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Improving Spare Parts Supply Chain Management at Kverneland Group

The Impact of Direct Deliveries from External Suppliers to the Central Warehouse on the Spare Parts Supply Chain Performance

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Master Thesis in International Business

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This thesis was written as part of the double degree program between the Norwegian School of Economics (NHH), Master of Science in Economics and Business Administration, and the University of Mannheim, Master of Science Mannheim Master in Management (MMM). Please note that neither the institutions nor the examiners are responsible - through the approval of this thesis - for the theories and methods used, or results and conclusions drawn in this work.

Abstract

The top management of the Kverneland Group, a Norwegian MNC which develops, produces and distributes agricultural machinery, wants to improve the performance of its spare parts supply chain and considers making some adjustments of its current purchasing strategy. In the present setting, all spare parts which are needed at the central warehouse are ordered from the Kverneland factories which developed the machines to which the respective parts belong. However, since most of the spare parts are not manufactured in-house by Kverneland factories but produced externally, the factories usually have to order the required parts from external suppliers on behalf of the warehouse. According to the proposed future purchasing strategy, the warehouse would order the parts directly from the external suppliers and they would also be delivered directly to the warehouse. Against this background, this thesis analyzes possible consequences of a change from the current to the future setting for the Kverneland Group, the Business Area After Sales and the Kverneland factories. The proposed purchasing strategy would especially affect the administrative ordering and physical order handling activities which are currently executed by the factories on behalf of the warehouse. Furthermore, the future setting would affect the total lead times of spare parts which have a high influence on the stock levels and the capital tied up in inventory at the central warehouse. The main purpose of this study is to find out if Kverneland should stay with its current setting of sourcing spare parts or if the group should implement the proposed purchasing strategy. At the end of this thesis, main conclusions and recommendations are drawn which can be used as guidelines for the implementation of the proposed purchasing strategy. Furthermore, this study discusses which compensation fees the warehouse should pay towards the factories if the future setting would be realized.

Preface

This thesis deals with the consequences of a change from the current to the proposed future purchasing strategy of spare parts within the Kverneland Group (KvG) and its impact on the group's spare parts supply chain performance. KvG is a successful and well known Norwegian MNC which develops, produces and distributes agricultural machinery. Since this study describes and analyzes a real-world business situation, the conclusions and recommendations drawn at the end of this thesis represent an important contribution and are of very high practical relevance for KvG. The main findings and advices were already presented to members of the KvG top management and the first implementation phase of the proposed purchasing strategy will start in the beginning of 2014 based on the results of this investigation. The whole research process has been a great experience and has provided me with in-depth insights into the theories and practices of spare parts supply chain management and after sales management at manufacturing and multinational corporations. However, this research would not have been possible without the valuable professional and moral support from others. First of all, I would like to thank my supervisor Sigrid Lise Nonås for her excellent academic guidance and her helpful and constructive feedback in our meetings and discussions. Furthermore, a special thank goes to Mario Guajardo, assistant professor at the department of business and management science at NHH, for his inspiring input and ideas at the very beginning of this research project. I would especially like to thank Magne Svendsen, managing director of BA After Sales and Crop Care, for the unique possibility to collaborate with KvG in writing my master thesis. Further, I am very grateful to Bård Berntsen, director of Information Systems & Planning at BA After Sales, for the numerous discussions we had and for sharing so many important insights of Kverneland's exciting business with me. Moreover, I would like to thank all Kverneland managers and employees which I have met since the beginning of this project. I really enjoyed all of my eight company visits with a total length of almost seven weeks in Norway, France and the Netherlands and I am very thankful for the great cooperation and fantastic assistance which I experienced at any time within the whole group. Finally, I would like to thank my family and friends in Norway, Austria and Germany for their endless support and for always having time for me.

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Table of Contents

List of Tables

List of Figures

List of Appendices

List of Abbreviations

$\tilde{ß}_s$	approximated fill rate achieved for a given reorder level
AI	Average Inventory
App.	Appendix
avg	average
avg inv	average inventory
BA	Business Area
BAAS	Business Area After Sales
BACC	Business Area Crop Care
C	Cost per unit (moving average price)
CEE	Central and Eastern Europe
cf.	confer (compare to)
CI	Cycle Inventory
CIS	Commonwealth of Independent States
D	average Demand per period (month/year)
DC1	Direct Cost 1 price
D_L	average Demand during the Lead time
DN	Dealer Net price
e.g.	exempli gratia (for example)
EBIT	Earnings Before Interest and Taxes
ED	External Dealer
ed.	edition
en	english

EOQ	Economic Order Quantity
ESC	Expected Shortage per replenishment Cycle
et al.	et alii/et aliae (and others)
FC	Final Customer
fr	fill rate
GRP	Global Retail Price
h	holding cost per year as fraction of product cost
i.e.	id est (that is)
IS	Information Systems
IT	Information Technology
IUP	In Use Part
KvG	(the) Kverneland Group
L	Lead time
l	liter
L_{new}	future Lead time (months)
L_{old}	current Lead time (months)
Ltd	private Limited company
max	maximum
min	minimum/minute
MMM	Mannheim Master in Management
MNC	Multinational Corporation
NDNS	Normal Distributed demand without Seasonality
NDS	Normal Distributed demand with Seasonality
NHH	Norges Handelshøyskole (Norwegian School of Economics)

NV	Nieuw-Vennep
OEM	Original Equipment Manufacturer
P&L	Profit & Loss
p.	page
pp.	pages
PBT	Profit Before Tax
PC	Production Company
PDNS	Poisson Distributed demand without Seasonality
PDS	Poisson Distributed demand with Seasonality
PDT	Planned Delivery Time
PO	Purchase Order
PR	Purchase Requisition
Prep	Preparation
Q	(economic) order Quantity
R&D	Research & Development
ROP	Reorder Point
RQ	Research Question
S	order up-to level/fixed cost incurred per order
s	reorder level
SAP	Systemanalyse und Programmentwicklung (System Analysis and Program Development)
SAS	Statistical Analysis Systems
SC	Sales Company
SCM	Supply Chain Management
SKU	Stock Keeping Unit

SPSC	Spare Parts Supply Chain
SPSCM	Spare Parts Supply Chain Management
ß	fill rate
SS	Safety inventory/Sub Supplier
ss	safety stock
STAP	Stand Alone Part
TC	Total annual Cost
TP1	Transfer Price 1
TP2	Transfer Price 2
WE	Western Europe
WH	Warehouse
x1	amount of parts which warehouse purchases
x2	amount of parts which warehouse needs
x3	amount of parts which warehouse sells
σ_D	standard deviation of Demand per month
σ_D	standard deviation of Demand per period
σ_L	standard deviation of demand during the Lead time

1 Introduction

This introductory chapter reveals the background and motivation of this master thesis and announces the focus and scope of this study. Furthermore, it introduces all relevant research questions and presents the thesis outline.

1.1 Background and Motivation

This thesis was written as part of the double degree program between NHH and the University of Mannheim. At NHH, the author of this thesis was enrolled in the Major in International Business and during his studies in Mannheim he has specialized in supply chain management (SCM) and logistics. Hence, he is very interested in the complex logistical challenges which especially manufacturing and multinational corporations face in their daily business life and he is fascinated by the broad variety of SCM approaches which support companies in their decision making process. Against this background, the author was very grateful and enthusiastic about the unique opportunity to collaborate with KvG in writing his master thesis. KvG is a Norwegian multinational corporation (MNC) which develops and produces agricultural machinery and served as a perfect object of investigation for the purpose of writing a practically oriented thesis within SCM. In his first meeting at the headquarters of KvG, the author discussed with the managing director of the Business Area After Sales (BAAS) and the Business Area Crop Care (BACC) about Kverneland's spare parts supply chain (SPSC) and the two concluded that it might be beneficial to adjust the current purchasing strategy of spare parts. After the meeting, the author was asked to analyze the present setting and to examine possible consequences of a change from the current to a proposed future purchasing strategy by conducting an academic study.

1.2 Focus and Scope

The proposed future purchasing strategy would lead to some changes of the current procurement process of spare parts within KvG. In the present setting, all parts which are needed at the central warehouse are ordered by a central planning team from the Kverneland production companies (in the following also called "factories") which developed the machines to which the respective spare parts belong. However, since most of the spare parts are not manufactured in-house by Kverneland factories but produced externally, the production companies usually have to order the required parts from external suppliers on behalf of the warehouse. Hence, the current purchasing strategy leads to a lot of double handling within KvG and furthermore results in long total lead times because the parts are not delivered directly from the external suppliers to the warehouse but first to the factories who serve as internal suppliers of the warehouse. The factories sell the parts at a transfer price to the warehouse which is approximately twice as high as the purchase price which they pay to the external suppliers. The warehouse then sells the parts at an even higher transfer price to the Kverneland sales companies. According to the proposed purchasing strategy, the central planning team would order the required spare parts directly from the external suppliers and the parts would be delivered directly to the warehouse. This strategy would result in shorter total lead times and a reduction of double handling. However, the factories would lose high amounts of their spare parts turnovers towards the warehouse because they would be excluded in the future procurement setting. On the other hand, the warehouse would achieve increasingly high margins with its spare parts sales because it would still charge the same transfer price towards the sales companies but would only have to pay the low purchase price to the external suppliers instead of the high transfer price which it currently pays to the factories. However, KvG wants to implement the proposed purchasing strategy only if the factories would not suffer from a change to the future setting. Therefore, the top management determined that the warehouse should pay compensation fees towards the factories when it would source spare parts directly from external suppliers.

Against this background, this thesis analyzes all possible consequences of a change from the current to the future setting for KvG, BAAS and the production companies. The proposed purchasing strategy would especially affect the administrative ordering and physical order handling activities which are currently executed by the factories on behalf of the warehouse. Furthermore, the future setting would affect the total lead times of spare parts which have a high influence on the stock levels and the capital tied up in inventory at the central warehouse. The main purpose of this study is to find out if Kverneland should stay with its current setting of sourcing spare parts or if the group should implement the proposed purchasing strategy. At the end of this thesis, main conclusions and recommendations are drawn which can be used as guidelines for the implementation of the proposed purchasing strategy. Furthermore, this study discusses which compensation fees the warehouse should pay towards the factories if the future setting would be realized. In the next section, more specific research questions can be found.

1.3 Research Questions

In the following, all relevant research questions (RQs) which will be discussed and answered within the scope of this thesis are summarized and presented.

1. RQ Is the proposed purchasing strategy of direct deliveries from external suppliers to the central warehouse beneficial for the spare parts supply chain performance of the Kverneland Group?

2. RQ What are the consequences of a change from the current to the future setting for the Kverneland Group, the Business Area After Sales and the Kverneland production companies?

3. RQ How does the proposed purchasing strategy affect the business processes at the Kverneland production companies?

4. RQ Which impact does the future setting have on the stock levels and the capital tied up in inventory at the central spare parts warehouse of the Kverneland Group?

5. RQ How can the Kverneland production companies be compensated for the lost turnovers which they experience when the central warehouse sources spare parts directly from external suppliers?

1.4 Thesis Outline

This section presents the basic structure of the thesis and briefly introduces its different chapters and sections. Furthermore, it shows in which chapters and sections the five different RQs will be discussed and answered. The second chapter serves as a more general theory and literature review on SCM, after sales management and spare parts supply chain management (SPSCM) and represents the theoretical frame of reference of this thesis. It deals with the most relevant concepts and the most recent developments within these three research areas. The third chapter provides information about the applied methodology and gives an overview of the different conducted research activities. The fourth chapter presents the history and organizational structure as well as the strategy and vision of KvG. The fifth chapter summarizes the empirical findings and serves as an important basis for the analysis part of this thesis. It introduces Kverneland spare parts and compares the current with the future SPSC. Furthermore, it presents the consequences of a change from the current to the future setting for the factories and BAAS (cf. 2. RQ). The sixth chapter represents the analysis of this thesis which is divided into three different sections. The first section deals with the double handling at the production companies (cf. 3. RQ), the second section examines possible stock reductions at the central warehouse (cf. 4. RQ) and the third section focus on the compensation fees which the warehouse should pay towards the production companies if the proposed purchasing strategy would be implemented (cf. 5. RQ). The seventh and last chapter of this thesis summarizes the main conclusions and recommendations and answers the questions if the future setting would be beneficial for Kverneland's SPSC performance and how KvG should implement the proposed strategy (cf. 1. RQ).

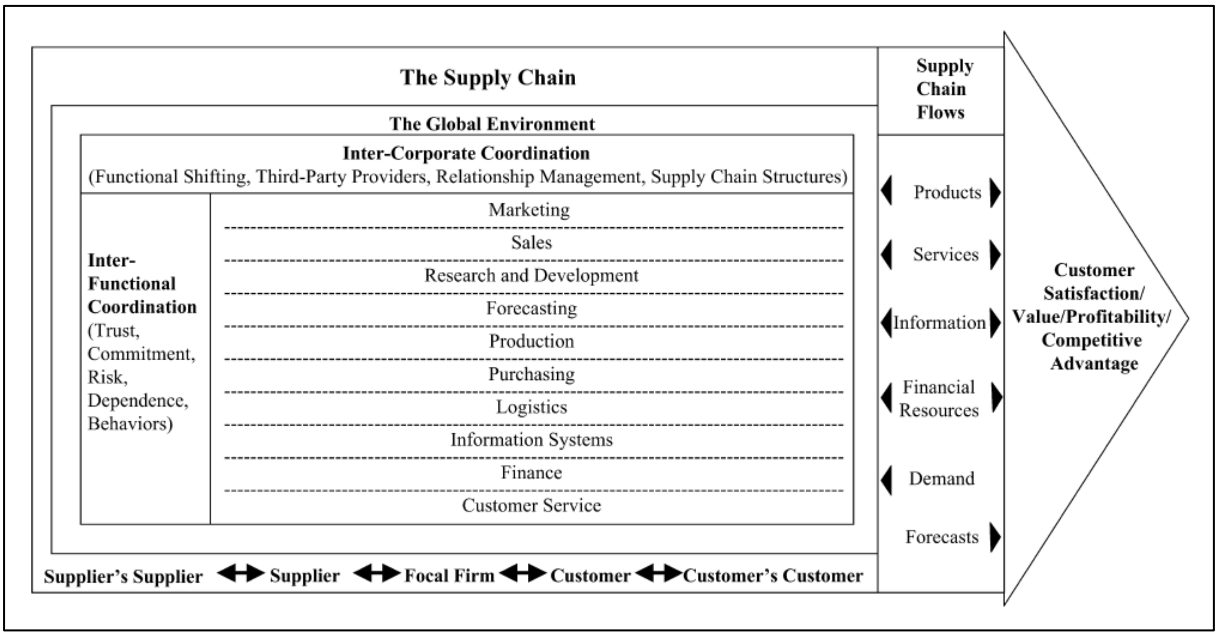
2 Theoretical Frame of Reference

This chapter serves as the theoretical frame of reference of this thesis and introduces the most important concepts and current developments within the research areas of SCM, after sales management and SPSCM.

