord and Hustad Kalk og Marmor. In 1959 Kjell's son Sturla Steinsvik went in to work for the company. 1965, Sturla took over the company in 1965, and from there they had an extended growth and become soon a leading industry in the North Europe on crushed marble granules that was used in the construction industry. 1970 was the start of producing new fillers to puss, putty and paint. In 1976 was a turn for Hustadmarmor and they began a closer cooperation with the family owned company Omya AG, (former Plüss-Staufer AG), that was the marked leader of processing lime-based fillers and pigments. Hustad Kalk og Marmor AS where splitted in to raw material producer Hustad Kalk AS, owned by the Steinsvik family and Hustadmarmor AS owned 50 percent by the Hustad Kalk and 50 percent by Omya AG. (AG 2012)

In 1979 it was decided to invest substantial on lime-based pigments as additive in the paper production industry. Chalk had never before been used for this purposes, and the new filler material Hydrocarb was quickly introduced, and from 1985, the paper industry became a substantial customer due to neutralized processes in the making of paper. Today 98,8 percent of the production to the paper industry, and almost everything is export. In 2007 Omya AG bought the last shares from the Steinsvik family and Hustadmarmor AS is today fully owned by Omya AG. (AG 2012)

1.2 Business

Their business process is to make hydrocarb slurry used in the paper industry made from marble.

The raw material is marble from mines in Eide, Fræna and Brønnøysund, and most of it is transported to the facility by boat. The marble is ground, washed and sieved at the production plant in Elnesvågen, and the finished product is liquid marble (or Hydrocarb Slurry). Liquid marble is used in the production of paper either as filler or as coating. The

primary marked is magazine paper or glossy paper and it contains up to 55% marble, while in ordinary copy paper the percentage of marble is somewhat less about 30%. The main customers are big paper manufacturers in North and Central Europe. (AG 2012)

For this process is essential to have spare parts, since the raw material is rocks and it tear a lot on equipment used in the process of making the liquid slurry. Therefore it is essential to have a good policy and control of their spare part logistics.

2. Research Problem

In this section of the thesis there have been attempted to describe the research problem given from the company, and also been outlined some research questions that should follow this thesis through.

2.1 Problem Specification

This thesis will consider issues related to transportation and transportation cost of transporting spare parts. HM have described their purchase operations and their strategy, and by now they have limited knowledge of their transportation cost for spare parts in to the facility.

This research problem will also consider exploring additional methods to reduce costs related to transportation and the supply chain cost of spare parts.

The outline of this research will consider the use of empirical data, related to order quantity, safety stock, transportation cost and carrying costs of inventory.

Spare part logistics is a touchy theme due to low demand, and the need of having them at the time you need them. This research will hopefully reveal and explore some either issue to current situation or new strategies to try to reduce costs related to their spare part logistics.

The main problem specified from this company is that they are in need of knowing what their transportation costs are and what they are paying for the transportation of spare parts. Today's purchasing strategy is to purchase articles when their ERP- system tells them to. Their values can be assumed that they are not fully updated in their ERP system and their ordering policy is therefore based on purchase when you need for some items. This research will also include statistical based analysis of a population of items to see if there are possibilities to reduce transportation and supply chain cost by changing safety stock, order quantities and reorder points.

The main objectives in this research are to approach the spare part policy from a selection of suppliers and work down too see if there are some disadvantages to the current policy. Either try to see if there are some improvements possible or if there is need for some new thinking and propose some strategies that could lead to sufficient increase in cost saving and efficiency.

2.2 Research Questions

In this research there is essential to make some questions that will be answered throughout this research for HM. These questions will regard different aspects of the research problem and will also discover some relevant issues for HM regarding purchasing articles and the procurement strategy for these articles/items.

- What is the actual transportation cost from a selection of suppliers?
  What is the transportation cost, are it too much, is it reasonable, and/or is it possible to improve it.

- What is the ordering policy?
  Is it possible to make a new effective purchasing strategy to reduce costs linked to purchasing from suppliers?

- How many articles pr. order.
  How much does HM order at each order? Is there any way to improve their order policy? Is it possible to reduce costs by changing parameters in their ERP system?

- Delivery conditions
  Delivery conditions or conditions for delivery are an important part of a procurement strategy. Should the company let the seller arrange the transport, or is it in the interest of making a standard procurement strategy from the firm and arrange with the transportation by them self? These are questions that this research will try to put a finger on. Should the articles be DDP or should it be in EXworks or other incoterms for example.

3. Theory Review

3.1 Classifying Items/Identifying Items

Spare part management has acquired great interest in literature over the recent time. Spare parts cover a wide range of relevant research areas such as inventory control, maintenance and reliability and supply chain management.

ABC- Analysis classification according to the pareto principle are the most known and perhaps the most commonly used classification scheme in logistics. It is easy to use and serves well the inventory management.(Huiskonen 2001)

Classifying articles according to the pareto principles will highlight which articles that represents the highest annual purchasing price. This is a helpful tool to use when considering which items to set focus on.

ABC analyses are as aforementioned commonly used in different inventory and procurement management decisions and was originally named and designed for three classes: A, B, and C. The method can easily be extended to more classes, simply by dividing items in to more groups. (Teunter, Babai, and Syntetos 2010, Silver, Pyke, and Peterson 1998)

The reasons why an ABC analysis is included in this research is because there is a useful tool for providing which articles that needs most focus and what their annual purchase cost are for the company. There are also important to be aware of the disadvantages the ABC analysis can involve.

> *"Despite the fact that the classical ABC-method is easy to understand and implement, it is only successful when the assortment differs mainly in terms of one single criterion. In the context of industrial spare parts, the assortment is far more heterogeneous and ABC-classification based on one parameter is therefore not considered as the most suitable method.(Ramanathan 2006)"*

(Syntetos, Keyes, and Babai 2009) have showed in their research that the ABC classification of items in demand value and demand volume can lead to cost inefficient solutions for inventory management. This has improved several researchers to extend the traditional ABC-classification to a multi-criteria ABC-analysis including other parameters like unit cost, critical factor and lead time.

In this research, it has been decided to only consider data from one supplier at the time, despite the theory on the probability for inaccurate data, there will in this paper only be provided a single criterion ABC analysis to classify the different articles. There is therefore selected to follow the pareto principle in a ABC analysis where twenty percent of the annual demand multiplied with the purchasing price stands for eighty percent of the total procurement cost pr. year.

3.2 Transportation Cost

The cost and mode of transportation has to be configured manually because there are no integration between their ERP system and their billing system.

There are desirable to determine the transportation cost for getting spare parts from suppliers and in to the production facility in Elnesvågen, Norway. Also at the same time discuss which conditions for delivery that should be suggested, and which terms that should be negotiated. There is not always the same, what suits the company best, and what should be negotiated. Supplier relations and conditions should be put up against each other to determine how strong the negotiation should be?(Brynhildsvoll 2011)

Historically, many buyers left the transportation decisions to the selling firm, and arrangements with carriers were made by the supplier. Many buyers were not concerned with how the shipments were made, as long as they arrived in good condition by a certain date. This should not be the mode in a partnership between seller and buyer; the primary goal should be to minimize the total transportation cost over a long-term perspective.(Gentry 1993)

"In a "perfect market", it will be the seller who is the best placed to contract for international carriage.(Ramberg 2011)"

- The seller can consolidate multiple shipments and reduce transport costs, serving multiple clients in the same country or region of destination.
- The seller can contract with an operator of his own choice.

Defining the procurement cost for purchasing transportation services is basically to take all the costs from the origin to the destination and calculate the costs. To figure out that cost we have to gather all the necessary data to get a real picture of the cost perspective. When talking about transportation costs from vendors, and try to define the transportation costs from vendors outside the Norwegian border. In case of that matter this research has to consider everything from local taxes, customs, and the cost of different modes of transportation. For all there is known, it can be said that some articles are purchased long before the arrival at the facility. For example ordered two or three months before and then shipped half the globe with boat, then stored for a week or two, then airfreight, and truck carrier to the destination. This is all relevant data that need to be sorted out. This research fortunately knows for a fact that there is a European supplier located in France for example, and there is only road transportation.