2.1 Supply Chain Management

For most leading companies of today's global economy, integrated SCM has become a key success factor and an essential part of their corporate culture (Cohen et al. 1990; Lee and Billington 1995). Against this background, this section introduces the concept of the supply chain and reveals key elements of SCM. A supply chain is a network of facilities which are responsible for the procurement of raw materials, the transformation from raw materials into intermediate goods, the transformation from intermediate goods into final products and the delivery of final products to final customers. Usually, the facilities or actors at the different supply chain stages represent separate firms but sometimes several actors (and in certain cases even all of them) belong to the same group or holding company (cf. section 5.2). SCM encompasses the management of the areas procurement, manufacturing, inventory and distribution which represent the key elements of any supply chain. The main purpose of SCM is to outperform competitors in the battle of meeting customer's demand as soon and as effective as possible. Hence, manufacturing companies should be aware of all linkages and interrelations between the different players and elements of their supply chain. Most supply chains are characterized by distribution systems which consist of multiple inventory holding actors at different stages across the supply chain (multi-echelon inventory system). Therefore, manufacturing companies should not only focus on the local optimization of one specific stage but they should pay high attention to the global management of the whole multi-echelon supply chain (Hiller and Liebermann 2001). Mentzer et al. (2001) explain that there exist a lot of ambiguity with regards to the concept of SCM and present and discuss various definitions of "supply chain" and "supply chain management". Besides, they analyze antecedents, consequences and boundaries of SCM. Antecedents are factors which enhance the implementation of a SCM philosophy within a company. The authors list the following single company antecedents: trust, commitment, interdependence, organizational compatibility, vision, key process, leader and top management support. When the different actors across the supply chain are willing to address to the antecedents and when they are willing to develop a supply chain orientation with a systemic and strategic view, the consequences of their SCM actions will be lower costs, increased competitive advantage and improved customer value/satisfaction. At the end of the article, the authors come up with their own definition of SCM which reads as follows: “Supply chain management is defined as the systemic, strategic coordination of the traditional business functions and the tactics across these business functions within a particular company and across businesses within the supply chain, for the purposes of improving the long-term performance of the individual companies and the supply chain as a whole.” (Mentzer et al. 2001, p. 18). Moreover, they develop a conceptual model of SCM (cf. Figure 2.1). The model pictures the supply chain as a pipeline with flows from supplier’s suppliers to customer’s customers and the final objective to improve customer value and satisfaction as well as profitability and competitive advantage. The supply chain flows refer to products, services, financial resources, the information associated with these flows and the informational flows of demand & forecasts. The traditional business functions of marketing, sales, research and development (R&D), forecasting, production, purchasing, logistics, IS, finance and customer service are responsible for the management and the realization of these flows. Furthermore, the model highlights the most important aspects and the role of inter-functional and inter-corporate coordination within the global environment of the supply chain.

FIGURE 2.1.: CONCEPTUAL MODEL OF SUPPLY CHAIN MANAGEMENT[1]



2.1.1 Responsive and Efficient Supply Chains

One of the main tasks of every manufacturing company is to create a supply chain strategy that fits to its competitive strategy and that best meets the needs and demands of its customers given the uncertain environment in which it operates. When developing such a supply chain strategy, companies should ask themselves the question if their supply chain should focus mainly on responsiveness or on efficiency. Chopra and Meindl (2010, chapter 3) explain that every company faces the trade-off between cost and responsiveness and that the desired level of responsiveness represents a key strategic choice for any supply chain.

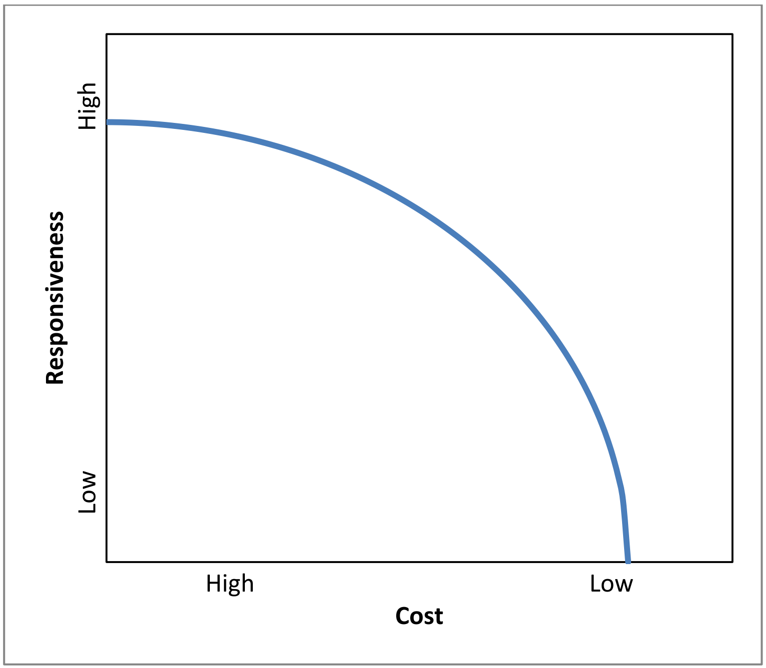
Supply chain responsiveness involves the management of various aspects like wide ranges of demanded quantities, short lead times, large varieties of products, highly innovative and expensive products, high service levels and supply uncertainty. Furthermore, responsive supply chains are depending on a flexible manufacturing process with low response times and the ability to produce custom-made or make-to-order products in very small batches. A large variety and quantity of products and styles implies a large amount of inventory and a high picking and packing capacity. Companies which are following a responsive supply chain strategy have to respond and react very quickly to replenishment and sales orders

[1] Cf. Mentzer et al. 2001

which requires rapid transportation and delivery modes. Hence, many responsive firms are able to execute orders within such a short time frame that they can change their available product variety (merchandise mix) by location and time of the day. The more of these aspects a supply chain can manage successfully, the more responsive it is. At the same time, responsive supply chains are related to high costs and low efficiency. As the cost-responsiveness efficient frontier in Figure 2.1.1.A indicates, supply chains can only achieve a high level of responsiveness when companies are willing to accept a high level of costs.

In contrast, efficient supply chains which are represented by low costs are characterized by a low level of responsiveness and can offer only little variety and flexibility. Efficient supply chains are typically based on traditional make-to-stock manufacturers with scheduled production runs (weeks or months in advance) and long production lead times. Since efficiency implies cost reduction and producing and supplying at the lowest possible cost, the manufacturers are mainly located in low-cost countries and also the suppliers are required to follow an efficient strategy. Companies which focus on efficiency usually hold little inventory and maintain a level load on the warehouse to lower picking and packing costs. The final products are often sold in large package sizes at large scale stores to benefit from economies of scale.

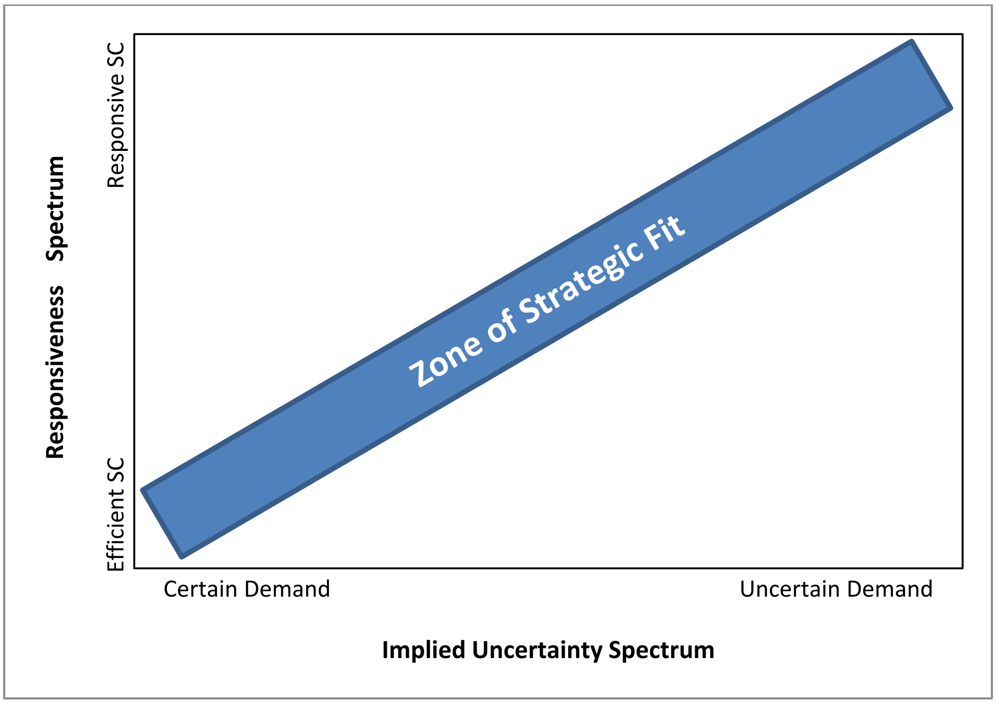
FIGURE 2.1.1.A: COST-RESPONSIVENESS EFFICIENT FRONTIER[2]



When companies decide on their level of supply chain responsiveness, they should consider the implied uncertainty of supply and demand within their business environment. Some companies are confronted with a high demand and supply uncertainty but other companies experience a relatively stable customer demand and a quite predictable supply which results in stable and predictable replenishment orders towards their suppliers. As Figure 2.1.1.B illustrates, companies which face a high implied uncertainty should choose a high level of responsiveness whereas companies which face a low implied uncertainty should focus on efficiency.

[2] Cf. Chopra and Meindl 2010, chapter 3

FIGURE 2.1.1.B: FINDING THE ZONE OF STRATEGIC FIT[3]



Besides of the implied uncertainty of supply and demand, companies should also take the needs and desires of their target customers into account when deciding about their supply chain strategy. If a company targets upper-end customers with high responsiveness requirements who are willing to pay a premium for a high level of service and availability as well as a wide spectrum of products and styles, the company should follow a responsive strategy. Although this strategy would involve high costs, companies could gain extra margins from customers who value to have the products they want when they want them. In contrast, if a company targets customers who are interested in a limited variety of products and styles at reasonable costs, the company should decide for an efficient supply chain strategy. Fisher (1997) proposes that companies which are mainly producing functional products should choose an efficient supply chain strategy whereas companies which are developing many innovative products should develop a responsive supply chain. The author also discusses the main characteristics of efficient and responsive supply chains which can be compared with the help of the following table.

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[3] Cf. Chopra and Meindl 2010, chapter 3

TABLE 2.1.1: COMPARISON OF EFFICIENT AND RESPONSIVE SUPPLY CHAINS[4]

	Efficient Supply Chains	Responsive Supply Chains
Primary Purpose	Supply predictable demand efficiently at the lowest possible cost	Respond quickly to unpredictable demand in order to minimize stockouts, forced markdowns and obsolete inventory
Manufacturing Focus	Lower costs through high average utilization rate	Maintain capacity flexibility to buffer against demand and supply uncertainty
Inventory Strategy	Generate high turns and minimize inventory throughout the chain to lower cost	Deploy significant buffer stocks of parts or finished goods to deal with demand and supply uncertainty
Lead Time Focus	Shorten lead time as long as it does not increase cost	Invest aggressively in ways to reduce lead time, even if the costs are significant
Approach to Choosing Suppliers	Select primarily for cost and quality	Select primarily for speed, flexibility, reliability and quality
Product Design Strategy	Maximize performance and minimize product cost	Use modular design in order to postpone product differentiation for as long as possible
Pricing Strategy	Lower margins because price is a prime customer driver	Higher margins because price is not a prime customer driver

As a result, companies and their supply chains differ quite substantially and they can be mapped on a responsiveness spectrum which ranges from highly efficient over somewhat efficient and somewhat responsive to highly responsive. Companies have to realize that there is never a supply chain strategy which is always right but there is always a supply chain strategy which is right for a given competitive strategy. The competitive strategy should be defined by the highest levels of the organization and should be communicated and coordinated properly within the whole company and across the whole supply chain. The supply chain design and all functional strategies within the organization should support the competitive strategy and the supply chain’s level of responsiveness (Chopra and Meindl 2010, chapter 3).

[4] Cf. Fisher 1997

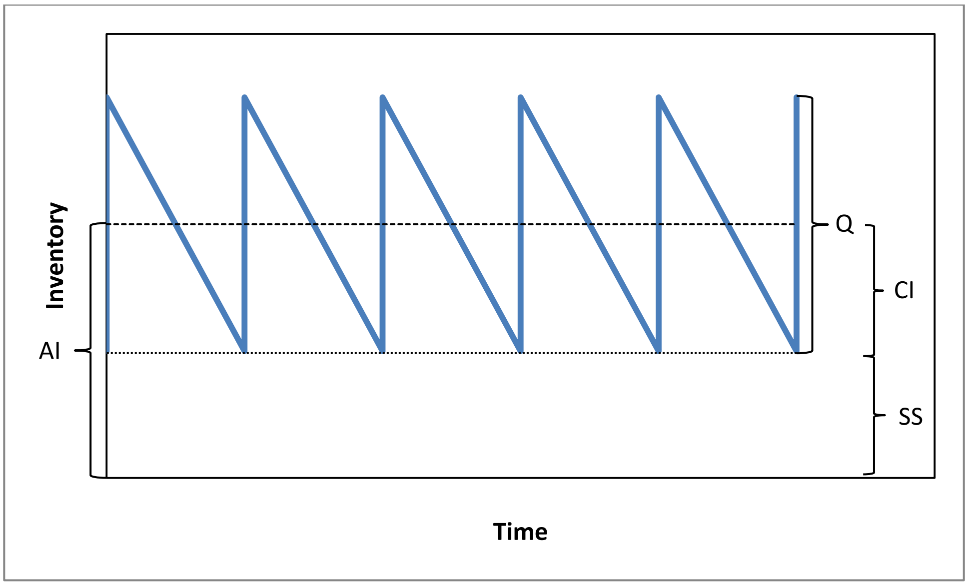
2.1.2 Inventory Management

Inventories are stocks of goods which companies hold for the future use or sale and they are available across the supply chain because there is a constant mismatch between supply and demand. They can be found at different stages and at different actors within the supply chain and they can be held in the form of raw materials, work in process goods (partially finished goods) and finished goods. Inventory management plays an important role within SCM since a company's inventory strategy has a high influence on its supply chain performance and profitability and effective inventory management can serve as a means to achieve competitive advantage. The costs of holding inventories are typically very high and a reduction of unnecessary large inventories can improve the competitiveness of every company which deals with physical products, including manufacturers, wholesalers and retailers. In the following, we consider the manufacturer as one of the most upstream players within the supply chain and the retailer as one of the most downstream actors. The manufacturer holds inventories of parts which he needs for the production of his goods. Furthermore, it is economically efficient for him to produce in large lots because thus he can exploit economies of scale. However, this strategy automatically leads to an oversupply of materials which have to be stored for future sales. The retailer holds inventories because he wants to have the finished goods ready and available when the customer needs them. An important objective of the retailer is to anticipate the future demand of the customer correctly and to increase the amount of demand which can be satisfied directly from stock (Hiller and Liebermann 2001).

Inventory represents one of the main costs across the supply chain but at the same time it also has a high influence on its responsiveness. Since inventory represents a significant binding cost for every manufacturing company (Guajardo et al. 2012), one of the main objectives of supply chain managers is to lower the amount of inventory without increasing costs or reducing responsiveness. Supply chains which are characterized by high inventory levels usually also have a high level of responsiveness whereas supply chains with little inventory are usually less responsive but very efficient because of less inventory holding costs. As indicated further above, high inventory levels facilitate economies of scale and can lead to a reduction of production and transportation costs. One way to increase the responsiveness of a supply chain is to locate large amounts of inventory close to the customer. The efficiency of a supply chain can be increased by reducing inventory through centralization. The chosen inventory policy should always support the company's competitive strategy and should fit to the needs of its customers. Hence, supply chain managers always have to deal with the trade-off between high responsiveness and high inventory on the one hand and high efficiency and little inventory on the other hand (Chopra and Meindl 2010, chapter 3).

Chopra and Meindl (2010, chapter 3) differentiate between the following three types of inventory: cycle inventory, safety inventory and seasonal inventory. Cycle inventory is the inventory which is needed to satisfy customer demand between the different shipments of a supplier. Since companies usually produce and purchase in large batches to exploit economies of scale, cycle inventories are often relatively high which implies high carrying costs. One way to reduce these costs is to decrease the order quantity and to increase the order frequency which results in lower cycle inventory. At the same time, however, this strategy leads to higher ordering costs and also often to higher purchasing prices. Hence, supply chain managers always face the trade-off between high order quantities, high holding costs and low ordering costs on the one hand and low order quantities, low holding costs and high ordering costs on the other hand when deciding about cycle inventories. As we will see in section 6.2.1, supply chain managers can apply the EOQ formula to determine the "Economic Order Quantity" which is the lot size that minimizes total annual costs (sum of annual material, ordering and holding costs). As Figure 2.1.2 shows, safety inventory is the inventory which is remaining when the replenishment lot Q arrives. Cycle inventory is defined as the half of Q and average inventory as the sum of safety and cycle inventory. Companies hold safety inventories to counter demand and supply uncertainties and to be able to satisfy unexpectedly high demands. If all demand forecasts would be correct and the world would be perfectly predictable without any forecast errors, no safety stocks would be needed at all and it would be sufficient to hold solely cycle inventories. However, demands frequently exceed the expectations of supply chain managers and companies should be well prepared for these situations because otherwise product shortages could occur. Supply chain managers should decide very carefully about the safety stock levels of every single stock keeping unit (SKU) since lost turnovers resulting from stockouts could have severe consequences for companies and should be avoided by all means. Hence, supply chain managers should trade off the costs of holding too much inventory against the potential loss of sales and margins because of holding too less inventory when deciding about safety inventories. Safety stocks also play an important role in determining replenishment parameters since the appropriate reorder levels are usually defined as the sum of the safety stocks and the average demands during the lead time (cf. Formula 6.2.2.B in section 6.2.2).

FIGURE 2.1.2: INVENTORY PROFILE WITH SAFETY INVENTORY[5]



Seasonal inventory is held to counter predictable and seasonal variability in demand. It is typically built up in low demand periods and stored for high demand periods when the demand is higher than the production at full capacity. The required amount of seasonal inventory depends mainly on the manufacturer and his ability to adjust the production rate quickly to the fluctuating demand pattern of the final customer without incurring large costs. If the costs of having a flexible production rate are low compared to the costs of holding additional inventory, only a little or no seasonal inventory at all is required. However, if it is very expensive to change the production rate and the inventory holding costs are relatively low, companies should build up more seasonal inventory during periods of low demand.

[5] Cf. Chopra and Meindl 2010, chapter 11

$Q = order\ quantity$

$AI = average\ inventory$

$CI = cycle\ inventory$

$SS = safety\ inventory$

2.1.3 Managing Safety Inventory

In this section, some basic considerations of safety inventory are introduced. Supply chain managers should be aware of these aspects when seeking for opportunities to increase product availability and margin captured from customer purchases. There are mainly two drivers which influence the amount of safety inventory which a company should hold on stock. One of these drivers is the desired level of product availability (service level) and the other driver is uncertainty (supply and demand variability).

The level of product availability represents the fraction of demand for an item which can be satisfied directly from stock without delay. A high level of product availability implies high supply chain responsiveness but also high costs since a lot of safety inventory has to be held on stock without being used. Hence, a lower level of product availability can lead to a reduction of safety inventory and less costs but also to a lower fraction of demand which can be satisfied on time. This means that the number of expected stockouts decreases with an increase in the desired service level (Chopra and Meindl 2010, chapter 3). Let us now take a closer look at the relevance of stockouts for the business of manufacturing companies. On the one hand, temporary stockouts might result in a loss of customer goodwill and some of the customers might cancel orders because of delayed deliveries. Further, stockouts could lead to lost interests on delayed sales turnovers and to a loss of future sales. On the other hand, permitting occasional and limited brief shortages might represent a reasonable business decision if the inventory holding costs are relatively high and the customers are able and willing to accept a short delay if necessary (Hiller and Liebermann 2001). Thus, supply chain managers should always trade off the cost of holding too much safety inventory against the loss from serving customers too late when determining the level of product availability. In many cases, already a marginal increase in the level of product availability can lead to an enormous increase in safety inventory. Therefore, supply chain managers should investigate thoroughly which items really require high service levels and consequently high safety stocks. It is not appropriate to choose the same high level of product availability for all SKUs because this strategy would lead to extremely high and redundant safety stocks. Especially for high priced items which represent significant binding and holding costs, companies should analyze carefully if stock reductions could be realized with the help of a marginal decrease in the desired service level. Such an analysis can lead to substantial cost savings and less capital which has to be tied up in inventory. Furthermore, supply chain managers should take the following product characteristics into account when deciding about service levels: product life cycle, product variety, ease of searching and price volatility. In industries with short product life cycles and markets with a high product variety resulting from a constantly increasing heterogeneity and customization, it is very difficult to forecast the individual product demands correctly and to determine appropriate service levels. Hence, these industries are often characterized by excessive and obsolete safety inventories because products have reached the end of their life cycles earlier than expected or customers have preferred other variants of the same products. The ease of searching describes how easy it is for the customer to search for the same product at different retailers and to check its availability. For many products of today's modern business world, the ease of searching is relatively high which emphasizes that the importance of being able to offer a specific product has increased considerably during the last years and decades. Finally, the price volatility of products which are hold on stock also plays an important role since decreasing sales prices combined with decreasing demands can be very painful for companies which expected to sell large amounts of their inventories at high prices (Chopra and Meindl 2010, chapter 11).

Uncertainty as the second important driver that affects the level of safety inventory can be measured and expressed in terms of the standard deviation of demand during the lead time σ_L. The standard deviation of demand during the lead time is an important input factor for the calculation of the appropriate safety stock level of a product (cf. section 6.2.2.1). The higher the σ_L-value of a specific item is, the higher should be the corresponding safety stock. σ_L is depending on the standard deviation of demand per period σ_D and the duration of the lead time L and is given as follows:

$$\sigma_L = \sigma_D * \sqrt{L}$$ **Formula 2.1.3**

As the formula shows, σ_L is increasing in both σ_D and L which means that the required safety inventory can be reduced with a decrease in both σ_D and L. The reduction of safety inventory subject to a service level constraint should be a main objective for every supply chain manager. Hence, companies should always try to find ways to reduce the lead time and the underlying uncertainty of demand. Many companies exert tremendous pressure on their suppliers when they require a reduction of the replenishment lead time since it takes a lot of effort from the suppliers to decrease the lead time. Therefore, suppliers should be motivated to cooperate in activities to reduce the lead time and some of the resulting benefits should be shared between the companies and its suppliers. A reduction of σ_D is difficult to achieve but there are some ways to reduce the demand uncertainty. The use of technological advanced forecasting methods based on detailed historical demand data, a better market intelligence and improved coordination across the supply chain can decrease the uncertainty significantly. Improved coordination implies a better communication between the different stages of the supply chain as well as sharing of demand data and all other information that influence demand. Furthermore, the different players across the supply chain should develop jointly forecasts instead of planning independently when the want to reduce the uncertainty within the supply chain (Chopra and Meindl 2010, chapter 11).

2.2 After Sales Management

This section serves as an introduction to after sales management and illustrates why and how companies should compete in the aftermarket. Cohen et al. (2006) explain the importance of after sales management for companies and focus on its benefits and challenges. The most important aspects in this context supplemented by findings of other authors are presented in the following.

2.2.1 Importance of After Sales Management

Since the early 1990s, the majority of companies in the classical industrialized countries in North America, Western Europe and Japan have changed their strategies from simply pushing products to the market to offering extensive solutions and delivering value to customers. Vandermerwe (2000) describes how companies can increase the value to their customers while at the same time improve their performance and the results of their businesses. The author explains that smart firms are increasing their returns by focusing on the whole customer and by defining goals in terms of market spaces instead of sales of discrete items. The main reason for the turn into more service oriented companies has been increasing competition which led to decreasing demand and decreasing profit margins. Wise and Baumgartner (1999) explain that the economic value in manufacturing has been pushed downstream to the customer and away from the production function. Successful manufacturing companies reconsidered their business strategies and realized that they have to shift their focus from operational excellence to customer allegiance. The arising service-centric view of the world put emphasis not only on the traditional core business of companies but also on the importance and the potential of the after sales business. Today, companies can choose from a broad variety of different after sales activities related to e.g. spare parts, repairs, upgrades, reconditioning, inspections, maintenance, technical support, consulting, training and finances. Mathieu (2001) discusses the great heterogeneity of after sales services within the manufacturing sector and develops a typology with the two dimensions organizational intensity (tactic, strategic or cultural) and service specificity (customer service, product services or service as a product) to classify different after sales approaches. Offering after sales services can be a source of competitive differentiation and can contribute to the profitability of companies. It has been noticed that after sales activities are high margin businesses and that after sales services often account for a high amount of corporate turnovers and an even higher amount of corporate profits. In some manufacturing industries the aftermarkets have become even bigger than the markets of the core products and the original equipment of manufacturing companies (Bundschuh and Dezvane 2003; Vandermerwe 2000). The total sale of spare parts and after sales services plays an increasingly important role in many countries concerning their national economies. Furthermore, it has been found out that the quality of after sales services has a high impact on a company’s stock price and its customer loyalty.

2.2.2 Benefits of After Sales Management

In general, there are three different phases in the life cycle of a product where manufacturing companies can compete against each other: design phase, production phase and after sales phase. Some businesses focus especially on the design phase which is mainly because 80% of the product costs are determined when it is designed. E.g. the Swedish furniture retailer Ikea lays its focus on the design phase to ensure the integrity of its image and to gain expertise in designing for efficient manufacturing (Hambrick and Fredrickson 2005). The majority of firms compete in the production phase where it is difficult to distinguish from each other because most companies apply the same global manufacturing standards. Only a few businesses however, realize that the after sales phase represents the longest period in a product’s life and thus also the longest-lasting source of turnovers. Providing after sales support generates a low-risk turnover stream over a long time period and the longer the life of an asset is, the more opportunities will come along for companies. This is especially true for firms which manufacturer industrial and consumer products. Levitt (1983) indicated already at the beginning of the 1980s that the relation between a selling company and a buying customer does not finish after the initial sale of a product but that this relation intensifies after the customer starts to use the product and considers to buy the next product from the company. Only the companies which focus on relationship management and offer their customers after sales services will get repeat orders and will achieve a high customer loyalty. If firms want to be successful they cannot ignore the after sales phase but should be aware of the strategic relevance and the benefits of the aftermarket. Therefore, the management of after sales activities should play a major role in manufacturing companies. One of the main strategic benefits of providing after sales services is that it can serve as a source of differentiation against competing companies and that it can be used as an instrument to overcome the homogenization of the production phase. Furthermore, offering effective after sales services can be a mean to achieve customer satisfaction and retention (Saccani et al. 2007). Cohen et al. (2006) describe the potential of the aftermarket as follows: "Being on par with your rivals in performance, price, and quality gets you into the game; after-sales services can win you the game." Additionally, the after sales phase requires the smallest investments and less marketing efforts compared to the two other phases because focusing on sales of spare parts and service products to already known and existing customers is cheaper and easier than finding completely new customers. Moreover, after sales activities provide important insights into customers' technologies, processes and plans. Companies can use the information about their customers' needs when they develop new products and services which can lead to higher success rates when they introduce them to the market (Alexander et al. 2002; Goffin and New 2001). Thus, aftermarket support generates knowledge which rivals cannot easily acquire and represents a competitive advantage.

2.2.3 Challenges of After Sales Management

Many companies perceive after sales services more as a necessary evil (Lele 1997), a cost generator or a needless expense than as a way to increase their turnovers and profits. Hence, most companies do not utilize the full potential of the aftermarket and could make far more money if they would pay higher attention to providing effective after sales services. Instead, their after sales management is inefficient and characterized by low inventory turns, a high amount of parts which become obsolete every year and many idle people and facilities. However, after sales is indeed a tough business and there are many different reasons why it is challenging to compete in the aftermarket. The most important challenges of after sales management are presented in the following.

Manufacturing companies which focus mainly on their production and sales functions have difficulties in managing the complex structures of their service networks and face problems in fulfilling their customers' service needs. This can have severe consequences for these companies because customer expectations are increasing constantly and disappointed customers will move towards competitors if they can offer better and especially quicker after sales services. Companies should be aware that there is a close relationship between the quality of after sales services and the intent to repurchase. This is especially true for firms which manufacturer industrial and consumer products. However, as Brax (2005) points out, it is very difficult to turn from a mainly manufacturing company into a business with a strong service orientation. Companies should be aware that they will face many different challenges within the areas of marketing, production, delivery, product-design, communication and relationship during the transition process. In the same vein, Mathieu (2001) highlights that manufacturing companies should not only consider the promising benefits of the aftermarket but also the costs which occur during the implementation of a service strategy. These costs can be divided into competitive costs and political costs. Competitive costs arise because the manufacturing firm enters into a new business field (service-providing field) where it has to compete with service providers, distributors and clients and where it has to develop its own competitive advantage. In general, there are three choices for the manufacturing company to build its own competitive advantage which are all linked with different competitive costs: using a driver of positional advantage nonaccessible to the competitors, weakening the competitors' drivers or developing new sources of competitive advantage. Political costs occur because the implementation phase represents a political process where the manufacturing company has to deal with resistance from different organizational units and conflicts among various groups of employees. Some employees might fear that they will lose power and authority under the new strategy whereas other employees might perceive it as a way to increase their influence and responsibilities. Hence, Mathieu (2001) explains that companies experience the implementation of a service strategy as an innovation which creates new ideas, processes, products and services but which, at the same time, leads to divergences, barriers and political costs within the organization. The more intense and the more specific the new service strategy is, the higher will be the uncertainty of the innovation and the higher will be the political costs. Additionally, Mathieu

(2001) indicates that companies have to adopt service management principles when they want to secure a successful implementation of a service strategy. This is only possible when manufacturing companies develop into service organizations based on the service culture which differs substantially from the traditional industrial culture.

A further challenge is that after sales networks are usually more complex than manufacturing networks because they have to deal not only with the products which are currently produced but also with all the different generations of products which were sold in the past and their respective suppliers and customers. Moreover, it is difficult to manage after sales networks successfully because spare parts, equipment and technically educated service staff have to be spread over many different locations when companies want to be able to react quickly to their customers' needs. Therefore, multinational companies often create centralized strategic business units which deal with all the different after sales activities and which are responsible for the management and the configuration of service provision, spare parts distribution and customer care (Saccani et al. 2007).

Additionally, there are increasingly many price competitive third party vendors who are constantly seeking for niches in the aftermarket. Many manufacturers cannot compete with these independent service providers and they are losing high amounts of their after sales businesses as soon as the initial warranty period of their products expires. The service providers and specialized distributors often have cost advantages over manufacturing firms because of economies of scale and learning. They can benefit from economies of scale because they provide services not only for one brand but for a whole product category. In addition, they have a learning advantage because they are focusing only on (one specific) service as their core business and not on manufacturing and service. Due to their long experience as service providers they can often anticipate customer expectations (e.g. flexibility, rapidity, proximity or professionalism) better than manufacturers (Mathieu 2001).

Furthermore, the after sales business is very unpredictable and inconsistent because aftermarkets are typically characterized by unexpected and sporadic demand patterns. However, many companies deploy the same processes and software tools which they use for their manufacturing planning also for the planning of their after sales services. This strategy involves some risks because manufacturing planning is usually based on schedules and deterministic forecasts whereas the demand for after sales services is typically stochastic. Using the same deterministic forecasting approaches for both manufacturing and after sales services could therefore lead to problems like mismatches between supply and demand, a poor customer service and lost sales. Thus, companies should apply special forecasting methods when they are planning and managing their after sales services (Silver et al. 1999).

Another important and challenging issue of the after sales business represents the environmentally friendly return, repair and disposal of failed parts.

2.3 Spare Parts Supply Chain Management

Providing spare parts is one of the most prominent after sales activities and widely applied by manufacturing companies. While the chapters 4-6 deal with practical insights from the analysis of the Kverneland SPSC, this section serves as an introduction to the spare parts business from a more theoretical point of view. SPSCM is a complex matter and differs from traditional SCM in various aspects because of the many special characteristics which are unique to spare parts and their supply chains. The most important special characteristics of spare parts and recent SPSCM developments are discussed in this chapter.

2.3.1 Special Characteristics of Spare Parts

Many of the below described special characteristics of spare parts can also be found within the SPSC of KvG which is presented in chapter 5.

Fortuin and Martin (1999) indicate that spare parts are needed for the maintenance of industrial systems and for consumer products. The authors divide spare parts into repairables (non-interchangeable or rotable) and non-repairables. A non-interchangeable repairable is a part which has to be repaired and cannot be replaced by another part when it fails. Therefore, the customer has to wait until the part is repaired before he can use the product again to which the part belongs. A rotable repairable can be replaced by an equivalent part when it fails but can also be returned to the company and can be put back on stock after it was repaired. A non-repairable part can logically not be repaired and has to be replaced by an equivalent part when it fails. In the following the focus is mainly set on non-repairables because the large majority of Kverneland parts cannot be returned and repaired when they fail but have to be replaced by new spare parts. Spare parts might be required because of service maintenance agreements, for the repair of machines which are in their warranty period or because customers or dealers order specific parts directly from the parts providing company (Drapner and Suanet 2005). Kennedy et al. (2002) differentiate between scheduled or preventive maintenance with predictable spare parts demand and unplanned repair as two fundamental types of maintenance. For the first type of maintenance it might be sufficient if spare parts arrive just in time but for unplanned repair safety stock policies have to be applied to compensate for demand variations (cf. section 2.1.3). Except of scheduled or preventive maintenance, the demand patterns of spare parts are usually very uncertain and it is difficult to develop spare parts demand forecasts (Huiskonen 2001). Spare parts demand patterns are in most cases intermittent which means that the demand is not constant but infrequent and there might be several time periods without any demand between different demand occurrences. Additionally, spare parts demands are often very lumpy which means that the demand occurrences vary a lot in terms of their demand sizes (Martin et al. 2010). Therefore, companies have to use specialized forecasting techniques when they want to run effective spare parts businesses (Silver et al. 1999). The demand for spare parts is linked with the probability of part failures and besides of historical demand data, machine install base information and marketing prognoses should be taken into account when planning spare parts inventories (Drapner and Suanet 2005).