When trying to define the transportation cost, there are also some impediments that are useful to have a good understanding about, and that is the different transportation terms, also referred to as Incoterms. Incoterms is a standardized contract practice that was founded in Great Britain in the nineteenth century. (Ramberg 2011, Sassoon 1981)The important part is to secure that the incoterm chosen is in harmony with the other contracts (contract of carriage, of insurance, etc.), and then the "right" incoterm will prevent disputes. (Richardson 1998)

Trade terms or incoterms is a short term that encompasses delivery obligations to be performed by either the seller or the buyer.

How to choose the right incoterm is difficult and it also should be to the best for both parties since this constitutes as a long term partnership for both seller and buyer.

The different terms that will be discussed hence to this research is taken from (Ramberg 2011, Malfliet 2011, Tan and Thoen 2000).

EXW (Ex Works): Represent the minimum obligation for the seller. The seller fulfills his obligation to deliver when he places the goods so the buyer can pick it up, at the seller's premises. The goods are not loaded and not cleared for export.

FCA (Free Carrier): The seller delivering the goods by loading it on to a vehicle provided by the buyer. The shipper on the waybill will be the seller.

CPT (Carriage Paid to): Has two "critical points". Delivery and the passing of risk will occur at the place of departure when the seller hands over the goods to the transportation that has been contracted for to the agreed place of destination. In other words the carriage is for the account of the seller, but occurs at buyer's risk.

CIP (Carriage and Insurance Paid to): This term is almost the same as CPT, but add on an extra obligation for the seller to procure cargo insurance for the goods to the agreed point of destination, and also complying at least with the minimum covered by clauses © of the *Institute Cargo Clauses.*

DAP (Delivered at Place): DAP means that the seller delivers when the goods are placed at the disposal of the buyer on the arriving means of transport ready for unloading at the contracted place of destination. Import and other formalities have to be conducted by the buyer.

DDP (Delivered Duty Paid): DDP is essentially the same as DAP, but whit added obligations for the seller such as all official authorizations, carry out all customs formalities and pay all duties, taxes and other charges that inquires to get goods from on origin to a destination in another country, and also includes VAT (Value added Tax). This term is the opposite of EXW and represents the maximum obligation for the seller.

There are only considered terms for road transportation since this is the way the goods are shipped today, but there are also terms that provides obligations for both sea and rail transportation as well.

3.3 Inventory Control/ Inventory Management

All organizations hold stocks of some kind, and there is an assumption that stock keeping is a form of wasting resources. (Waters 2009)

That can be true, but inventory or stock keeping is necessary for most companies. In this case there is essential to see if there is possible to minimize the inventory stock and still maintaining a high performance service level.

One method to use is the EOQ formula, also known as the Wilsons formula. It has been around for a long time and is it easy to understand, but there are some weaknesses to it:

- Simplified view of inventory systems
- Assumes that demand are fixed and constant, and all costs are fixed and known
- Assumes constant lead time

Therefor the EOQ Formula is a good tool for basic analysis as a starting point and then uses it for further research. There are also more advanced models that work on the basis of the EOQ Formula. (Waters 2009)

The area of inventory management has a lot of attention in operation research over time, and inventory management approaches rely on recent study's when demand is fast moving. Demand in the lead time is also assumed to be normally distributed.(Strijbosch and Moors 2005, Porras and Dekker 2008)

There is there for so much theory and so many different models and software modelling for similar problems.

(Botter and Fortuin 2000) have said that such assumptions on spare parts are invalid since demand is usually intermittent.

Operators of production facilities depend on high reliability of their machines, as one of the key factors for an efficient production.(Lanza, Niggeschmidt, and Werner 2009)

To be able to rely so much on the machinery, warranty and guarantee is a contractual obligation offered from the manufacturer, vendor/supplier, in connection with sale of the product, machine. Warranty and insurances from the manufacturer is intended to assure the buyer that this product is reliable and the manufacturer will take the cost for the broken unit or parts in the unit, for a limit of time. Often set to the life cycle of the product, and off course that service and maintenance is provided accordingly to the warranty agreements.(Monga and Zuo 1998)

For most of the inventory on spare parts at HM, can be sees as service parts, and most of the parts are regular replacing of service parts. In the "An overview of recent literature on spare parts inventories" article there is mentioned that the reorder point for spare parts, such as service parts that you change regularly should be equal to demand in the lead time.

$$F_D(\text{reorder point}) = \frac{C_H Q}{C_S D} = \frac{\text{holding cost per unit year} \times \text{quantify ordered per lot}}{\text{stockout cost per unit} \times \text{quantity used per year}}$$

$$Q = \sqrt{\frac{2D \times (S + E_S)}{C_H}},$$

Figure 1 – Formula for reorder point (Kennedy, Wayne Patterson, and Fredendall 2002)

Where E_S=expected stockout cost, i.e. stockout cost as experienced over an extended period of time and S=cost of placing an order.
It is also discussed that this model doesn't take in consideration fluctuating demand or the difficulty of getting good value for the ordering cost.(Kennedy, Wayne Patterson, and Fredendall 2002)

This formula will be perfect in a perfect world where everything are known, but since everything is unknown, there are needed to use a little more advanced statically based calculations.

3.3.1 Statistical Analysis

In inventory management there is essential to know a little statistics to use it for calculating "closer to" optimal parameters for deciding safety stock and reorder points based on the empirical data that has been gathered for this research. There have been concluded with the use of software programming and some reasonable arguments what kind of distribution that fits best for this analysis.

3.3.1.1 Poisson Distribution

The Poisson distribution is a discrete probability distribution used to describe events that occur independently. (Haight 1967)

The Poisson distribution is calculated with this formula:
There are two rules, or cost structures that are being used related to slow moving A articles, and calculating reorder points.

Notation:

- D = Demand
- r = Internal rate of interest
- A = order cost
- V = Value/Purchase cost for one item
- Q = Order numbers (how many articles pr order)
- S = Reorder point
- L = Lead time
- DL = Demand in lead time
- B2 = Penalty stockout cost in percent of purchase value
- B1 = Fixed penalty cost

First rule B2 cost structure:

If demand is smaller or equal to $\frac{Vr}{A}$ one should order one item at a time, Q=1.
Then we calculate indifference between reorder points (S) and (S+1).

Formula: $\frac{P_{po}(S+1|\hat{}X_L)}{P_{po\leq}(S+1|\hat{}x_L)} = \frac{r}{DB_2}$

The fraction of the probability divided by the cumulative probability by the same outcome.
Then finding the range where the value $\frac{r}{DB_2}$ fits reorder point S.

Second rule B1 cost structure:

If demand is larger or equal to$\frac{Vr}{A}$, then you get Q ≥1.

Formula: $\frac{P_{po}(S+1|\hat{}X_L)}{P_{po\leq}(S|\hat{}x_L)} = \frac{QVr}{DB_1}$

Use the Wilson formula $\sqrt{\frac{2DA}{Vr}}$ to decide Q in B1 cost structure for use in the formula.

The formula changes under the B1 cost structure where you divide S+1 with the cumulative S. Then finding the range where the value $\frac{QVr}{DB_1}$ fits reorder point S.

Then the reorder points will also give a percentage estimate for the service level at S. The source for these formulas and calculations are from the book Inventory Management and Production Planning and Scheduling. (Silver, Pyke, and Peterson 1998)

3.3.1.2 Normal Distribution

The normal distribution is a very commonly occurring continuous probability distribution used to describe events between any real numbers, and it is widely used in inventory management for high demand articles.(Casella and Berger 2001)

Notation:

- σ = Standard deviation
- σ_L= Standard deviation in lead time
- $p_{u\geq}(k) = 1 - P_1$ = K factor
- $\hat{x}L$= Demand in lead time
- SS = Safety Stock
- % = Service level

Normal distribution probability is used for deciding safety stock and reorder point for inventory management decisions. Calculating safety stock with a proposed service level of a given percent % with the formula$k\sigma L$, and reorder point$S = \hat{x}l + SS$.

The source for these formulas and calculations are from the book Inventory Management and Production Planning and Scheduling. (Silver, Pyke, and Peterson 1998)

3.3.2 VMI (Vendor Managed Inventory)

VMI occurs when organizations is trying to reduce effort to put in an inventory control, it is the same as outsource certain operations. The organization will then let the seller of a product be in control of certain items in their stock. It will be everything from ordering and the right amount of articles at the right time. (Zanoni, Jaber, and Zavanella 2012)

VMI has gotten a more and more attention over the past years, where different authors have proved that VMI are able to reduce costs in supply chain between single buyer and single customer.

There are also different forms of VMI, and different methods of organizing VMI.

The usual products or articles that are the ideal candidates for starting an implementation of VMI are usually low cost articles with a certain demand and the stock level are frequently assessed by the vendor, like screws, bolts, and some raw materials. VMI are able to contribute on reducing supply chain total cost by using information technology and share information on sales, stock levels and inventory policy. (Yao, Evers, and Dresner 2007, Zanoni, Jaber, and Zavanella 2012)

The biggest effects from VMI can be that with the proper use of information sharing supplier are able to reduce cost on production because they can produce according to their customers' demand and then produce and ship goods. The effects can be summarized as reduced costs on inventory for both the supplier and the buyer, improved customer service such as reduced order costs and higher fill rates. Wal-Mart as a retailer and Proctor and Gamble as a key supplier to the retail industry have been very successful implanted the VMI policy. (Cetinkaya and Chung-Yee 2000)

In the article Supply chain integration in vendor managed inventory, the authors have assumed that there will be a decrease in total supply chain costs by implementing a VMI strategy.

They have showed two formulas, one total cost without VMI (TC^*_{noVMI}), and one total cost with VMI (TC^*_{VMI}).

Formula notation:

- R = Demand
- C = Supplier setup cost
- c = Buyer setup cost
- c' = New buyer setup/ordering cost after VMI implementing
- H = Supplier holding cost
- h = Buyer holding cost.

VMI (TC^*_{noVMI}) $\sqrt{2R} * (\sqrt{CH} + \sqrt{ch})$

VMI (TC^*_{VMI}) $\sqrt{2R} * (\sqrt{CH} + \sqrt{c'(H+h)})$

These two formulas are based on the EOQ formula where it represent the optimal order quantity and the minimization of the holding costs on both buyer and supplier to reduce total supply chain cost.(Yao, Evers, and Dresner 2007)
This model by (Yao, Evers, and Dresner 2007) are working under the assumption that all data are deterministic and all costs are known. In real life this model can be difficult to use since the byer and the supplier probably will not give up their cost advantage in letting the other parties known their cost and then reduce their competitive advantage.

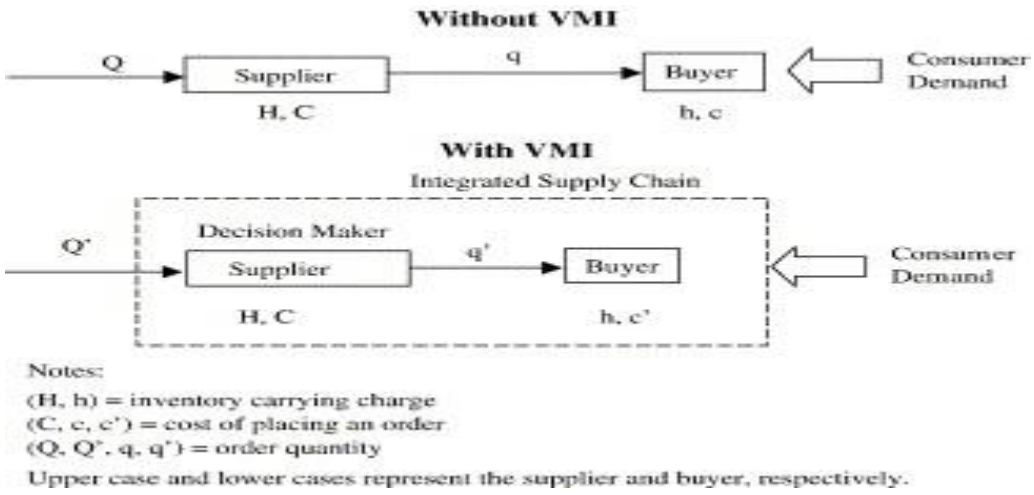


Figure 2 Yao-model. (Yao, Evers, and Dresner 2007)

This is how (Yao, Evers, and Dresner 2007) says the VMI integrated supply chain can look like.

The model has also got some criticism and several conclusions from their model seem to be arguable. In the article by (van der Vlist, Kuik, and Verheijen 2007) they mention two points that are criticized.

(1) The model ignores shipping costs.

(2) The model manages the income and outcome flow at the supplier in a worst-case scenario, and also overstating the inventory kept at the supplier.

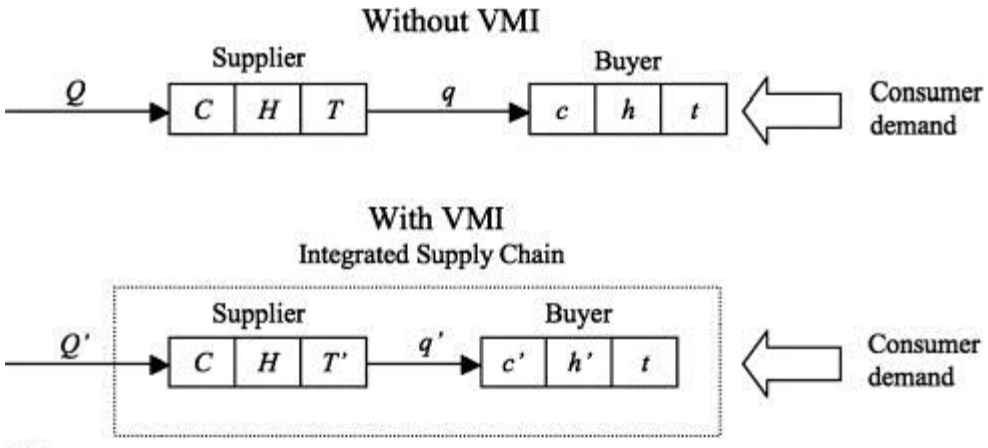
The authors in this article will show that:

(1) Shipment sizes will increase

(2) Inventory at the supplier goes down

(3) Inventory at the buyer goes up

When taking the extending version of the YAO model first considered there is reasonable to extend it with the use of another parameter noted as T for the supplier and t for the buyer, to describe the transportation cost.



Notes:

H, h, h' = inventory carrying charge
C, c, c' = cost of placing an order
T, T', t = cost of delivering an order
Q, Q', q, q' = order quantity
Upper case and lower cases represent the supplier and buyer, respectively.

Figure 3 – Extended Yao modell with the extra parameter T. (van der Vlist, Kuik, and Verheijen 2007)

This is how (van der Vlist, Kuik, and Verheijen 2007) says the VMI integrated supply chain can look like with their extension of the model.

There are also drawn a conclusion that there is a lot of things that are considered already done, for example set up cost for the whole VMI system, supplier selection, etc. regarding the first presented model.

The model also handles deterministic data, and considering total cost perspective, when there in real life no existing data that are deterministic, but there is reasonable to argue that there is an possibility to approximate more accurate data when there is only one of the parties that handle the flow of goods. If the conclusions from (van der Vlist, Kuik, and Verheijen 2007) is correct, it will basically means that there are a reasonable assumptions that the inventory at the buyer will increase and the shipments will be fewer. This will or can results in larger inventory costs, especially when dealing with high value low demand articles like spare parts. Therefore there has also been considered to look at different stocking policies, and since the lead time is an important factor, there is another policy that is interesting to discuss.