The lifetime of spare parts is usually longer than the lifetime of the products in which they are used which can range from a couple of years up to 25 years. Spare parts still have to be provided when the manufacturing period of the corresponding products is over and even when the products are already phased out (Drapner and Suanet 2005). However, some stocked spare parts might be never demanded at all or they might be stocked for many years until they are sold for the first time. Most spare parts have a very low demand probability but nevertheless, many parts have to be delivered in the shortest possible time when ordered (Sherbrooke 1992).

Another special characteristic of spare parts is the existence of substitutions which adds the complexity of SPSCs. Products and the parts they contain are subject to a continuous improvement process which leads to the development of new products and parts which serve as substitutions for the old products and parts. Therefore, companies tend to store many different versions of functionally the same parts in their warehouses which should be taken into account in the forecasting, planning, ordering and delivery process (Drapner and Suanet 2005).

A further important part of SPSCM represents reverse logistics which deals with the management of used parts and machines which are returned from the customers to the providing company (cf. repairables). The returned parts can be considered either as good or defective. Good parts can be directly reused as spare parts or for the repair of a machine whereas defective parts have to be repaired before they can be reused. As a result, there is an increasing amount of companies which are specialized in the repair of defective parts which facilitates reverse logistics. When complete machines are returned, companies can carry out dismantling processes to identify which parts can be reused and transferred back into the spare parts inventory (Fleischmann et al. 2003).

Huiskonen (2001) proposes that companies should differentiate their spare parts according to the following four characteristics: Criticality, specificity, demand pattern and value. In the following each characteristic is analyzed in more detail.

Criticality illustrates how important it is for a customer that a specific spare part can be replenished immediately after a failure occurred. One can differentiate between three degrees of criticality: the failure has to be corrected immediately and the spare part has to be replenished as soon as possible (high criticality), the failure can be tolerated for a short time and the spare part should be replenished within a short period of time (medium criticality), the failure can be tolerated for a longer time and the spare part can be replenished within a longer period of time (low criticality).

The second characteristic, specificity, is related to manufacturing aspects and reveals that spare parts can either be standard parts or user-specific parts. Standard parts are usually needed by multiple companies but typically they can also be offered by multiple suppliers. In most cases, suppliers have standard parts on stock and can benefit from economies of scale because of high order volumes. In contrast, user-specific parts are exclusively produced by suppliers for specific company purposes and are usually not on stock because of very low order volumes.

As described further above in this section, the demand patterns of spare parts can differ in terms of volume and predictability. High demand volumes facilitate economies of scale both at the suppliers and at the companies. However, the majority of spare parts have a very low and irregular demand. They belong to the group of so called “Slow Movers” which have such a low demand that statistical inventory control methods cannot be applied. Only “Fast

Movers" can be managed effectively with the help of these methods because they are demanded more frequently (Fortuin and Martin 1999). Concerning the demand predictability, spare parts can be grouped into parts with random failures and wearing parts with a more predictable demand. In general, one can say that the higher the demand predictability of a spare part is, the less safety stock will be needed.

Finally, the spare part value is an important characteristic and should be taken into account when making stock decisions. Companies usually try to reduce their stocks of high value parts. However, they should be careful because a certain amount of these parts should always be held on stock to satisfy the customer demand. Furthermore, Kennedy et al. (2002) explain that companies should prefer repair over replacement and should store cheap components instead of expensive major units whenever possible. Regarding spare parts with a low value, companies should try to develop efficient replenishment processes so that the administrative costs are not extremely high in proportion to the part values.

2.3.2 Recent Spare Parts Supply Chain Management Developments

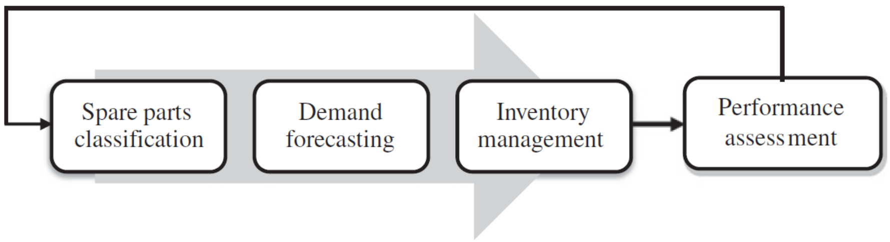
SPSCM has been around since many decades but it has become increasingly important during the last years because many companies have changed from a product oriented business approach to a service orientated philosophy since today's customers require a higher service than ever before (cf. section 2.2.1). This chapter presents recent trends in SPSCM and explains about which aspects companies should be aware of when setting up their spare parts business.

Bacchetti and Saccani (2011) investigate the gap between research and practice concerning spare parts classification and demand forecasting and propose an integrated approach to spare parts management.[6] The authors explain that researchers and companies tend to focus on specific spare parts aspects at the planning and operational level instead of looking at SPSCM from a strategic point of view. As Figure 2.3.2.A indicates, the integrated approach encompasses the following four steps: spare parts classification, demand forecasting,

[6] In the second chapter of the article, a thorough and detailed literature review on spare parts classification and demand forecasting can be found.

inventory management and performance assessment. The authors emphasize that decisions on these aspects should not be made isolated but interdependent.

FIGURE 2.3.2.A: INTEGRATED APPROACH TO SPARE PARTS MANAGEMENT[7]



Besides of applying the integrated approach, the authors propose that theoretical models should be supplemented with practical relevance and that in future, researchers and companies should pay more attention to contingency-based managerial guidelines[8] and the knowledge accumulation process within companies.

Kennedy et al. (2002) conduct a literature review on inventory management of spare parts and divide the different research areas into general and management issues, age-based replacement, multi-echelon problems, problems involving obsolescence, repairable spare parts and special applications (cf. section 2.3.1). According to the authors, spare parts inventories differ from traditional manufacturing inventories in several ways and companies should take the unique aspects of spare parts into account when making stock decisions. Manufacturing companies can reduce their inventories and can save considerable amounts of money with the help of specialized spare parts inventory policies and forecasting techniques (cf. section 2.2.3).[9]

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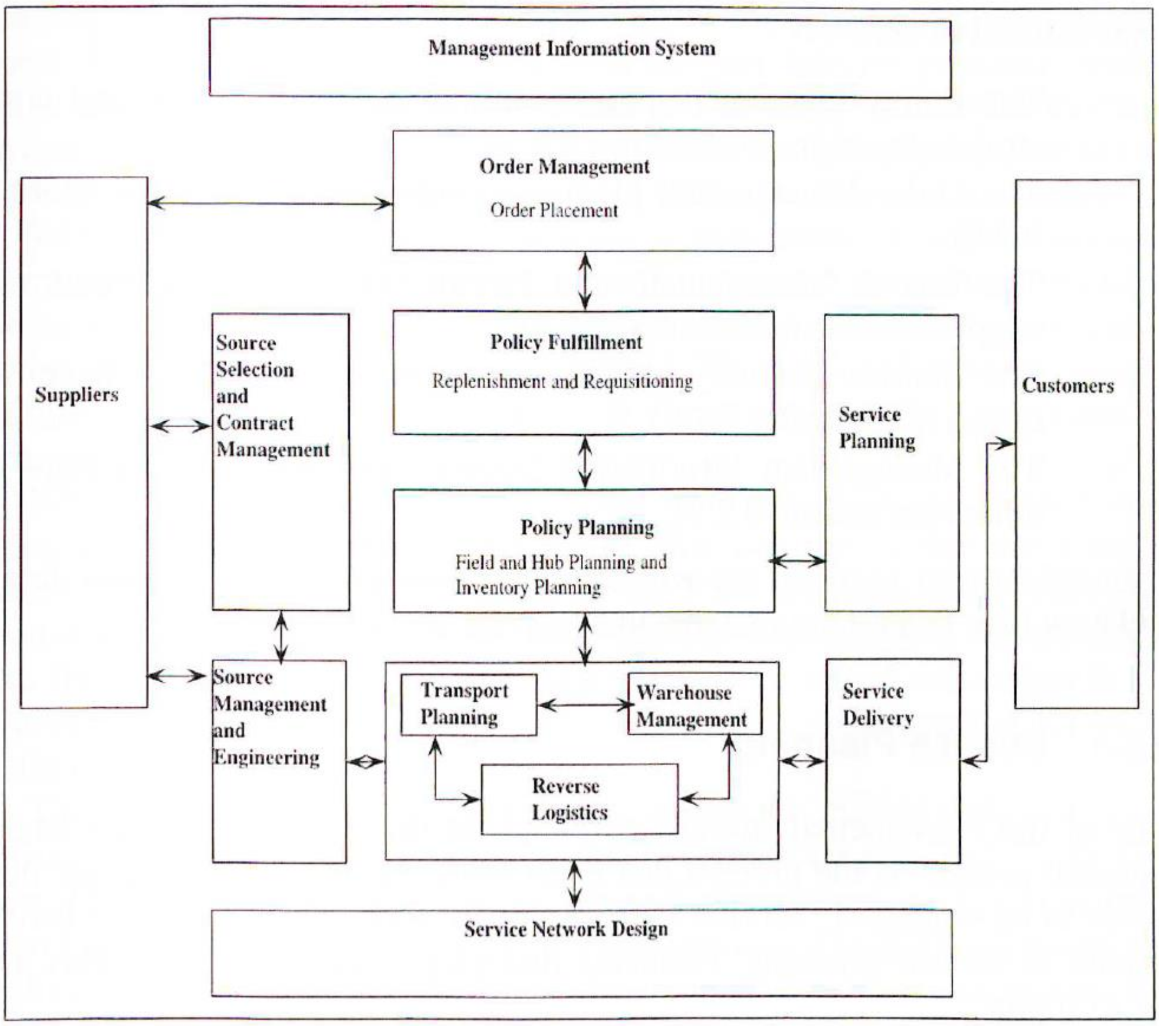
[7] Cf. Bacchetti and Saccani 2011

[8] The contingency perspective argues that differences in technological and environmental dimensions result in differences in structure, strategies and decision processes (Thompson 1967).

[9] In section 6.2 the prevailing inventory planning and replenishment policies of Kverneland's central spare parts warehouse in Metz are modeled and explained in more detail.

Drapner and Suanet (2005) study recent SPSCM developments within IBM and divide its service logistics management process into preparing & planning processes and operational processes (cf. Figure 2.3.2.B) The preparing & planning processes encompass service planning, service network design, policy planning and source selection & contract management whereas the operational processes deal with policy fulfillment, order management, source management & engineering, service delivery and management information system. The most important aspects of these processes which can be generalized to manufacturing businesses are summarized in the following.

FIGURE 2.3.2.B: THE SERVICE LOGISTICS MANAGEMENT PROCESS[10]



[10] Cf. Drapner and Suanet 2005

According to Drapner and Suanet (2005), companies should decide which services for which kinds of products and for which types of customers they want to provide before they set up their spare parts business. Usually, it is beneficial to make service decisions based on criteria like customer agreement, product type, importance of spare part, inventory budget and geographical area. Furthermore, many companies take the heterogeneity of the market into account and offer differentiated services (e.g. same day delivery vs. next day delivery). That way, companies can reach different customer segments with different market expectations. During the last years, new service needs have emerged because in many businesses it is not sufficient anymore to have the required spare parts on stock but additionally companies must be able to deliver them within the shortest possible time frame. Therefore, the applied service parameters should not only focus on the availability but also on the actual lead time of spare parts. The finally chosen service levels have a big influence on the stock planning process. However, before companies can determine concrete stock levels, they have to allocate the total inventory within their network structures. During that process they have to take all possible inward and outward flows and the overall inventory targets into account. The actual planning and determination of stock levels should be based on the inventory, service and cost targets set by the company management and the interdependences between these three targets. There exist special algorithms which take the respective targets and demand data into account and generate optimal stock levels automatically. Nevertheless, the local planners can usually also set and adjust stock levels manually. Companies often group their spare parts into different categories and choose specific service levels for each of these categories. This facilitates the planning process and is less time consuming than to decide for each spare part separately which service level fits best. E.g. spare parts could be categorized according to the following criteria: product group, reparability, forecasted demand/demand intensity, purchasing lead time, delivery time, planning horizon, essentiality/vitality/criticality/importance, price, inventory holding costs and (re)ordering costs (Fortuin and Martin 1999).

Additionally, one should keep in mind that spare parts belong to products which can be in different phases of their lives. Companies should at least differentiate between three life cycle phases of products and their respective characteristics. Fortuin and Martin (1999) distinguish between the initial phase, the normal phase and the final phase which are presented in the following. Spare parts are often already introduced when the sale phase of the corresponding product begins to offer the customer a high service as soon as he starts to use the product. In the initial phase of a product no historical demand data for spare parts is available because most of the parts have never been used before. Nevertheless, some parts might have already been used as components of other comparable products and their past consumption could serve as a starting point for further forecasts. However, in the beginning, demand forecasts are mainly driven by marketing sales plans and failure rates which are difficult to estimate because very little is known about the failure behavior in the first life cycle phase. Hence, companies should continuously update their forecasts with the latest demand data (Silver 1999). In the normal phase of a product, companies are getting more experienced with the parts' characteristics and failure rates and increasingly more demand data becomes available. Special statistical forecasting techniques can be used to estimate the future consumption of spare parts. Additionally, substitutions and returned parts should be taken into account when deciding about the stock levels of spare parts in the normal phase (cf. section 2.3.1). In the final phase of a product, the production period comes to an end but the service period goes on and spare parts still have to be provided. At the beginning of the final phase, manufacturing companies have to decide on a last time buy of spare parts which have to be purchased from external suppliers. After this last time buy, it is usually not possible anymore to order parts or it would be extremely expensive to purchase them. Therefore, manufacturing firms should take the last time buy very serious and should incorporate the latest demand data, substitutions and the reuse of returned parts into their planning process. There are some specialized methods available which facilitate the ordering of the last time buy (Teunter and Klein Haneveld 2003).

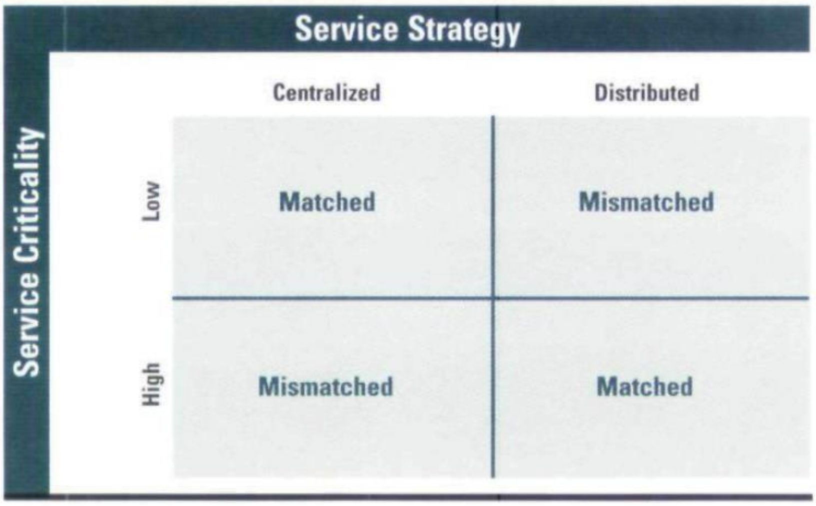
Farris II. et al. (2005) highlight a similar issue and explain that the management of obsolete parts represents one of the main challenges of the aftermarket. Obsolete parts are technologically outdated and not used in production anymore. It is very difficult to forecast the future demand of these parts and companies have to decide carefully on the sourcing and inventory strategies for obsolete parts. The authors identify four different approaches on how to deal with the obsolescence of parts which have to be procured from external suppliers. The first approach suggests to purchase and to store all the forecasted future demand of parts already at the beginning of their life cycles. This strategy leads to high inventory holding costs but at the same time enables short lead times and a quick response to customer needs. As discussed in section 2.1, the trade-off between high customer response and low inventory costs or between responsive and efficient supply chains represents one of the most important and widely discussed topics in SCM. The second approach proposes end-of-life purchases shortly before the production of the parts terminates (cf. last time buy). This strategy leads to lower inventory holding costs compared to the first approach because manufacturing companies do not have to store all the future demand of parts during their whole life cycles. Additionally, forecasts about the future demand of parts are usually more accurate at the end of the production phase than at the beginning of the life cycle. The two other approaches deal with the period after the production phase and situations where it is not possible anymore to purchase the required obsolete parts directly from the initial suppliers. One possibility in these situations is to contact companies which are specialized in storing and selling obsolete parts. However, these companies usually require high prices because they have to cover very high inventory holding costs. Another opportunity is the so called reverse engineering which means that products are disassembled into their initial parts and serve as sources for obsolete parts. Nevertheless, this approach is usually also related to high cots.

Another essential part of SPSCM represents identification, selection and contract management of supply sources. Hence, the most important aspects concerning supply sources are presented in the following. The majority of spare parts can be ordered from the same external or internal suppliers which are responsible for the manufacturing of production parts. Furthermore, there is an increasing amount of external vendors which are specialized in the repair of returned and defective parts (cf. section 2.3.1). However, as Fortuin and Martin (1999) explain, problems can occur when manufacturing companies choose the same supply sources for spare parts as for production parts. Many suppliers prefer to deliver production parts and neglect their spare parts business because the order quantities of production parts are usually higher than the order quantities of spare parts. This can result in long lead times for spare parts and can have severe consequences for the entire service performance of manufacturing companies. Finally, when purchasers have found appropriate supply sources, they should try to agree upon reasonable prices, lead times and minimum order quantities with their suppliers. An increasing amount of suppliers gives companies more options but at the same time adds the complexity of the procurement process (Drapner and Suanet 2005).

2.3.3 Centralized and Decentralized Spare Parts Supply Chains

Multinational companies often decide to centralize their SPSC and introduce a central spare parts warehouse which can cover the demand and inventory needs of multiple countries. The advantage of centralized SPSCs is that they are usually cheaper to maintain than decentralized SPSCs. This is because frequently in decentralized SPSC, basically the same activities have to be executed at several locations and the same parts types have to be stored at several warehouses since each location has to keep its own (safety) stocks of spare parts. Hence, the smaller the number of stock locations is, the lower will be the operating costs and the less capital will have to be tied up in inventory. At the same time, however, a small number of stock locations could also result in longer response times and lower service levels. Thus, we have again the prominent trade-off between responsive and efficient supply chains as discussed in section 2.1. Therefore, companies should reflect how important they consider the proximity to customers when they make network design decisions. In general, the chosen network strategy of a company should always fit to the chosen service strategy and the characteristics of the offered spare parts (Saccani et al. 2007). If companies want to succeed in the aftermarket, they should align their SPSC strategy with the needs of their customers. Cohen et al. (2000) develop a matrix which companies can use as a tool to check if their service network strategy fits with the service criticality of their customers' needs. The service strategy can either be centralized or distributed (decentralized) and the service criticality can either be low or high. As Figure 2.3.3 shows, a centralized service strategy matches with a low service criticality and a distributed service strategy matches with a high service criticality. In the following, the two terms service criticality and service strategy are explained in more detail.

FIGURE 2.3.3: SERVICE STRATEGY AND SERVICE CRITICALITY[11]



The degree of service criticality describes the urgency of a customer's need and how valuable the fulfillment of this need is perceived by the customer (cf. section 2.3.1). In the context of the aftermarket a high criticality could represent a situation where a customer needs a specific spare part very quickly because it is essential for his daily business. The failure and absence of the part could lead to high losses for the customer and hence the part providing company has to deliver the missing part as soon as possible. A low criticality could occur in cases where the customer could wait for a specific period of time until the part is delivered because he does not need it on a daily basis or because it is not critical to his core business. In general, there are two different types of service network strategies for SPSCs: centralized supply chains and distributed supply chains. Centralized supply chains with only one central warehouse are more economically reasonable when the customer needs are normally not very urgent. When companies are usually confronted with situations of a high service criticality, a distributed supply chain with several coordinated stocking locations serves as the best strategy to satisfy the customer. When companies want to find out which service strategy fits best into their business environment, they should be aware that centralized and distributed SPSCs differ mainly in four aspects. These four different aspects are performance targets, network structure, planning process and fulfillment process and they will be analyzed in more detail in the following. Centralized supply chains focus

[11] Cf. Cohen et al. 2000

especially on cost reduction and efficiency. Hence, maximum inventory turnover is often used as a performance target. Distributed networks try to make sure that all customers are quickly delivered with the needed parts and service metrics such as availability and rapid response are most important. Distributed supply chains are logically more complex than centralized supply chains and include multiple stock and repair locations at several echelons. The warehouses should be located close to the most important customer regions which guarantees a high service performance but also results in high costs. Centralized supply chains usually only consist of one stocking location and maybe some smaller repair or retail locations at a second echelon and are relatively cheap to maintain compared to their distributed counterparts. The planning process involves the management of inventories and material flows within a network. This process differs considerably between centralized and distributed supply chains. In centralized supply chains, planning is based on the point of sale at the retail level and statistical forecasting methods are used. The stocking decisions at the retailers are made independently and only focus on the local demands and lead times. The planning strategy is similar to a classic push distribution of finished goods. In distributed supply chains a more pull oriented planning strategy is applied. The forecasting is based on assumptions about the reliability of parts and the geographical dispersion of customers. The main difference to the centralized setting is that stocking decisions for all parts and locations are linked and interdependent. The last aspect to consider when comparing centralized with distributed supply chains is the physical order fulfillment process. In the centralized setting there is not a lot of coordination needed and the fulfillment process mainly focuses on the links between the suppliers and the central warehouse. In some cases, it might be beneficial to outsource certain fulfillment activities to third party logistic providers. The fulfillment process of distributed supply chains is more complex and therefore requires more coordination between the several stocking locations. Outsourcing is seldom chosen as an option to improve the fulfillment process of distributed supply chains.

3 Methodology

As described in the introduction, this study represents a very practically oriented thesis which analyzes a real-world business situation within the areas of after sales management and SPSCM at the Norwegian MNC KvG. Hence, the conclusions and recommendations drawn at the end of this study represent an important contribution and are of very high practical relevance for the examined company and its future procurement process of spare parts. Against this background, it was decided together with the managing director of BAAS and BACC that the author should visit different Kverneland locations personally on site. This approach was identified as the most appropriate method for investigating all possible consequences of a change from the current to the future setting (cf. 2. RQ) and for finding out if the proposed purchasing strategy would be beneficial for Kverneland’s SPSC (cf. 1. RQ). The purpose of the company visits was to observe the prevailing administrative ordering and physical order handling activities and to talk to the employees which would be mostly affected from the proposed purchasing strategy and which have the most advanced knowledge about the current setting. Besides of the IS & Planning department of BAAS in Klepp (Norway), the author visited the central spare parts warehouse in Metz (France) and the production company in NV (the Netherlands) which served as a representative case for all other Kverneland factories within the scope of this study (cf. section 5.2.5.1.3). This thesis mainly follows a qualitative observational research approach. Hence, the empirical findings (cf. chapter 5), the analysis (cf. chapter 6), the conclusions and the recommendations (cf. chapter 7) of this study are mainly based on primary qualitative data. However, additional quantitative data was collected, analyzed and interpreted to proof and verify the assumptions which were made based on the qualitative data. The next section serves as an overview of the different research activities and introduces the chosen research approach in more detail.

3.1 Overview of Research Activities

During the first weeks and months of this research project, the author was mainly engaged in collecting qualitative and quantitative data. In total, the author made eight company visits at three different Kverneland locations in three different countries (Norway, France and the Netherlands). The total length of his visits was around seven weeks and the author met more than 25 different Kverneland employees in various positions to talk with them about the proposed purchasing strategy. Furthermore, he observed business processes at around 15 different office, factory and warehouse facilities. A thorough overview of all company visits with detailed information about length, location and main travelling reason as well as corresponding research activities, discussed topics, interviewed persons and observed facilities can be found in Appendix 3.1. Most of the qualitative data was collected with the help of semi structured interviews with open questions and discussions. The interviews were conducted directly on site with key managers of the three different group locations and with the employees who were most familiar with the business settings, processes and flows which were object of investigation. Except of the managing director of BAAS and BACC, nobody within the whole group had a global and thorough knowledge of the whole SPSC and the current procurement process of spare parts but the interviewed persons could give detailed information about their own functions and facilities. The most important and most relevant empirical findings which could be gathered during the qualitative data collection phase are presented in chapter 5. The quantitative data which was gathered during the first phase of this research project was handed over by IT experts, IS managers, purchasers and procurement managers. This data mainly represents SAP extracts and Excel spreadsheets with detailed information about purchase orders (POs) and demand patterns of spare parts. All quantitative data which was used for the purpose of this study and all corresponding sources will be presented at appropriate sections of this thesis and can be found in the appendix. Of course, the qualitative and quantitative data which was gathered during the various company visits was supplemented by information which could be collected before and after the different trips with the help of video conferences, phone talks and conferences, email communication and company presentations about internal procedures and policies. Furthermore, the official KvG homepage[12] served as an excellent source for more general information about Kverneland. Additionally, during the whole research process, the author presented updated versions of his research progress and outline towards his academic and company supervisors and incorporated their comments and feedback as accurately as possible.

In the weeks and months after the qualitative and quantitative data collection, the author mainly focused on the writing process, linked the practical investigations and observations

[12] Cf. Kverneland Group. <http://ien.kvernelandgroup.com/> (12/15/2013).

with theoretical literature and developed the analysis part. Many aspects which are mentioned within the theoretical frame of reference also apply to the after sales management and SPSCM of Kverneland. At appropriate sections of the following chapters, it will be referred to the theory part of this thesis and vice versa. Furthermore, in section 6.2, many prominent inventory management concepts and theories will be applied to model the prevailing stock planning and replenishment policies of Kverneland's central spare parts warehouse in Metz. Among others, the EOQ model, the (s, S) replenishment system and assumptions about normal and Poisson distributed demand with and without seasonality are introduced. The last step of this research project represented the development of the final conclusions and recommendations based on the analysis of the empirical findings. The main findings and advices were presented towards members of the KvG top management shortly before the final thesis was submitted. Based on the result of this study, the first implementation phase of the proposed purchasing strategy will start in the beginning of 2014. In conclusion, the whole research process has been a great experience for the author and has provided him with in-depth insights into the theories and practices of SPSCM and after sales management at manufacturing and multinational corporations.

4 Company Presentation

In this chapter, we want to introduce KvG and present important background information which are required to understand the business environment in which the Kverneland SPSC is embedded.[13] The SPSC and the proposed purchasing strategy which represents the main subject of this study should not be regarded isolated but in the context of the historical developments and the strategic goals and objectives of KvG. Therefore, the company's history, its current situation, its organizational structure and its strategy & vision are presented in the following sections.

4.1 History

The company's history dates back to 1879 when Ole Gabriel Kverneland founded the factory in the village of Kvernaland near Stavanger (Norway) and started the production of the first scythes and sickles with the help of his small self-build forge. He named the family owned business "O.G. Kvernelands Fabrik" and turned it into a Ltd in 1894 after he had started the production of small horse powered ploughs and harrows. In 1928 the company began to develop agricultural implements suited to tractors. Kverneland's first acquisition phase started in 1955 when the company bought a complementary Norwegian producer of agricultural implements. In 1973, Kverneland made its first foreign acquisition and ten years later the company was listed on the Oslo stock exchange. Today's parent company Kverneland AS was established as a legal entity in 1989 after the company had acquired two additional firms. Since the mid-1990s, KvG has been expanding considerably through further acquisitions of a number of well-known major manufacturers of agricultural machinery from all over Europe. As a result, by the end of 1998, the group was the world's largest manufacturer of farming equipment.

In 2006, KvG decided to merge its spare parts warehouses in Giessen (Germany) and Orléans (France) into one central spare parts warehouse in Metz (France) with an area of

[13] All background information about KvG which are presented in this chapter can be found on the corporate website (Kverneland Group. <http://ien.kvernelandgroup.com/About-us> (12/15/2013).) or at Kverneland Group. 2013. Kverneland Group Corporate Presentation. <http://download.kvernelandgroup.com/content/download/89050/731100/KvG%20Corporate%20Presentation.pdf> (12/15/2013).

15,000 m² (officially opened in 2008). The main reason for this move was to further support and strengthens the group's services and operations, especially in the French and German markets. In 2008, the group launched a more focused branding strategy and started to reduce the number of product brands. However, Kverneland acquired two additional European companies in 2009 and 2012, opened new sales offices in Russia and China (2005), built a new plant in China (2010) and signed an OEM (Original Equipment Manufacturer) agreement with a competitor for North America (2011). In May 2012, the Japanese tractor company Kubota Corporation acquired KvG and the group was delisted from the Oslo stock exchange.

4.2 Kverneland Group Today

Today, KvG is a leading international company developing, producing and distributing agricultural machinery, implements and services. It offers a broad product range towards professional farmers within the areas of seeding equipment, forage and bale equipment, spreading, spraying and electronic solutions for tractors and agricultural machinery. The group is still headquartered next to Kvernaland (Klepp) and holds a total global workforce of 2,130 employees of which 71% work outside Norway. In 2012, KvG had a total turnover of around 478 million € and achieved an EBIT margin of 2%. The following table serves as an overview of the group's P&L (Profit & Loss) headlines of the years 2010-2012 and shows more detailed figures about Kverneland's business performance.

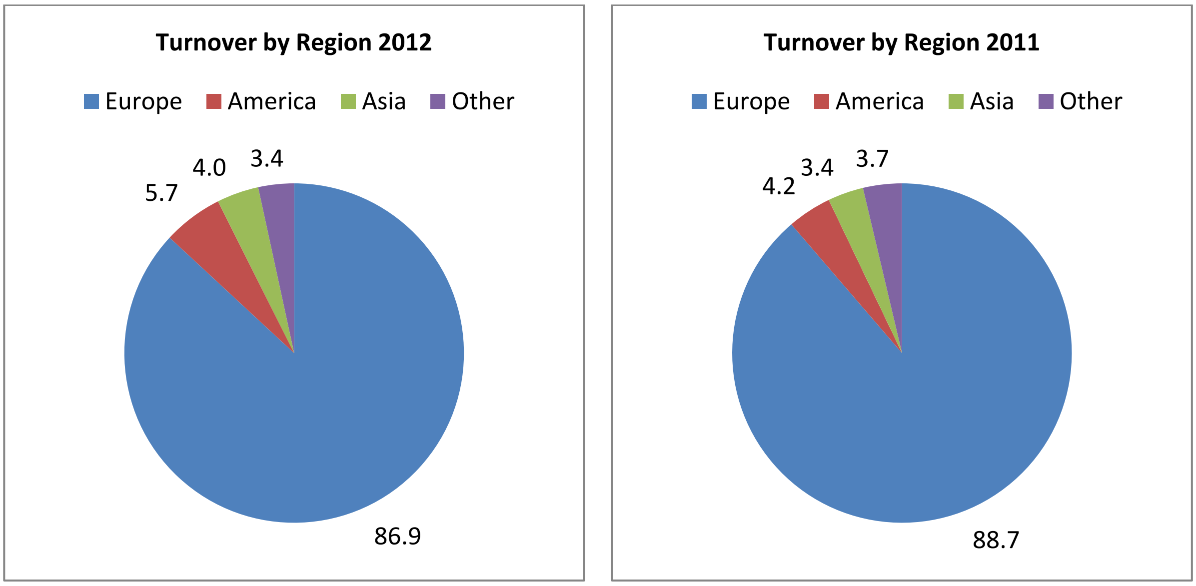
TABLE 4.2: KVERNELAND GROUP P&L HEADLINES14

	2012	2011	2010	Change 11/12
Order Book	162,739	150,735	111,605	8.0%
Order Intake	489,621	485,576	424,241	0.8%
Net Sales	477,837	447,140	380,253	6.9%
Operating Profit (EBIT)	9,466	12,768	4,930	-25.9%
as % of Net Sales	2.0%	2.9%	1.3%	
Profit Before Tax (PBT)	2,845	6,534	6,824	-56.5%
as % of Net Sales	0.6%	1.5%	1.8%	
Number of Employees	2,130	2,127	1,969	0.1%

As Figure 4.2 shows, the group's main markets in terms of total yearly turnover are located in Europe (especially in Germany and France) but it can also be observed that the amount of the total turnover achieved in America and Asia increased from 2011 to 2012.