3.3.3 Consignment Inventory

Another use of the VMI is to include consignment inventory policy. There has over the past decades been an increasing amount of researcher that has started to concern the importance related to profitable vertical relationships between seller and buyer. From before and little back in time company's where working in short terms perspective if we compared it with the normality of today. The most important factor was price and how there was possible to reduce the price on articles to get the cost down. Today there are more focus towards strong integration, collaboration and information sharing between both parties to make profit, and be able to reduce cost so everybody gain profit, and also leaning towards strong relationship with fewer and more strategic suppliers. (Valentini and Zavanella 2003)

CS will in this case assume it will work under the assumption that the vendor will increase the service level on the warehouse for seller according to an optimal service level and to reduce the probability of a "stock-out" situation.

Recent studies show that there can be a lot of advantages of using VMI with consignment stock policy, so there are made a list of advantages and disadvantages considering the

possible implementation of VMI policy with CS, trying to highlight some important factors to be aware of.

These papers (Sui, Gosavi, and Lin 2010), (Williams 2000), & (Yao, Evers, and Dresner 2007) sums up the advantages and potential disadvantages related to implementation and/or negotiation of VMI and consignment stock policies.

Supplier advantages:

- Coordination of their own supply processes: Since the supplier will be integrated with their customer according to warehouse and usage rates, it is reasonable to believe that they will be able to reduce cost to optimize production since it will be less unexpected orders.
- Reduced transporters can be a factor, since it must be assumed that the supplier also will arrange the transportation, they can also arrange transportation to ship goods to multiple customers at the same time to reduce cost of transportation.
- Binding the customer to the supplier. When a policy like this is in place, the cost of changing supplier will be very costly and inefficient for both parties involved. Increased sales can occur due to better service level and no need for substitute replacement parts from other suppliers, as well as the supplier may also deliver articles or parts that usually have been bought from other suppliers.

Supplier disadvantages:

- An increase in their own carrying cost for parts, and finished goods.
- Deliver goods without getting any sort of revenue of sales.
-

Customer advantages:

- Increase in service level: When the supplier has access to the current stock at the customers warehouse, the suppler can predict when there is necessary to send goods, and the supplier will also not risk a probability for stock out, so then the service level is likely to increase.
- Reduction and/or increase: Since the supplier has access to the customers' inventory level, and the customer doesn't pay for the inventory, it is likely that you will have two expensive spare parts on stock instead of one, since there is no

capital tied up in inventory. The inventory levels for certain articles can also decrease since the supplier knows when there are necessary for new delivery.

- Reduction of ordering and planning costs: Since the supplier will stand for the customers inventory, it is likely to believe that there will be a reduction in cost related to ordering, and as a mentioned the supplier could gain from it by not depending on orders to arrive, but know approximately when they “will come”.

Customer disadvantages:

- Unnecessary increase in stock that could lead to higher inventory costs will not occur under the CS policy, but should be watched such as inventory not building up to much so it will affect the practical use of the warehouse.
- Stock out: Could lead to stock out situations if the supplier runs with low margins on service level to reduce his own transportation costs to make more money.

These are the most common things that need to be aware of and consider it so not one of the parties in the agreement ends up losing.

4. Methodology

4.1 Definition of Research Design

There are a lot of definitions linked to research design, and there is difficult to choose one or another.

> *"Research design is a plan that guides the process of collecting, analyzing, and interpreting observations. It is a logical model of proof that allows the researcher to draw inferences concerning casual relations among the variables under investigation.(Frankfort-Nachmias, Nachmias, and Thompson 1992, p. 77-78)"*

> *"Research design is a blueprint for your research, dealing with at least four problems: what questions to study, what data are relevant, what data to collect, and how to analyze the results. (Philliber, Bast, and Sloss 1980)"*

4.2 Research Design

In this research problem it has been chosen to follow the case study approach. According to (Ellram 1996) there is a misconception that the case study method is only a qualitative research tool.
The case study method is widely used as a research design in business research, and a case can be:

- Single organization.
- Single location.
- Person, as a study of men as leaders as each man is a case.
- Single event, such as an airplane crash, etc.

(Bryman and Bell 2011)

4.2.1 Components of Research Design Case Study

In case study there are five components that are important for the research design structure:

1. Case study questions;
2. Propositions, if any;
3. Unit of analysis;
4. Linking data to propositions;
5. Criteria for interpreting finings;

Case study questions are the first component and describe the design on the questions. In case study, the questions should be in term of who, what, where, how, and why.(Yin 2009)

Propositions, the second component, propositions, direct attention to the scope of the study! If there are reasons to make some propositions, the research is heading in the right direction. For example this research, have on overlying proposition of the possibilities for cost reduction due to given attention to certain factors in the supply chain of spare parts logistics. (Ragin and Becker 1992, Yin 2009)

Unit of analysis, the third component in a case study design, are related to the problem of defining what the case is. There are important to have the two components above to help identify what relevant information to be collected and analyzed. The selection of the appropriate unit of analysis will start when the primary research questions have been specified.(Yin 2009)

Linking data to propositions, and criteria for interpreting findings, the fourth and fifth component in the case study design! Theory requires that the actual analysis will be combined or calculated with the case study data as a direct reflection of the initial study propositions. Some criteria's may also be the use of statistical factors and consider a p value of less than 0.5. A major alternative strategy would be to address rival explanations of findings with lots of discussion and arguable theory to "back it up". (Ragin and Becker 1992, Bryman and Bell 2011, Yin 2009)

4.2.2 Theory in Research Design

By covering the five components above in the research design, it will force the researcher to construct a sufficient amount of topic related theory to support the researcher in the work.

Theory development for case studies in the design phase is essential, whether the case study's purpose is to develop or test theory. (Markus 1983)

There are also different forms of theory to consider.

- Individual theories: Example; theory of individual development, cognitive behavior, individual perception
- Group theories: Example; informal groups, work teams, interpersonal networks
- Organizational theories: Example; organizational structure and functions, organizational performance
- Social theories: Example; urban development, international development

(Yin 2009)

Theory development in research design requires that a theoretical framework is conducted. Yin also says that a good case study investigator should make the effort to develop this theoretical framework, also if the study is to be, explanatory, descriptive, or exploratory.(Yin 2009)

Building and design theory takes a lot of time, but in some fields there are huge amount of existing theory and theoretical framework that allows new researchers to build a strong theoretical foundation for their research.

4.2.3 Quality Research Design Criteria

Research design is supposed to represent a logical set of statements, there is possible to judge the quality of any given design according to certain logical tests. (Yin 2009, Kidder, Judd, and Smith 1986)

Four test have been described here and are summarized in a text book by (Kidder, Judd, and Smith 1986, p. 26-29)

- Construct validity
- Internal validity
- External validity
- Reliability

The first test is construct validity, and is also known to be challenging in case study research. Some people that are often critical to case studies points that case study investigators fails to develop a sufficient set of measures and that subjective judgments are used in data collection.(Kidder, Judd, and Smith 1986, Yin 2009)

The tactics in construct validity testing says by (Yin 2009):

- Use multiple sources of evidence
- Establish chain of evidence
- Have key informants review draft

In other words this basically means that there are of higher importance to be sure that the given data are real and that there is possible to prove that the given data are correct.

The second test is internal validity and has been given great attention in experiments. Internal validity is mainly a concern for explanatory case studies where the desire is to cover or prove the relation between events. For example why event x led to event y. (Yin 2009)

The tactics in internal validity testing says by (Yin 2009):

- Do pattern matching
- Do explanation building
- Address rival explanation
- Use logic models

This means that the importance of analyzing tools for internal validity is highly recommended to get reliable results.