[14] Order book, order intake, net sales, EBIT and PBT are given in 1,000€. Cf. Kverneland Group. 2013. Kverneland Group Corporate Presentation. <http://download.kvernelandgroup.com/content/download/89050/731100/KvG%20Corporate%20Presentation.pdf> (12/15/2013).

FIGURE 4.2: KVERNELAND GROUP TURNOVER BY REGION (IN %)[15]



In the following two subsections, the decentralized organizational structure of KvG and its strategy and vision are presented.

4.2.1 Organizational Structure

Kverneland's organizational structure includes five different business areas (BAs) with eleven production locations in eight countries. The five business areas are: BA Soil Equipment (seeders, precision drills, conservation tillage, harrows and cultivators); BA Plough Equipment; BA Grass Equipment (forage equipment, balers, wrappers and feeding equipment); BACC Equipment (sprayers, spreaders and KvG Mechatronics) and BA After Sales (after sales services, spare parts sales and logistics). Each production facility is specialized in developing and producing specific agricultural implements for only one of the five different business areas and has an own competence center for R&D, manufacturing and product & marketing management. As Figure 4.2.1 illustrates, the group's factories are located in Norway, Denmark, Germany, France, the Netherlands, Italy, Russia and China. Furthermore, the group has own sales companies in 18 countries and exports to another 60

[15] Cf. Kverneland Group. 2013. Kverneland Group Corporate Presentation. <http://download.kvernelandgroup.com/content/download/89050/731100/KvG%20Corporate%20Presentation.pdf> (12/15/2013).

countries. Besides of the central spare parts warehouse in Metz, there are three additional smaller satellite warehouses in Norway, Great Britain and Spain.

FIGURE 4.2.1: KVERNELAND GROUP INTERNATIONAL PRESENCE[16]

4.2.2 Strategy and Vision

KvG wants to become a competitive and international market leader of high quality products and services for tomorrow's professional farming community. Kverneland's goal is that its customers become sure that they can rely on the group to provide first class machines and support wherever and whenever its products are sold in the world. The company operates under the slogan "The Future of Farming" and as the following figure indicates, the group's vision is focused on becoming the "leading broad line supplier of agriimplements in Europe and targeting global positions in other areas of mechanised agriculture".

[16] Cf Kverneland Group. 2013. Kverneland Group Corporate Presentation. <http://download.kvernelandgroup.com/content/download/89050/731100/KvG%20Corporate%20Presentation.pdf> (12/15/2013).

FIGURE 4.2.2: KVERNELAND GROUP SUPPLIER CONCEPT[17]

Kverneland's strategy to achieve this vision is based on four central elements which are illustrated as rectangles in Figure 4.2.2 and which are presented in more detail in the following. First of all, Kverneland wants to keep its leading market position in Western Europe (WE). However, in the future, the group wants to increasingly turn its attention to expanding its activities in other areas and markets of the world, including CEE (Central and Eastern Europe), CIS (Commonwealth of Independent States), South East Asia, China and both South and North America. Secondly, KvG wants to position itself as the global leader with the most complete and competitive product & brand portfolio in the market of professional and high quality grass & arable implements. To fulfill this ambition, the company follows an expansion strategy which is characterized by constantly expanding activities, the formation of strategic alliances, the innovation and development of the current product portfolio and a customer and market oriented product development. The third central element of the group's strategy represents a dedicated and competent dealer and distribution network. According to Kverneland, close, strong and professional partnerships with dealers are increasingly important for the long-term focus and cost effective business processes. Through the best total offering to dealers, KvG could provide mutual security and would be

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[17] Cf Kverneland Group. 2013. Kverneland Group Corporate Presentation. <http://download.kvernelandgroup.com/content/download/89050/731100/KvG%20Corporate%20Presentation.pdf> (12/15/2013).

able to increase its market share with its current products, brands and markets. The final central element of Kverneland’s strategy is competitive operational effectiveness. Since Kverneland is a large international group, it can profit from economies of scale in its production and from a cost effective distribution through its sales company and importer network. Furthermore, the size of the group and the volume behind its activities enable Kverneland to benefit from synergies between various operations and from the presence of extensive knowledge, competences, experiences and resources within the company.

5 Empirical Findings

This chapter deals with the most important empirical findings which could be gathered during the qualitative and quantitative data collection for this thesis (cf. section 3.1) and which could be obtained after various company visits and discussions with key managers of the BAAS planning department in Klepp (Norway), the Kverneland production company in NV (the Netherlands) and the BAAS central spare parts warehouse in Metz (France). The first part of this chapter introduces the broad spectrum of Kverneland spare parts (cf. section 5.1), in the second part the current Kverneland SPSC is presented (cf. section 5.2) and the third part discusses the future Kverneland SPSC (cf. section 5.3).

5.1 Kverneland Spare Parts

Almost every part which is used in the production of Kverneland machines and implements can also be used and needed as a spare part at the final customer base. However, each Kverneland spare part has its own distinctive characteristics and the parts differ in various aspects like age, procurement practice and demand frequency. The objective of this chapter is to introduce the product life cycle, a general categorization and the demand pattern of Kverneland spare parts.

5.1.1 Product Life Cycle

At Kverneland there are seven different stages in the life cycle of a spare part. Each stage is characterized by a different material status for the respective spare part. During the first two stages which are called “Design Phase” and “Calculation Status”, the actual spare part is not yet available because the machine to which it belongs is still in the engineering phase. When the production of the machine has started and the sales phase of the machine has begun, also the sales phase of the spare part commences. During the first three sales years, the part holds the material status “Phase In” and after that period it automatically changes to “In Use”. Then, the part belongs to active machines which are out in the market. When the machines are not produced and sold anymore, the “Stand Alone” phase of the spare part begins. Kverneland commits itself to sell each spare part for a period of at least ten years after the respective machine was phased out. During the first seven years of this period, the spare part holds the “Stand Alone” status and during the last three years it has the status “Phase Out”.

After the ten years period and a final evaluation, the spare part is usually no longer available and gets the status “Blocked”. However, some good selling parts with high turnovers are sold longer than ten years. In the future, Kverneland wants to be able to offer its customers every spare part for a period of 15 years after the corresponding machine was phased out. This means that under constant market conditions, the number of “Stand Alone” parts will increase. Although there are seven different material statuses which each part experiences, most employees at KvG only differentiate between “In Use” parts (IUPs) and “Stand Alone” parts (STAPs). IUPs are also called production parts because they are used in the production of active machines whereas STAPs are usually perceived as spare parts because they are mainly used in the aftermarket and not in the production of machines anymore. Referring to section 2.2.2, especially manufacturing companies as Kverneland should not ignore the promising benefits of the after sales phase since it can serve as a long-lasting source of turnovers (Cohen et al. 2006).

5.1.2 General Categorization

There are various categorization or classification approaches possible to group the broad spectrum of Kverneland spare parts into different segments (cf. Huiskonen 2001). E.g. for pricing considerations, Kverneland groups its spare parts into eight main groups with 5-34 different subgroups. These eight main groups are: wearing parts, standard parts, hydraulic parts, transmission parts, electronic parts, machine parts, repair parts & assemblies and miscellaneous parts (Kverneland Group Business Area After Sales. 2013. Pricing Strategies and Methods. PowerPoint presentation.). Moreover, one could classify the spare parts according to their value, criticality[18] or age since Kverneland stores many different materials with different technological characteristics. However, for the purpose of this thesis, it is not necessary to focus in detail on these different categorization approaches. Instead, the different procurement types and material statuses of Kverneland spare parts should be analyzed to figure out which parts can be considered relevant for investigation. That means, which parts could be delivered directly from external suppliers of KvG to its central spare parts warehouse in Metz.

[18] The criticality of a spare part might depend on its context of use.

In a very general way, one can distinguish between two different procurement types and mainly two different material statuses of spare parts. Parts can be either manufactured in-house by Kverneland factories or they can be procured externally from suppliers. This means that one must differentiate between parts which are really produced by Kverneland factories and which can only be sourced internally and parts which are just used as components in the production of Kverneland machines but which are originally produced by external suppliers. Some of the external procurement parts have to be painted at the factories or modified in a certain way to be ready for sale to the customers but for the majority of external procurement parts no value is added at the Kverneland factories. Furthermore, there are external procurement parts which are rather standard parts and there are parts which are exclusively produced for Kverneland after agreed drawings. Additionally, parts can be either used as production parts for machines which are in active production or they can belong to machines which are already phased out. As described in the last section, the parts which are still used in production have the material status “In Use” and the parts which are not used in production anymore are called “Stand Alone” parts. Most of the IUPs are on stock at the factories whereas most of the STAPs are not available at the factories anymore. All parts which are still available at the factories can be just picked up from stock when needed as spare parts but all parts which are not on stock anymore have to be either manufactured in-house or procured externally when ordered by the central spare parts warehouse.[19] Therefore, it is usually more costly and time-consuming for the factories to fulfill warehouse orders for STAPs than for IUPs. The following table illustrates the four different types of parts and the respective activities which have to be performed at the factories when they are needed as spare parts at the central warehouse.

[19] In reality, BAAS often orders high amounts of external procurement IUPs from Kverneland factories which cannot be picked up from stock but which have to be ordered by the factories from external suppliers on behalf of BAAS (main orders). In these cases, the parts cannot be picked up from stock because the factories simply do not have the required quantities available or because they do not want to reduce their own stocks to a critical level because this could result in problems with their production flow. Hence, the factories have to order the required IUPs as in the case of STAPs but in contrast to the STAPs, the factories often place combined orders for IUPS for both BAAS and production purposes and not only exclusive orders on behalf of BAAS. However, for reasons of clarity and comprehensibility, let us assume in the following that all IUPs can be picked up from stock at the factories when ordered by BAAS and do not have to be ordered by the factories from external suppliers on behalf of BAAS.

FIGURE 5.1.2: PROCUREMENT TYPES AND MATERIAL STATUSES OF KVERNELAND SPARE PARTS

		Material Status	
		In Use	**Stand Alone**
Procurement Type	**Manufactured In-House**	Pick up from Stock	Manufacture Spare Part
	External Procurement	Pick up from Stock	Order Spare Part

The following sections describe the different types of spare parts and their characteristics as well as the respective tasks which have to be executed at the factories in more detail.

5.1.2.1 In Use Parts

IUPs are held on stock at the factories because they are needed for the production of active Kverneland machines. The parts can be either manufactured in-house or procured externally. When the factories receive orders for IUPs, they just have to pick them up from stock before they can be shipped to the central warehouse. Depending on the factory, the parts are either stored in warehouses or belong to the so called Kanban system. Kanban parts are stored in small bins which are located directly next to the assembly lines (cf. 5.2.5.2.1). Besides of their own forecasted consumption of production parts, the factories should also consider the demand of BAAS when planning their stock levels. Otherwise, problems with the production flow could occur, especially when BAAS orders extraordinary high quantities of IUPs or when parts have to be delivered as fast as possible. Furthermore, the factories should take care that their inventories do not fall below a critical level since this could also endanger the production flow. According to the proposed purchasing strategy, the factories would not have to consider the warehouse demand anymore since they would be excluded from the future purchasing process of spare parts.

5.1.2.2 Stand Alone Parts

STAPs are usually not held on stock at the factories because these parts belong to Kverneland machines which are already phased out and which are not in production anymore. Nevertheless, it might be possible that several STAPs are still available at the factories because there are some leftovers from the production phase or because the factories have ordered excess quantities of STAPs. In most cases, however, STAPs are not available anymore and they have to be manufactured in-house or procured externally when needed at the central warehouse.

Stand Alone Parts - Manufactured In-House

Sometimes, the warehouse needs STAPs which are not available anymore and which have to be manufactured in-house by Kverneland factories to satisfy the customer request. These parts cannot be procured externally because they require Kverneland production know-how. The materials which are needed for production are either on stock at the factories or have to be purchased from external suppliers. This distinction can already have high implications for the total production costs and the total lead times. The order quantities for this type of spare part are usually very small and the production of the required parts can be very costly. The same observations can be made for the further below described case of STAPs which have to be produced by external suppliers after drawings. The production of small quantities of parts is very inefficient compared to the production in large batches because the factories cannot utilize economies of scale and the regular production flow has to be interrupted. This leads to very high unit costs for many STAPs. The unit costs are often even higher than the final unit sales prices. Nevertheless, Kverneland has to provide these spare parts even if the company makes losses because the group is committed to deliver all spare parts for a period of ten years after the last sale of the corresponding machine (cf. section 5.1.1). In these cases, the most important consideration is to satisfy the final customer and to secure that he stays loyal with Kverneland. If this cannot be realized, the customer could get frustrated and could decide against Kverneland when he buys his next agricultural machine. This would lead to lost sales and could have far more negative financial consequences than the expensive production of a small amount of spare parts.

Stand Alone Parts - External Procurement

Let us now consider STAPs which have to be procured from external suppliers. This group of parts is very heterogeneous because some of them can be procured very easily whereas the procurement of other parts can be quite complicated. To make things clearer one could divide this group into standard parts and parts which have to be produced after drawings.

Stand Alone Parts - External Procurement - Standard Parts

The external suppliers of the Kverneland factories hold most of the standard parts on stock because these parts are frequently demanded and good selling. Therefore, it is not very difficult for the factories to procure standard parts and in most cases the suppliers can deliver them within a short time frame. Standard parts are usually produced in large batches which lead to relatively low unit costs. However, the sales prices of standard parts are also relatively low compared to the sales prices of parts which have to be produced after drawings.

Stand Alone Parts - External Procurement - Parts Produced after Drawings

The procurement process of STAPs which have to be produced after drawings is usually more complex than the procurement of standard STAPs. In the following, some general aspects of parts which have to be produced after drawings are presented and thereafter the procurement of the parts is described. The drawings are developed by the R&D departments of the factories during the design phase of the respective machines. Afterwards, they are handed over to the external suppliers which are then responsible for the production of the parts according to the agreed drawings. The factories do not have the necessary resources or capacities to produce them in-house whereas the suppliers can be seen as experts which are specialized in their production. The suppliers try to produce the whole required quantities of parts in as few batches as possible to benefit from economies of scale and deliver them to the factories where they are used in the assembly of machines.

When the parts get the material status “Stand Alone” because the corresponding machines are phased out and not produced anymore, it becomes difficult to find leftovers at the factories or at the suppliers. Hence, when spare parts are needed at the warehouse but no leftovers can be found, they have to be produced again by the suppliers. This production process can be very costly because the suppliers have to produce very small quantities of parts and cannot utilize economies of scale (cf. Stand Alone Parts - Manufactured In-House). Additionally, many suppliers require minimum order quantities which are often higher than the quantities ordered by BAAS. Nevertheless, in these situations, the factories have to take the respective minimum order quantities because there are no alternative ways of purchasing parts which have to be produced after drawings. This shows the suboptimal character of the current purchasing process because for producing companies it is very risky to be that highly depending on single external suppliers. Hence, it would be optimal and would lead to more independence if the factories could find different suppliers which could produce the same or comparable parts. Besides of the cost issue one should also consider that the procurement of parts which have to be produced after drawings is usually more time-consuming than the procurement of standard parts. The main reason is that they are not stocked at the suppliers and that they have to be reproduced when ordered but additionally it could also take some time until the respective drawings are found and the production is set up. In some cases, the parts have not been produced since years and the suppliers have to discuss technical issues with the R&D departments of the factories before the actual production can start. This can result in very long total lead times between the initial purchase orders of BAAS and the final goods receipts in Metz which are even more extended because in the current setting the parts are not delivered directly from the external suppliers to the warehouse but first to the factories.