The third test is external validity and deals with the problem of knowing whether the research findings are generalizable. The generalization is not automatic and a theory should be tested by replicating findings over again where the theory has specified that the same results should occur. This is also known as the replication logic that also allows scientists to accumulate knowledge across experiments. (Yin 2009)

The tactics in external validity testing says by (Yin 2009):

- Use theory in single case studies
- Use replication logic in multiple case studies

This means that there are important to test external data results several times before generalize it, so there is with high security that the generalized data will be accurate or not a product of high variations, or else the results could be divergent.

The fourth test is reliability and the assurances to other studies that the procedure is reliable and the same results should occur when an investigator follows up the same procedure.(Yin 2009)

The tactics in reliability testing says by (Yin 2009):

- Use case study protocol

This basically means that there is important to follow the case study recipe and validate methods for collecting and sorting data to get reliable results.

4.3 Data Collection

When it comes to data collection there are some points or "evidence" (Yin 2009) talks about. Yin speaks of six types of evidence, but in this research there has been focused on the use of empirical data to investigate or explore a current situation.

The two types of evidence in this case study research are documentation and archival records. Those two are commonly quantitative and a basically the same, especially for this research. Both documentation and archival records in this research are in first place secondary empirical data gathered from the research object to analyze in this research, the second data collection are also secondary data to support the findings, and the data are gathered from a third party operator related to the research object. (Yin 2009, Edmonds and Kennedy 2013)

Data have been gathered from the companies ERP- system and converted in to excel spreadsheet for analysis.

5. Calculations

In this research there have been focusing on exploring ways of saving cost related to the issue of getting spare parts from the supplier to the buyer. There have therefore been done some small calculations to try to illustrate if there are potential for improvements in one or more links in the supply chain.

5.1 Transportation Cost

Transportation costs are in this research related to the cost of transportation from supplier to buyer. HM has an agreement with a contracted third party logistics provider for transportation, and the suppliers have been requested to use the aforementioned firm for transportation from them, to HM's facilities in Elnesvågen.

Contact where made with the authorization from the company to extract all the bills and payments for transportation between the involved parties. From there it was easy, because SAP (their ERP system) gave lists of all the procured goods and the cost for the goods for a whole year, so it was easy to calculate the percentage of the total cost for procured goods and how many percent they were actually using on transportation.

The actual transportation cost for one article however, is very hard to obtain because of the company's billing system and the billings from the transportation company. There is lack of details of costs, and the prices are only measured in number of coli, weight and space.

Some other issue are also the integration between their billing system and their ERP system, there are only one way to link purchase orders to billing receipts, and that is manually.

The total number of PO's where aggregated and divided by the total sum of transportation cost to get a good estimate of the actual transportation cost since there were not so much variation in the different invoices from the transportation company. All external cost related was also considered, like customs and local taxes.

5.2 Inventory Calculations

This research has provided some inventory management based calculations to get a picture of their cost in their supply chain from the supplier to the buyer. There have been used several methods based on inventory management theory to compare reorder point, service level, and stock levels to compare with current strategy. This is used to see if there are possibilities to optimize or rearrange procurement decisions to make more efficient purchases and reduce number of transportations and costs as well. The basis for the calculations is made by using statistical methods based on empirical data for three years.

5.2.1 ABC- Analysis

There has been a decided in this research to look at HM's inventory policy for items from the selected suppliers. There has therefore been made an analysis on the articles from a population of suppliers. The starting point where to make an ABC- analysis on the selection of suppliers, and the main reason why it was done was because there was needed to get a population of articles that stands for a significant percent of the total procurement cost from the suppliers.

As aforementioned there have been some criticism to the use of single criterion ABC-analysis, but this research used it and followed the pareto principle since there was used on one single supplier at the time, and no coordination between the suppliers due to geographical distance between them.

The ABC- analysis gave this research a population of articles from several suppliers that there was interesting to look at according to safety stock, reorder point and service level for comparison with the current policy to see if there are possibilities for improvements. In the analysis, the pareto principle have been used to select the articles that stands for 80 percent of the total procurement cost from those given suppliers.

5.2.2 Inventory Management

There are some different methods to use in inventory management decisions, and there have been used some of them in this research. The considered parameters that were looked up were, reorder point, safety stock and the Q (order quantity) to reduce number of total transportations and the issue related to tie up unnecessary inventory and binding up to much capital in unused inventory.

When the ABC-Analysis was done, all the article that was given as A articles hence to the pareto principle was arranged in excel spreadsheet after weakly demand. Then they were inserted in to a software simulation program called ARENA and used the input analyzer to see which distribution the orders where made or in other words the demand pattern for the given articles. Then the EOQ formula was implemented with the given data to get the "optimal" order policy given the data that was gathered from HM.

Lead time from supplier to buyer is also a very important factor to consider, because if the lead time is miscalculated there is a possibility that the stock is running low and the risk of shortages is far too real than it should be. Fortunately SAP have data from when the goods were ordered when it should arrive and actual arriving date, so the lead time was calculated very basically by taking the difference from order date and actual arriving date and average over a three year period individually for the three suppliers that are considered in this research.

Then the theoretical framework were used on Normal and Poisson distribution to calculate standard deviation and the standard deviation in lead time to figure out which reorder points and safety stock the company should use, and the different service level. When the Poisson distribution is used the service level is given due to the different values of S (reorder point). In the Normal distribution the service level have to be manually decided as a K factor to implement in the formula to get reorder points and safety stock hence to the decided service level. In this research the decided service level was set to 95 percent since there is no reason to risk any stock out situation. The formula known in inventory management as the TRC (Total Relevant Cost) formula is used to see if there are any positive changes in the cost structure after key parameters are modified.

The TRC formula looks like this:

Notation:

- D = Demand
- A = order cost
- Q = order Quantity
- i = internal rate of interest
- v = Unit cost
- SS = Safety stock

TRC=$\frac{DA}{Q} + \frac{Qiv}{2} + SSiv + Dv$

(Silver, Pyke, and Peterson 1998)

5.2.3 VMI & Consignment Stock Policy

This research was basically started to try to reduce the cost of transportation between supplier and buyer for spare parts, and the research have gone more over to try to reduce and explore the supply chain costs for the spare parts chain for this company. Then there are also reasonable to look at the possibilities for the use of VMI and the implementation of consignment inventory stock policy. Making calculations on this theme is almost impossible since the suppliers cost structure are unknown and there is reasonable to assume that the supplier will not give up key data related to his own supply chain cost and risk to lose his competitive advantage in contract arrangements etc. In this research there is therefore not calculated any form of VMI or consignment inventory, but there are argued for that there are possibilities cost reduction in total supply chain cost from the point of order at HM, until the goods arrive at HM's facilities in Elnesvågen.

6. Research findings & Comparison with Current Strategy

The current situation at the company will be compared with new calculations to see if there are any significant changes in the total cost parameters that will affect the total cost in a positive direction.

The findings in this research and discussion will be:

- Transportation cost, and the cost in percentage of total procurement cost
- Inventory management decisions and the possibility for decreasing the number of total orders

6.1 Transportation Cost and Terms of Delivery

The transportation cost for the company in year 2013 from the given suppliers was calculated with the given data to be approximately 4, 67% (Flowserve), 30, 52% (Lemvigh-Müller) and 4, 29% (Andritz BV), of the total procurement cost. HM today arranges its transportation between them self and the supplier with the use of a third party logistics provider.

Table 1 – Transportation cost

Purchase cost	2013
Flowserve pumps	kr 1 300 494,00
Lemvigh-Müller A/S	kr 110 191,12
Andritz B.V.	kr 743 766,76

Percentage transportation cost of Total purchase cost	2013
Flowserve pumps	4,67 %
Lemvigh-Müller A/S	30,52 %
Andritz B.V.	4,29 %

The purchase contract states EXW (Ex Works) on the terms of delivery, but in practice they have more like an FCA (Free Carrier) agreement since HM has decided which logistics provider the supplier should use.