5.1.2.3 Conclusion

One should not generalize all spare parts which are ordered by BAAS from Kverneland factories because each above described type of spare part is linked with different procurement activities which imply different costs and result in different lead times. IUPs are stocked at the factories and can be delivered quite fast to the warehouse since they just have to be picked up from stock when needed. STAPs however are not stocked at the factories and they have to be either manufactured in-house or ordered by the factories from the respective external suppliers on behalf of BAAS. The production of STAPs in-house is very expensive because the factories cannot utilize economies of scale but also the procurement of STAPs from external suppliers can be very costly and time-consuming because in cases of stockouts the suppliers have to reproduce the needed spare parts as well. There exist two different types of parts which have to be procured from external suppliers. Some of them are standard parts which are usually on stock at the suppliers and the other parts have to be produced after drawings. In the following sections and chapters, we are focusing on external procurement parts where no value is added at the factories. These parts are considered relevant for investigation because they could be delivered directly from external suppliers to the central spare parts warehouse in Metz. Especially regarding the STAPs which are procured externally, it seems to be a more efficient solution to deliver them directly to Metz because it is not the core business of the factories to handle spare parts which are not used in the production of machines anymore. The IUPs which are procured externally represent a different case because they are still used in the production of machines and hence just have to be picked up from stock when needed at the warehouse. Of course, all parts which are manufactured in-house by Kverneland factories and all external procurement parts where value is added at the factories are not affected by a change to the proposed purchasing strategy. They still have to be delivered from the factories to Metz when they are needed at the warehouse and no other purchasing strategy is possible. The same applies to external procurement parts which have to undergo an advanced quality control which can only be executed at the factories.

5.1.3 Demand Pattern

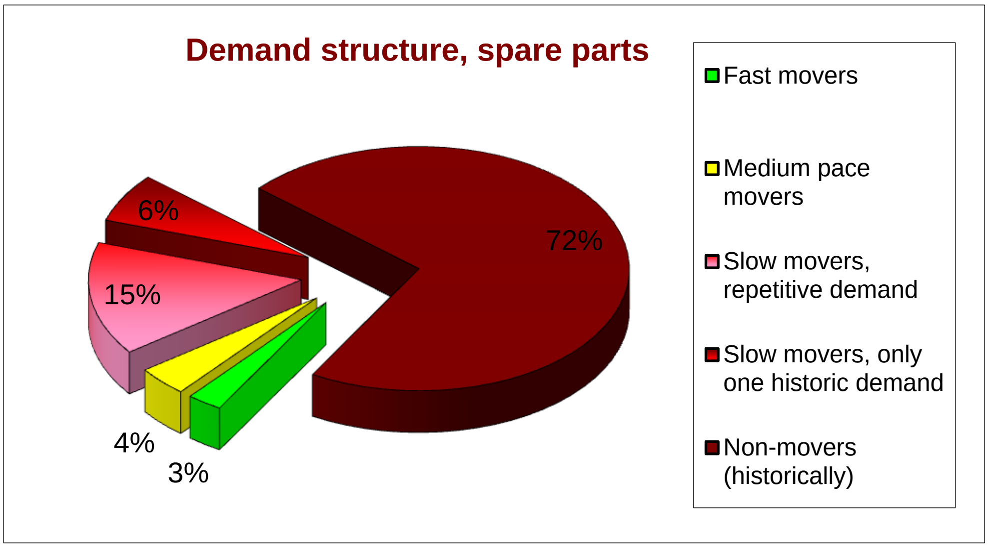
The demand for the different active spare parts which KvG offers is very uncertain and there are high seasonal variations and big fluctuations over the years. E.g. a spare part might not be required for years but suddenly it might be needed a couple of times within a few days. The demand is depending on many different aspects like type and age of the machine to which the specific spare part belongs and time when the farmer is usually working with the machine. It is almost impossible to generalize the demand for Kverneland spare parts because KvG can be seen as a broad line supplier which offers machines for all different agricultural needs from early spring to late autumn. However, in principle one can say that the main demand season is during spring and summer when the farmers are actively working with Kverneland machines in the fields. Consequently, this is the period when the most failures with machines occur and many parts wear out and have to be replaced (express orders). Specific spare parts also have a relatively high demand at the end and at the beginning of the year because this is the time when many dealers and farmers are filling up their stocks of spare parts (main orders). They anticipate that they will need these spare parts during the upcoming year and want to be well prepared before their high seasons start. Furthermore, Kverneland usually offers good discounts during the winter season which should serve as extra incentives for customers to buy spare parts. The demand pattern shows that providing after sales services is a full time and full year business even if the different machines and the corresponding spare parts are only used during a limited period of the year.

Kverneland's after sales strategy focuses on a high customer service and hence the company has a long term commitment towards its customers. The company wants to be able to supply its customers with spare parts at least ten years after the last sale of the corresponding machines (cf. section 5.1.1). According to BAAS, this policy generates a total number of around 200,000 different active articles of which around 65,000 are currently stocked at the central warehouse.[20] The management of such a high number of different active articles involves enormous administrative efforts and ties up many resources within the whole group. Therefore, BAAS should look for ways to reduce this immense number if it wants to ensure a more efficient SPSCM in the future. The head of the BAAS planning department calls a total number of around 70,000 different active articles a realistic target for the future. As Figure 5.1.3 illustrates, 72% of the total number of active articles are "Non-Movers" without any historical demand, 6% are "Slow Movers" with only one historical demand, 15% are "Slow Movers" with repetitive demand, 4% represent the "Medium Pace Movers" and only 3% of the parts belong to the group of "Fast Movers". A "Medium Pace Mover" is a spare part of which 10-100 pieces are sold during a year and a "Fast Mover" is sold more than 100 times during one year. In the year 2011, KvG could achieve a total turnover of around 97 million € with spare parts sales.[21]

[20] Cf. Kverneland Group Business Area After Sales. 2012. Planning Presentation. PowerPoint presentation.

[21] Cf Kverneland Group. 2013. Kverneland Group Corporate Presentation. <http://download.kvernelandgroup.com/content/download/89050/731100/KvG%20Corporate%20Presentation.pdf> (12/15/2013).

FIGURE 5.1.3: KVERNELAND SPARE PARTS DEMAND STRUCTURE[22]



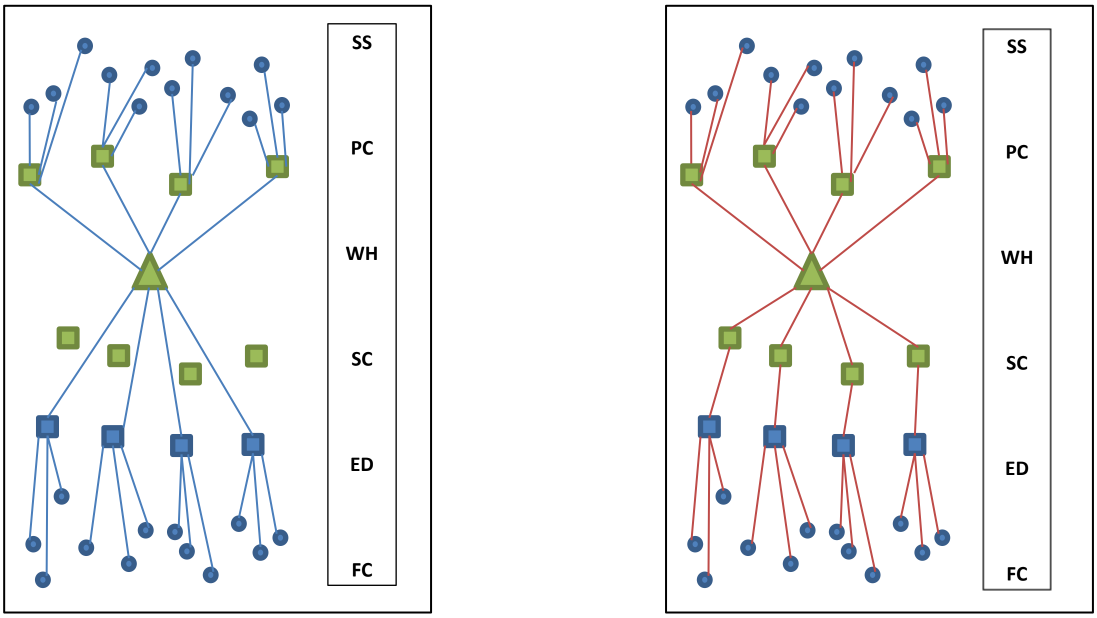
5.2 Current Kverneland Spare Parts Supply Chain

This section deals with the current SPSC of KvG which consists of six different stages. As illustrated in Figure 5.2, these six stages include the final customers (FC), the external dealers (ED), the Kverneland sales companies (SC), the central spare parts warehouse (WH), the Kverneland production companies (PC) and the external/sub suppliers (SS). Referring to Cohen et al (2000) (cf. section 2.3.3), Kverneland's service strategy can be described as centralized which would lead to the assumption that its service criticality is relatively low. With regard to the responsiveness spectrum which was presented in section 2.1.1, Kverneland's SPSC should be characterized in between somewhat efficient and somewhat responsive (Chopra and Meindl 2010, chapter 3).

[22] Cf. Kverneland Group Business Area After Sales. 2012. Planning Presentation. PowerPoint presentation.

FIGURE 5.2: CURRENT KVERNELAND SPARE PARTS SUPPLY CHAIN

Material Flow (downstream) | **Information and Capital Flow (upstream)**



In the following, each stage of the supply chain is described in more detail and the most important processes and settings of the current purchasing strategy are presented. We start with the final customers as the most downstream stage and finish with the external suppliers as the most upstream stage. In section 5.3, the proposed purchasing strategy is introduced and the respective consequences for the business of the production companies and BAAS as the two main players of the future Kverneland SPSC are analyzed.

5.2.1 Final Customers

The final customers of KvG are mainly professional farmers who are using Kverneland machines and implements for many different needs and purposes of the modern agricultural business. Since Kverneland offers a broad spectrum of agricultural implements which are needed at different stages of the farming business (cf. section 4.2), it is common that customers are not only using one single Kverneland product but several machines of different ages and for various purposes. Thus, it is very important to keep good relationships with the customer base and to convince the farmers to stay loyal with Kverneland as long as possible and to buy as many different products as possible. The customers should perceive Kverneland as a broad line supplier for all the different needs of the daily farming business and should choose Kverneland as their preferred supplier.

Kverneland's after sales strategy focus on supporting the farmers as fast as possible when technical problems and failures with the machines occur, or new spare parts are needed. Failures could either occur because specific parts of the machines have worn out after a certain period or because of plenty other different random occasions like wrong handling of machines or spare parts. KvG supports the farmers with its technicians who are spread out all over Europe and who are located next to the most important customer bases. These technicians are experts of the various specifications and functionalities of Kverneland machines and can support the customers in all technical questions regarding the machines (Kverneland Group. <http://ien.kvernelandgroup.com/Service-and-Parts/Technical-Service> (12/15/2013).). The majority of spare parts are needed during spring and summer when the farmers are working in the fields and when they are actively using the different Kverneland machines (cf. section 5.1.3). During that period it is essential that the farmers get the needed spare parts as fast as possible. A time out of a machine which is only used for a couple of weeks during a year caused by a broken or missing spare part could be very costly and could create many problems for the regular workflow of the farmer. It could have many negative consequences for the brand image and could lead to a loss of customer goodwill when farmers realize that Kverneland has problems with providing the right spare parts in the right place at the right time. The farmers as the final customers are depending on a high service offered by the Kverneland SPSC and a weak service could result in frustrated customers who would like to change their supplier of agricultural machinery.

When a spare part is needed at the customer base, the farmer has in theory three different choices. He could contact his dealer who is usually an external seller and not part of KvG, he could visit the online search engine Agroparts[23] or in case of standard parts he could try to find a hardware store who sells a similar spare part. In most cases, the farmer would contact his local dealer who sold him the Kverneland machine which is in need of a spare part and who usually holds the most common spare parts on stock. However, it is also possible to get in direct contact with the central warehouse when a spare part is urgently needed and it is difficult to purchase the part on a different way. In very urgent cases, the farmer could even pick up the needed spare part directly at the warehouse if it is present there.

[23] Cf. Agroparts. <http://www.agroparts.com> (12/15/2013).

5.2.2 External Dealers

Since the external dealers are in charge of the supply chain stage which has the most interactions with the farmers as the final customers, they usually have frequently required and commonly ordered spare parts on stock. When the dealers need spare parts to fill up their own stocks they usually place aggregated orders towards their local sales companies. The Kverneland sales companies which are responsible for all sales and marketing issues towards the dealers forward these orders towards BAAS. When the orders can be fulfilled and all parts are ready for shipping they are delivered directly from the warehouse to the dealers. After the arrival of the parts at the dealers, the sales companies take care of the final financial transactions between the dealers and KvG.

Furthermore, some dealers order good selling wearing parts already at the same time as they purchase the actual Kverneland machines from the factories and both machines and wearing parts are delivered together in one single shipment from the factories to the dealers. In this way, Kverneland can make sure that the dealers do not only sell the original Kverneland machines but also the genuine Kverneland wearing parts to the farmers. The dealers can advise the farmers already during the sales phase of the machines that they also have the appropriate wearing parts on stock and that they should be their first choice partner when it comes to after sales. This strategy leads to short response times and a high customer service what should be also in the best interest of KvG. Additionally, if the farmers could be convinced to buy the parts through the same supply chain as the machines they would not consider alternative ways of purchasing. Furthermore, a good service at the end of the supply chain also helps to maintain the good reputation of Kverneland as a company with a high customer service.

5.2.3 Sales Companies and Importers

The Kverneland sales companies act as middlemen between the spare parts warehouse and the external dealers. They buy spare parts from the warehouse and sell them to the local dealers in the countries where they operate. As described in section 4.2.1, Kverneland has own sales companies in 18 different countries worldwide whereby most of them are located in Europe where the main sales take place. In all other countries where KvG exports machines and spare parts, external importers carry out the function of the sales companies. The sales companies/importers are responsible to develop and maintain dealer networks within their local markets and to perform sales campaigns to promote the broad product portfolio of Kverneland machines and spare parts. Usually, they do not hold stocks of spare parts and the parts are not delivered to the sales companies/importers but directly from the warehouse to the dealers. Therefore they do not really belong to the Kverneland SPSC from a material flow perspective but definitely from an information and capital flow view (cf. Figure 5.2).

5.2.4 Business Area After Sales

A customer oriented after sales business is a key element in reaching a high customer loyalty. However, it is a main challenge to forecast all the different customer needs and demands for thousands of different spare parts and to secure the availability of the right parts at the right time at the right place. The after sales business should be treated very carefully and separately from the main business of producing companies. Therefore, Kverneland decided to establish an own BA which is responsible for all after sales activities of the whole group. BAAS consolidates all spare parts orders from all customers of all Kverneland factories and takes care of all spare parts sales for all machines of all factories. The factories should focus on their core business and competences, i.e. the production and the development of machines, and should not spend too much time and too many resources on the after sales business.

BAAS consists of three different departments which are mainly located in Norway and France. The departments “IS & Planning” and “Marketing, Orders, Customer Service” are located in Klepp (Norway) at the headquarters of KvG and the “Warehouse & Distribution” department which is in charge of the central spare parts warehouse is located in Metz (France). Additionally, there are three smaller satellite warehouses for spare parts in Norway (Klepp), Great Britain (St. Helens) and Spain (Barcelona) which serve their respective local markets. However, these warehouses are not considered in the following and they are not part of this study because for the moment the proposed purchasing strategy would only affect the business of the central spare parts warehouse but the smaller warehouses would not be influenced by a change to the future setting. Nevertheless, it would be interesting to examine and analyze the impact of direct spare parts deliveries from external suppliers to the satellite warehouses of KvG in a separate study.

In the following four subsections the administrative handling of sales and purchase orders as well as the stocking policies and the shipping process at the central spare parts warehouse in Metz are presented and described in more detail.

5.2.4.1 Sales Orders

The “Marketing, Orders, Customer Service” department receives all sales orders from the further downstream located stages of the SPSC. The customers of BAAS usually place aggregated orders for many different types of spare parts of different quantities to fill up their own stocks. These so called main orders contain mostly orders for spare parts which are good selling and frequently needed by farmers. For the main orders, BAAS and its customers typically agree upon fixed lead times. However, it is quite common that customers need specific spare parts as fast as possible and place express orders. When BAAS receives express orders, the warehouse tries to deliver the customers within the shortest possible time frame. BAAS tries to cover the majority of customers’ demand with spare parts which are stocked at the warehouse but in many cases not all of the ordered spare parts are available in the required quantity. Then, a planner of the department “IS & Planning” has to place purchase orders for the missing spare parts towards the suppliers of the central warehouse (cf. section 5.2.4.3). In the current setting, most of these suppliers represent the respective Kverneland factories which developed and produced the machines to which the required spare parts belong and which serve as internal suppliers of the warehouse.