Two of the questions in this research were to look at the transportation costs and the terms of delivery. Due to the fact that some of the articles are made to order at the supplier the result is that purchase orders are picked up over time and shipped from the supplier when the production of the ordered articles with production time are finished. This result in fewer deliveries from the supplier than there are orders which is pushing the transportation cost down.

There are reasons to believe that the cost of transportation could be even lower with the use of another incoterm, such as Delivered Duty Paid (DDP) for example. Given that the cost for DDP will be less than the percentage of the total transportation cost today, and also provided that this does not interfere with HM's other transportation arrangements with the third party logistics provider in regards to transportation from other suppliers etc.

If the transportation agreements changes to for example a DDP delivery condition with a given percentage cost, there are reason to assume that the cost reduction could be even higher. Due to the fact that the suppliers cost structure are depending on their delivery frequency to this company and there are in their best interest to reduce number of deliveries to HM and instead send optimized orders.

6.2 Inventory Management

In this research as an approach to try to reduce transportation cost, an improved analysis on stock levels, reorder points and safety stock have been provided. HM have also provided this research with their given data for reorder point, safety stock and how much they are ordering each time. This data have been compared with the data gathered from this research and the findings were positive. There can clearly been seen that by just changing the key parameters for reorder point, safety stock and order quantity, they will have potential savings given the TRC formula.

These are positive changes and it shows that there are also high potential of savings with the same transportation agreements as before.

This is the compared number with the articles that stand for 80 percent of the total purchase cost from Lemvigh-Müller A/S, Flowserve pumps, and Andritz B.V.

Table 2 – Lemvigh-Müller A/S

Current situation

Mat #	TRC Total Relevant Cost
1092938	4782,97
1077920	1872,99
1078256	1123,04
1078270	1168,78
1078257	956,8617
1092909	838,74
1078135	1018,152
1077595	1097,845
1078255	696,0267
1077651	1715,965
1078647	800,6725
1082676	802,626

Proposed situation

Mat #	TRC Total Relevant Cost
1092938	2751,467
1077920	1617,982
1078256	968,49
1078270	1883,126
1078257	1138,637
1092909	869,7712
1078135	773,5423
1077595	808,5529
1078255	729,9005
1077651	882,3329
1078647	526,9312
1082676	1714,204

1078203	622,31		1078203	635,8238	
1092929	526,3075		1092929	520,9651	
Sum	**DKK**	**18023,3**	**Sum**	**DKK**	**15821,73**

Potential Savings	**2201,6**

Lemvigh-Müller A/S, will have a potential cost reduction on A articles of 2201,6 DDK, the savings could be potential higher if the rest of the articles were included.

Table 3 - Andritz B.V

Current situation

Material number	TRC
1074179	€ 5 898,56
1078446	€ 3 320,41
1090560	€ 1 764,15
Sum	**€ 10 983,12**

Proposed situation

Material number	TRC
1074179	€ 2 627,34
1078446	€ 1 704,49
1090560	€ 1 251,32
Sum	**€ 5 583,15**

Savings	**€ 5 399,97**

Andritz B.V will in this scenario have a potential saving of almost 5400 euro's on these three articles by reducing stock level and reorder point.

Table 4 - Flowserve pumps

Current situation

Material number	Trc
1073967	€ 2 586,09
1092247	€ 4 509,56
1074022	€ 1 484,90
1073856	€ 1 351,75
1073796	€ 1 446,71
1074477	€ 1 905,23
1074644	€ 930,27
1073886	€ 1 782,16
1069090	€ 1 070,56
1074171	€ 656,08
1092405	€ 1 410,09

Proposed situation

Material number	Trc
1073967	€ 2 586,09
1092247	€ 4 509,56
1074022	€ 1 484,90
1073856	€ 1 059,64
1073796	€ 1 014,48
1074477	€ 1 512,25
1074644	€ 1 045,92
1073886	€ 1 016,08
1069090	€ 758,15
1074171	€ 602,64
1092405	€ 1 410,09

1076934	€	673,49		1076934	€ 673,49
1089176	€	6 443,05		1089176	€ 6 443,05
1075373	€	1 193,35		1075373	€ 1 193,35
1073729	€	527,81		1073729	€ 509,30
1076933	€	759,53		1076933	€ 759,53
Sum		**28730,63**		**Sum**	**26578,52**
Savings			**€ 2 152,10**		

Flowserve pumps will have a potential saving of 2141 euro on these articles. These are the articles with the given demand that stands for 80 percent of the total purchase cost from this supplier.

There are reason to believe that optimized reorder points and safety stock will reduce total number of orders pr. year and likely also reduce the transportation cost and give a better cost structure and coordination of the different articles. Most of the savings here are still the reduction in tying up capital, and also shows have important there are to work with certain key parameters like order quantity and reorder point to reduce high levels of inventory and also gain the possibility for better coordination between articles and what you order when you order. This research and this basic calculations gives an indication of what the current situation are and what they should look at further for trying to reduce cost related to their spare parts logistics.

What also can be seen is that the reorder points calculated in this research versus the reorder points calculated from the company is the same most places. Because where HM have reorder point equals one, with max level also equals one, it's basically means that they order when they are out of stock. But the important factor is to look where HM have two or three articles on stock, where the findings in this research calculates with less, it is the reduction in inventory that gives the most saving from the suppliers. There are also important to look at the Q values (see appendix), and how they differ from the current policy. For some articles there are actually potential saving by order more than one but still keep the average stock at a lower level. This will result in lower capital binding and fewer orders that could lead to fewer transportations and also reduce the transportation cost.

If we look at the average amount of orders calculated in this research compared with the average amount of orders with the current policy there can clearly bee seen that the average number will decrease with new ordering policy based on statistical methods.

Table 5 - Lemvigh-Müller A/S # orders pr. year

Current situation		Proposed situation	
Mat #	# orders pr year	Mat #	# orders pr year
1092938	1,57	1092938	3,88
1077920	1,20	1077920	1,23
1078256	1,67	1078256	1,07
1078270	0,63	1078270	1,01
1078257	1,14	1078257	1,00
1092909	1,85	1092909	0,94
1078135	2,17	1078135	0,85
1077595	2,65	1077595	0,82
1078255	1,35	1078255	0,81
1077651	5,25	1077651	0,79
1078647	2,00	1078647	0,76
1082676	1,63	1082676	0,75
1078203	0,95	1078203	0,73
1092929	0,60	1092929	0,70
Average	1,76	Average	1,10

Table 6 - Andritz B.V # orders pr. year

Current situation		Proposed situation	
Material number	# orders pr year	Material number	# orders pr year
1074179	20	1074179	5
1078446	12	1078446	3
1090560	8	1090560	1,333333
Average	13,33	Average	3,11

Table 7 – Flowserve pumps # orders pr. year

Current situation

Material number	# of orders pr year
1073967	4
1092247	1
1074022	3
1073856	4
1073796	3
1074477	2
1074644	3
1073886	2
1069090	3
1074171	4
1092405	1
1076934	2
1089176	1
1075373	1
1073729	3
1076933	1
Average	**2,38**

Proposed situation

Material number	# of orders pr year
1073967	4
1092247	1
1074022	3
1073856	2
1073796	2
1074477	2
1074644	3
1073886	2
1069090	2
1074171	2
1092405	1
1076934	2
1089176	1
1075373	1
1073729	1
1076933	2
Average	**1,94**

Here it can be seen that by changing key parameters in their ordering policy there are likely that the total supply chain costs will decrease and the number of orders also will. By reducing number of orders, number of transportations can also be reduced, and that could result in a more cost efficient policy for the company than they actually have today.

There are also important to know that these models combine different parameters that are quite hard to obtain accurate, like for example penalty shortage cost and the order/transportation cost.

There are also important to know that these models combine different parameters where some of them are quite hard to obtain accurate, like penalty shortage cost and the order/transportation cost. The transportation cost has been figured out like mentioned earlier, and the penalty stock out cost had to be assumed as a percentage cost of the total value of the article. But one thing that is given is that if the penalty shortage costs are to be higher, the inventory levels will increase and will also give a higher reorder point.

6.3 VMI & Consignment Stock Policy

According to this research problem, it was decided by the author to try to see and mention a possible new strategy for the company to look at if they should find it interesting.

One thing that was interesting too look at according to the given operational information was the possibility for VMI and Consignment stock policy. Calculations to prove such statements are basically impossible due to the fact that there is no knowledge of the cost structure at the supplier.

There is only knowledge of the cost structure at the company, so there have been done some basic calculations hence to the discussed theory to see if it was worth mentioning. Yet there where positive signs, but no calculations are presented here due to the lack of information and most of it where just assumptions. But still there is an idea worth mentioning because of the effects it could give in a long term run.

There are by now known that the lowest percentage cost for transportation is equal to 4,29 percent and HM are calculating with an internal rate of interest at 10 percent. As aforementioned consignment stock means that you don't pay for your inventory before you use it and that could be beneficial with a lot of important spare parts with high value that are in the warehouse for months before it is taken in use.

What can be said is that by trying to reduce transportation cost, HM should also look at the possibilities for implementing new and different strategies. In this research there have only been considered three suppliers, but there are known that there spare part inventory are excess to approximately 90 million nok, and if this is a solution that several suppliers could be interested in to reduce their own cost, there could be potential of large savings.

VMI solutions have been showed in theory that with the right use there is possible to reduce total supply chain cost, and from there it should be possible for both parties to benefit from such solution.

Suppliers could also benefit from this by not waiting on orders to come, produce and send when it fits them best and for HM to not pay for anything before it is taken from the warehouse and in use.

Still there are lot of things to consider, but the world have gone forward and the possibilities for sharing information have never been so good, so working with your suppliers for a long term relationship could be a good and sustainable idea for reducing total supply chain cost for products in the long run.

7. Conclusion & Further Research

7.1 Conclusion

In this research there have been some questions that the author has tried to answer throughout this investigation. This research can be sees as an exploratory case study analysis where the primary goal where to find several methods to achieve results that could be cost efficient for the company. The conclusion in this research relies on the observations and the discussion made on the basis of the theory foundation in this research case.

When it comes to transportation costs and transportation agreements, as aforementioned HM have a transportation agreement with a third party logistics provider, and the agreement between HM and the supplier's states that they shall use that company for transportation of their goods. With those agreements staying it can look like there will be difficult for HM to reduce their transportation cost directly with the use of terms like DDP with a fixed price for the transportation. Since there is more likely that the supplier then will choose other transportation company's than the one HM has an agreement with today. But the top conclusion is that they should investigate and negotiate for a fair DDP agreement where the cost are based on percentage of total purchase cost, and are less than it is today. If it is possible!

Inventory policy and purchases, the conclusion here is that there are worth investing more attention in to the procurement policy, both order quantities and reorder points. This is for trying to reduce total supply chain costs related to purchase costs and inventory carrying costs. There are proven in this research that there are possible savings for putting more attention to articles from suppliers and in to HM. Optimizing these values are considered, for a short term period a good solution for trying to reduce total supply chain costs for spare parts from supplier to buyer. For example, if the statistical based forecast method for deciding inventory management decisions says that article X have a demand in lead time at 1.2 units, there is no need to have a reorder point at 3. If this concerns high cost low demand articles, the reorder point should be at 2, to reduce the tying up of capital and still maintain a high probability for not running short. These are important things to consider when dealing with inventory management decisions, since there are probably not so much

to save on one article, but if there are considered thousands articles with different value and demand etc. the savings could be high and significant for the company.

VMI & consignment stock policy have only been discussed in this research and there are no calculations to argue for implementing such strategy. There are worth mentioning that a strategy like this could be worth investigating further for the purpose of cost reduction and the possibility for not binding up to much capital in inventory that sits for several months.

The major goal in long term perspective for this company will be to focus on the reduction of costs, and to implement strategies that will give them competitive advantage in the industry and good collaboration with suppliers to gain efficiency and revenue for both.

7.2 Further Research

For further research the author would recommend to figure out where and what the company want to do in the coming years, and where they want to be.

The author would recommend some further investigation on the statistical analysis part and also building a model that can handle dependent variables. The possibilities for gaining high dependent results are good, and in the same time could be beneficial for reduction in transportation costs and other inventory management related costs.

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9. Appendix

A Flowserve pumps

Material number	Annual demand (D)	Unit price € (V)	Internal rate of interest ®	Order cost (A)	EOQ	Actual order quantity		L	B2	DL	Reorder point	HM Reorder point	ss	HM ss	HM Maxlevel
1073967	4,0	14574,0	0,1	100	0,74089422	1	1	0,115068	0,2	1	0	1	1	1	1
1092247	1,0	29397,1	0,1	100	0,260833307	1	1	0,115068	0,2	1	0	1	1	1	1
1074022	2,7	8121,6	0,1	100	0,810362062	1	1	0,115068	0,2	1	0	1	1	1	1
1073856	3,7	5842,1	0,1	100	1,120386086	1	2	0,115068	0,2	1	0	1	1	1	2
1073796	3,0	4322,4	0,1	100	1,1781868	1	2	0,115068	0,2	1	0	1	1	2	2
1074477	1,3	9192,8	0,1	100	0,538592404	1	1	0,115068	0,2	1	0	1	1	1	2
1074644	2,3	4646,3	0,1	100	1,002194704	1	2	0,115068	0,2	1	0	1	1	1	1
1073886	1,7	5662,8	0,1	100	0,76723018	1	1	0,115068	0,2	1	0	1	1	2	2
1069090	2,7	3124,1	0,1	100	1,306584782	1	2	0,115068	0,2	1	0	1	1	2	2
1074171	3,3	2179,9	0,1	100	1,748791675	1	2	0,115068	0,2	1	0	1	1	1	3
1092405	0,7	8956,1	0,1	100	0,385841495	1	1	0,115068	0,2	1	0	1	1	1	1
1076934	1,7	3378,8	0,1	100	0,993248985	1	1	0,115068	0,2	1	0	1	1	1	1
1089176	0,3	16721,0	0,1	100	0,199674795	1	1	0,115068	0,2	1	0	0	0	0	0
1075373	0,7	7511,2	0,1	100	0,421322271	1	1	0,115068	0,2	1	0	1	1	1	1
1073729	2,3	1963,2	0,1	100	1,541795055	1	2	0,115068	0,2	1	0	1	1	1	1
1076933	1,0	4396,9	0,1	100	0,674439024	1	1	0,115068	0,2	1	0	1	1	1	1

Current situation				**Proposed situation**	
Material number	Trc			**Material number**	Trc
1073967	€ 2 586,09			1073967	€ 2 586,09
1092247	€ 4 509,56			1092247	€ 4 509,56
1074022	€ 1 484,90			1074022	€ 1 484,90
1073856	€ 1 351,75			1073856	€ 1 059,64
1073796	€ 1 446,71			1073796	€ 1 014,48
1074477	€ 1 905,23			1074477	€ 1 512,25
1074644	€ 930,27			1074644	€ 1 045,92
1073886	€ 1 782,16			1073886	€ 1 016,08
1069090	€ 1 070,56			1069090	€ 758,15
1074171	€ 656,08			1074171	€ 602,64
1092405	€ 1 410,09			1092405	€ 1 410,09
1076934	€ 673,49			1076934	€ 673,49
1075373	€ 1 193,35			1075373	€ 1 193,35
1073729	€ 527,81			1073729	€ 509,30
1076933	€ 759,53			1076933	€ 759,53
Sum	**€ 22 287,58**			**Sum**	**€ 20 135,47**
Savings		**€ 2 152,10**			

B Andritz B.V.

Material number	3 year demand	Annual demand (D)	Unit price € (V)	Internal rate of interest	Price X Annual demand	akkumulert price X annual average demand	Akk price %	number of items	% items	class	Order cost (A)	Distribution	EOQ for R and SS	EOQ Calculations	L	B1 Fixed penalty cost	DL	D < Vr/A	Q	QVR/DB1
1074179	60	20,00	5424,47	0,1	108489,4	108489,4	60,24 %	1	7,7 %	A	200	Poisson	3,84	4,00	0,060027	1084,894	2	2,712235	>1	0,096008
1078446	36	12,00	3681,647	0,1	44179,8	152669,2	84,77 %	2	15,4 %	A	200	Poisson	3,61	4,00	0,060027	736,3294	1	1,840823	>1	0,150449
1090560	8	2,67	4923,25	0,1	13128,7	165797,8	92,06 %	3	23,1 %	A	200	Poisson	1,47	2,00	0,060027	984,65	1	2,461625	>1	0,275988
1092449	3	1,00	7472	0,1	7472,0	173269,8	96,21 %	4	30,8 %											
1092441	21	7,00	247,5082	0,1	1732,6	175002,4	97,18 %	5	38,5 %											
1075129	8	2,67	611,8	0,1	1631,5	176633,9	98,08 %	6	46,2 %											
1075331	15	5,00	311,05	0,1	1555,3	178189,1	98,94 %	7	53,8 %											
1072620	2	0,67	825,02	0,1	550,0	178739,1	99,25 %	8	61,5 %											
1075306	7	2,33	225,8983	0,1	527,1	179266,2	99,54 %	9	69,2 %											
1073770	7	2,33	225,86	0,1	527,0	179793,2	99,84 %	10	76,9 %											
1091970	24	8,00	32,53	0,1	260,2	180053,5	99,98 %	11	84,6 %											
1073451	1	0,33	69,4	0,1	23,1	180076,6	99,99 %	12	92,3 %											
1121979	1	0,33	39,7	0,1	13,2	180089,8	100,00 %	13	100,0 %											

Material number	Distribution		
1074179	Poisson		
S	Ppo(s)	Ppo<(s)	Ppo(s+1) Ppo≤(s)
0	0,135335283	0,13533528	2
1	0,270670566	0,40600585	0,666667
2	0,270670566	0,67667642	0,266667
3	0,180447044	0,85712346	0,105263
4	0,090223522	0,94734698	0,038095
5	0,036089409	0,98343639	0,012232
6	0,012029803	0,99546619	0
Reorder point (QVR/DB1		2	
Safety stock		1	
Proposed service level		67,67 %	
Current policy			
Safety stock		3	
Reorder point		3	
Max level		4	
Current service level ≈		0,86 %	

Material number	Distribution		
1078446	Poisson		
S	Ppo(s)	Ppo<(s)	Ppo(s+1) Ppo≤(s)
0	0,367879441	0,367879	1
1	0,367879441	0,735759	0,25
2	0,183939721	0,919699	0,066667
3	0,06131324	0,981012	0,015625
4	0,01532831	0,99634	0,003077
5	0,003065662	0,999406	0,000511
6	0,000510944	0,999917	0
Reorder point (QVR/DB1)		1	
Safety stock		1	
Proposed service level		73,58 %	
Current policy			
Safety stock		2	
Reorder point		2	
Max level		2	
Current service level ≈		91,97 %	

Material number	Distribution		
1090560	Poisson		
S	Ppo(s)	Ppo<(s)	Ppo(s+1) Ppo≤(s)
0	0,367879441	0,367879	1
1	0,367879441	0,735759	0,25
2	0,183939721	0,919699	0,066667
3	0,06131324	0,981012	0,015625
4	0,01532831	0,99634	0,003077
5	0,003065662	0,999406	0,000511
6	0,000510944	0,999917	0
Reorder point (QVR/DB1)		1	
Safety stock		1	
Proposed service level		73,58 %	
Current policy			
Safety stock		2	
Reorder point		2	
Max level		2	
Current service level ≈		91,97 %	

Current situation

Material number	TRC	
1074179	€ 5 898,56	
1078446	€ 3 320,41	
1090560	€ 1 764,15	
Sum	**€ 10 983,12**	
Savings		**€ 5 399,97**

Proposed situation

Material number	TRC
1074179	€ 2 627,34
1078446	€ 1 704,49
1090560	€ 1 251,32
Sum	**€ 5 583,15**

C Lemvigh-Müller A/S

Mat #	Annual demand (D)	Internal rate of interest	Unit price DKK	Price X Annual demand	Class items for this supplier	Order cost (A)	EOQ	standard dev.	σL	d in lead time ^xl	K factor 95% service level	SS	HM SS	Reorder point S	HM reorder point	HM Max level
1092938	377	0,1	239,54	90306,58	A	300	97,18	2,57	10,75	18,09	1,645	17,7	60,0	35,8	60,0	300,0
1077920	12	0,1	756,50	9077,94	A	300	9,76	1,69	7,07	0,58	1,645	11,6	15,0	12,2	15,0	25,0
1078256	25	0,1	276,91	6922,667	A	300	23,27	1,7	7,11	1,20	1,645	11,7	15,0	12,9	15,0	30,0
1078270	12,5	0,1	490,64	6133	A	300	12,36	3,78	15,82	0,60	1,645	26,0	10,0	26,6	10,0	30,0
1078257	20,5	0,1	292,95	6005,475	A	300	20,49	2,67	11,17	0,98	1,645	18,4	12,0	19,4	12,0	30,0
1092909	37	0,1	141,87	5249,19	A	300	39,56	3,16	13,22	1,77	1,645	21,7	10,0	23,5	10,0	30,0
1078135	32,5	0,1	133,87	4350,883	A	300	38,17	2,85	11,93	1,56	1,645	19,6	20,0	21,2	20,0	35,0
1077595	26,5	0,1	151,42	4012,696	A	300	32,40	3,05	12,76	1,27	1,645	21,0	15,0	22,3	15,0	25,0
1078255	27	0,1	145,51	3928,86	A	300	33,37	2,44	10,21	1,30	1,645	16,8	10,0	18,1	10,0	30,0
1077651	21	0,1	176,21	3700,34	A	300	26,74	3,39	14,19	1,01	1,645	23,3	6,0	24,3	6,0	10,0
1078647	30	0,1	114,67	3440,1	A	300	39,62	0,92	3,85	1,44	1,645	6,3	10,0	7,8	10,0	25,0
1082676	6,5	0,1	525,21	3413,865	A	300	8,62	3,49	14,60	0,31	1,645	24,0	4,0	24,3	4,0	8,0
1078203	19	0,1	168,66	3204,445	A	300	26,00	1,7	7,11	0,91	1,645	11,7	10,0	12,6	10,0	30,0
1092929	15	0,1	197,89	2968,35	A	300	21,33	40,45	169,3	0,72	1,645	5,0	5,0	5,0	5,0	30,0

Current situation				**Proposed situation**		
Mat #	**TRC Total Relevant Cost**	**# orders pr year**		**Mat #**	**TRC Total Relevant Cost**	**# orders pr year**
1092938	4782,97	1,6		1092938	2751,467	3,9
1077920	1872,99	1,2		1077920	1617,982	1,2
1078256	1123,04	1,7		1078256	968,49	1,1
1078270	1168,78	0,6		1078270	1883,126	1,0
1078257	956,8617	1,1		1078257	1138,637	1,0
1092909	838,74	1,9		1092909	869,7712	0,9
1078135	1018,152	2,2		1078135	773,5423	0,9
1077595	1097,845	2,7		1077595	808,5529	0,8
1078255	696,0267	1,4		1078255	729,9005	0,8
1077651	1715,965	5,3		1077651	882,3329	0,8
1078647	800,6725	2,0		1078647	526,9312	0,8
1082676	802,626	1,6		1082676	1714,204	0,8
1078203	622,31	1,0		1078203	635,8238	0,7
1092929	526,3075	0,6		1092929	520,9651	0,7
Sum	**DKK**	**18023,3**		**Sum**	**DKK**	**15821,73**
Potential Savings			**2201,6**			