5.2.4.2 Stocking Policies of Central Warehouse

As described in section 5.1.3, there are substantial differences in the demand pattern of Kverneland spare parts. The majority of active spare parts have a very low or no historical demand at all and it would not be efficient to store all these materials during the whole year. Each individual SKU is linked with many different costs like ordering costs, transportation costs, handling costs, inventory holding costs, stockout costs and scrapping costs which should be saved whenever possible. Additionally, it would lead to an unnecessary high amount of capital tied up in inventory if every single active spare part would be held on stock at the central warehouse. On the other hand there are some spare parts which have a relatively high demand and generate a significant turnover every year. These spare parts should always be held on stock to avoid lost sales. The big differences in the demand pattern of spare parts gave reason to create a rule which defines which spare parts should be held on stock at the central warehouse: all spare parts which had at least two sales during the last year or at least three sales during the last 36 months fulfill the minimum criteria to be a SKU.

Furthermore, BAAS categorizes its spare parts according to an ABC-XYZ matrix. As Table 5.2.4.2 shows, the ABC letters correspond to the yearly turnover and the XYZ letters to the yearly demand for the respective spare part. For each element of the matrix a specific service level should be realized. BAAS is using the fill rate as service level which is a quantity-oriented performance measure and describes which amount of customer demand can be satisfied directly and without delay from stock on hand (Chopra and Meindl 2010, chapter 11).

TABLE 5.2.4.2: CATEGORIZATION OF STOCK KEEPING UNITS

	X	Y	Z	Yearly Turnover (€)
A	98%	98%	92%	≥ 4,000
B	98%	98%	92%	400 – 3,999.99
C	98%	98%	92%	0.01 – 399.99
Yearly Demand (pcs)	≥ 120	119 - 13	12 - 1	

All decisions concerning inventory planning and replenishment policies are made automatically by an inventory optimization system (SAS Service Parts Optimization).[24] This involves decisions about safety stock levels, reorder levels, order up-to levels and order quantities for every SKU. SAS is linked with Kverneland's SAP and extracts demand data, targeted service levels, cost parameters and fixed lead times between the warehouse and its suppliers for every SKU. The system is monthly updated with the latest demand data and forecasts the weekly demand and the corresponding inventory parameters for a period of more than one year ahead. SAS uses dynamic algorithms for its calculations what means that all inventory parameters can change over time. This dynamic approach is a very good characteristic of the inventory planning of the warehouse because it allows BAAS to adjust its stock quickly to market changes.

[24] In section 6.2, the prevailing inventory planning and replenishment policies of the central spare parts warehouse in Metz are modeled and explained in more detail.

5.2.4.3 Purchase Orders

A purchase order (PO) always refers to only one supplier and usually consists of different order lines (PO lines). However, it is also possible that a PO consists of only one PO line. Each PO line refers to one specific spare part of a specific order quantity with a specific delivery date. In most cases all order lines of a PO have the same delivery date but sometimes the delivery dates of the different PO lines vary or have to be changed later. As mentioned in section 5.2.4.1, a PO could be either a standard order or could refer to an express order. The SAS inventory optimization system forecasts the future demand for all spare parts which have a demand history[25] and creates purchase requisitions (PR). A PR is a suggestion for a planner to place a PO at a specific time towards a specific supplier of the central warehouse. It is technically possible that SAS orders spare parts automatically from the respective suppliers but at the moment this function is only used in some special cases. Usually, the planners control all PRs created by SAS and decide which POs should really be placed. In most cases the planners agree with the PRs but they could also decide against a PR or could modify it if needed. In general, there are two different types of POs which planners could place towards the suppliers of the central warehouse. One option is that planners place stock orders towards suppliers because SAS requisitions propose to fill up the stock of the warehouse for specific spare parts. The other option is that planners have to place POs towards suppliers because sales orders from customers could not be completely satisfied from the stock of the central warehouse. These stockout situations occur when the customer demand for the respective spare parts exceeds the forecasted demand plus the safety stocks which the warehouse holds for these spare parts. Each planner is responsible for placing POs towards a limited amount of suppliers. The planners are also in charge of all expediting issues between BAAS and the suppliers and have to take care of any discrepancies between the order confirmations and the actual performances of the suppliers.

The suppliers and BAAS have agreed lead times for every SKU which BAAS internally calls PDTs (Planned Delivery Times). These lead times are fixed in SAP and they are crucial for the calculations and requisitions of SAS. In some cases, the lead times are not very reliable and in the reality the suppliers are sometimes delivering earlier or later than stated. Orders which are delivered too early can lead to unnecessary high stock levels at the warehouse and

[25] Cf. Figure 5.1.3: fast movers, medium pace movers and slow movers

orders which are delivered too late can lead to stockout situations or lost sales and can result in a poor customer service. Furthermore, fixed lead times which are not reliable can lead to many problems with the planning and ordering process because SAS takes these lead times as given and calculates all inventory and replenishment parameters based on them. In cases of highly variable lead times, BAAS should increase the safety stocks of the respective spare parts and should talk to its supplier to find solutions together to realize more constant lead times in the future.

5.2.4.4 Shipping Process at Central Warehouse

The “Warehouse & Distribution” department is in charge of the transportation of spare parts from the warehouse to the further downstream located stages of the supply chain and takes care of import and export declarations. Additionally, it coordinates the shipments which arrive at the warehouse from the different suppliers. The inbound process at the warehouse is executed by a subcontractor of BAAS who manages all the physical order handling activities on behalf of BAAS. Before a shipment arrives at the warehouse, BAAS informs the subcontractor via SAP about the content of the shipment. When the shipment arrives at the warehouse, the subcontractor unpacks, registers, counts and controls the parts and informs BAAS about discrepancies between the planned content and the actual delivered parts. However, an advanced quality control of the parts is not executed at the warehouse but rather a visual quantity control. The subcontractor is also responsible to store the parts at their respective stocking locations within the warehouse and to pick and pack parts when they have to be shipped to a customer. BAAS takes care of the discrepancies between the planned and actual delivered parts and has to follow them up. Although there is no structural quality control executed at the warehouse, in some very obvious cases, parts with a poor quality can be detected during the visual control. When the quality of certain parts is not sufficient enough, the parts cannot be sold to the customers. In these cases, BAAS has to contact the respective suppliers and the parts will be shipped back or scrapped, reordered and replaced with new parts. These cases are rather exceptions but sometimes they take place and create problems between the warehouse and its suppliers but also for the regular workflow. In the regular cases without quantity or quality discrepancies, BAAS only has to pay the invoices which the suppliers send after the parts have arrived at the warehouse. Most of the internal suppliers send invoices via SAP towards BAAS which facilitates the payment process.

5.2.5 Production Companies

As pointed out in section 5.2.4.3, the BAAS planners have to contact the respective Kverneland production companies when customer orders cannot be completely satisfied from stock or when SAS requisitions trigger stock orders for spare parts. The factories serve as internal suppliers for the central warehouse and are responsible for the procurement of the spare parts which have been ordered by BAAS. Each spare part has to be ordered from the factory which developed and produced the machine to which the required spare part belongs. Almost every part which is used for production purposes at the factories can also be required as a spare part at the final customer base. When the BAAS planners order parts which are still used in production, the factories just have to pick them up from their own stocks and can deliver them as spare parts to the warehouse. This seems to be an efficient and straightforward way of ordering spare parts and is probably one of the main reasons for the current setting of the Kverneland SPSC. Nevertheless, not all parts which the BAAS planners order are stocked at the factories and can be picked up from stock when needed. As emphasized in section 5.1, Kverneland parts can have two different material statuses ("In Use" and "Stand Alone"). IUPs can be picked up from the factory stocks but STAPs have to be ordered by the factories from the external suppliers on behalf of BAAS. This leads to a lot of additional work for the factories in terms of administrative ordering and physical order handling. In section 5.2.5.2 a qualitative analysis of the activities which have to be executed at the factories on behalf of BAAS is conducted by taking the example of the factory in NV (BACC). Furthermore, in the sections 6.1 and 6.2, a rather quantitative analysis of the current purchasing process of spare parts within the factory in NV is executed. However, before we are focusing on the production company in NV, we are first introducing the two different types of Kverneland factories in the next section.

5.2.5.1 Factory Types

In addition to the discussion about the different types of spare parts (cf. section 5.1.2) it should also be mentioned that there are two different types of Kverneland factories which are delivering spare parts to the warehouse. Most Kverneland factories are specialized in the assembly of machines out of many different components which are sourced from various external suppliers whereas some other factories are specialized in producing machines out of parts which are mainly manufactured in-house out of raw materials. The next two different subsections describe the two factory types and the corresponding spare parts in more detail.

Afterwards, the factory in NV which serves as a representative case for the factories which have their focus on assembly is presented (cf. section 5.2.5.1.3).

5.2.5.1.1 Focus on Manufacturing

A good example for a factory which manufactures parts in-house which can either be used as components for machines or as spare parts for the warehouse is the Kverneland factory in Klepp (BA Plough Equipment). This factory mainly manufactures Kverneland ploughs which are produced out of raw materials like steel or iron and there are not many assembly activities executed with parts coming from external suppliers. The majority of spare parts which are ordered by BAAS from factories which are specialized in manufacturing belongs to the group of “manufactured in-house” parts which are not part of this study (cf. section 5.1.2.3). These parts require Kverneland production know-how and cannot be procured externally. Therefore, the proposed purchasing strategy would not affect the business of these factories to a large extent.

5.2.5.1.2 Focus on Assembly

The factories which are specialized in assembly (e.g. NV) source the components which are needed for their assembly lines from many different external suppliers. These external suppliers are experts in producing specific parts for which the factories do not have the necessary competences or resources (cf. section 5.1.2.2). In some cases, these parts are standard parts and in other cases the external suppliers are producing them exclusively for Kverneland. In the last case, the parts have to be produced after drawings which the R&D departments of the factories develop and which are agreed upon between the factories and the external suppliers. Most of the parts which are coming from external suppliers are delivered to the factories and used in the assembly process without being further modified. But there are also some parts which have to be adjusted in some ways for the right Kverneland purposes (e.g. painting). The factories which have a focus on assembly produce the final Kverneland products by assembly all the different components together to a machine. Obviously, the majority of spare parts which are ordered by BAAS from factories which are specialized in assembly belongs to the group of “external procurement” parts which are the main object of this study (cf. section 5.1.2.3). Therefore, the proposed purchasing strategy would affect in particular the business of these factories.

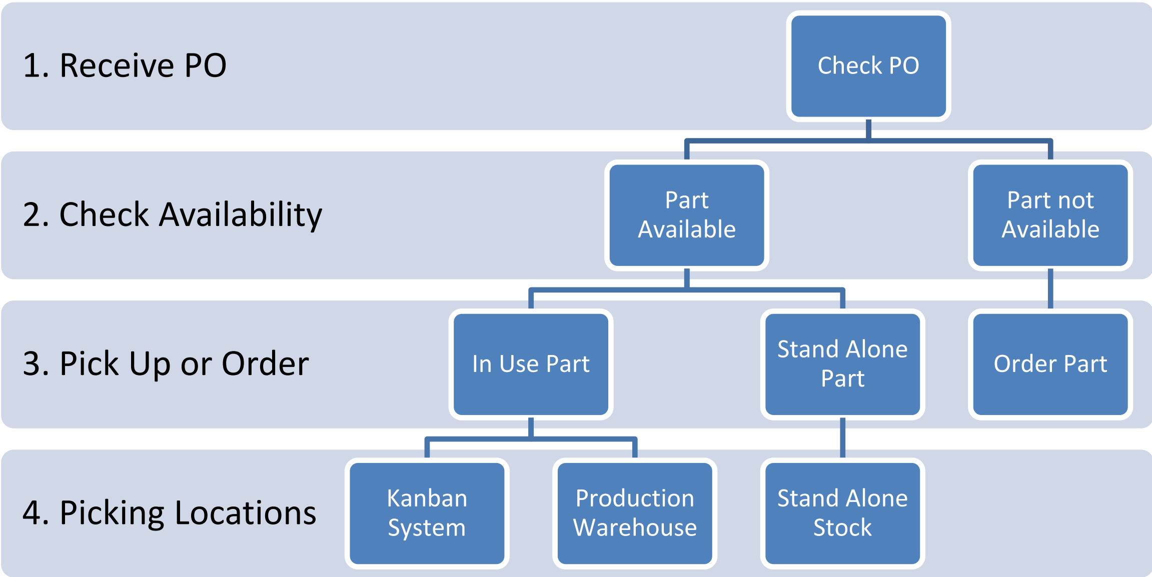
5.2.5.1.3 Production Company Nieuw-Vennep

There might be slight differences among the factories regarding the administrative ordering and the physical order handling of spare parts on behalf of BAAS but in general these activities should be relatively similar at most of the production companies. Therefore and to narrow down the scope of this thesis, it was decided to choose one specific Kverneland factory as a representative case to investigate how BAAS orders influence the work of the production companies. Together with the managing director of BA After Sales and BACC, it was agreed upon to examine and analyze the current spare parts purchasing processes within the Kverneland factory in NV (cf. section 5.2.5.2). As described in the last section, the production company in NV is specialized in assembly and handles a lot of spare parts which are procured from external suppliers and which could be delivered directly from the suppliers to the warehouse in Metz if the proposed future purchasing strategy would be realized. The factory in NV is located next to Amsterdam in the Netherlands, holds a workforce of around 170 employees and belongs to BACC. It is the competence center for the development and production of mounted and trailed field sprayers as well as for pendulum and disc fertilizer spreaders.

5.2.5.2 Purchasing Process of Spare Parts

The POs from BAAS can be accessed by the factory in NV via SAP and when a PO was selected, the first step is to check for each PO line if the required quantity of parts is on stock. If the needed parts are on stock, it has to be checked if they can be taken from stock or if the stock is blocked for production purposes. If the stock is free and available, the parts can be picked up and sent from the factory to the central warehouse but if the stock is blocked or the parts are not on stock they have to be ordered by the factory from an external supplier on behalf of BAAS (cf. Figure 5.2.5.2). From an administrative point of view this means that either a transfer order or a PO has to be created. A transfer order contains all relevant information to carry out the physical movement of a part within the factory whereas a PO has to be placed towards an external supplier. We start with the first case where an order for a specific part arrives at the factory and the needed quantity can be picked up from stock (cf. Picking Process as described in section 5.2.5.2.1). Afterwards, the second case is introduced where the factory has to order the required amount of parts on behalf of BAAS (cf. Ordering Process as described in section 5.2.5.2.2). Thereafter, the shipping process of spare parts from the factory to the central warehouse is presented (cf. section 5.2.5.2.3) and a conclusion of the current purchasing process is drawn (cf. section 5.2.5.2.4).

FIGURE 5.2.5.2: PURCHASING PROCESS OF SPARE PARTS



5.2.5.2.1 Picking Process

Most of the parts which can be picked up from stock are IUPs but sometimes even STAPs are available at the factory and do not have to be ordered from external suppliers. There are two different types of stocking locations for production parts and one separate stock only for STAPs. Most of the production parts are stocked directly next to the assembly line and are part of the Kanban system (cf. section 5.1.2.1) while the other production parts are stocked in a warehouse next to the production building. The stocking location of parts can have an influence on the picking process which is more time-consuming for parts which have to be picked up from the assembly line than for parts which are stored in the warehouse or in the STAP stock. In the following three subsections, the different stocking locations are presented and described in more detail.

Kanban System

At the factory in NV, Kanban was introduced as a system to improve the efficiency of the assembly line and to simplify the purchasing process of parts which are frequently needed in the production of machines. The factory uses Kanban mainly for small-sized parts with a relatively low value and low inventory holding costs. The Kanban parts are stocked in small bins on racks directly next to the assembly line. If the stock levels of Kanban parts decrease to a critical point, new parts will be ordered and delivered automatically from the respective external suppliers and no separate POs have to be placed.

Production Warehouse

All parts which are still used in the production of active Kverneland machines, but which do not belong to the Kanban system, are stored in a separate warehouse on the premises of the factory. The warehouse is located directly next to the production building in the same building as the inbound area and the stock of STAPs. The parts which are stored in that warehouse are usually bigger and more valuable than the Kanban parts and they are not used that frequently in the production.

Stand Alone Stock

It sounds counterintuitive but the factory also stores some parts which are not needed for production purposes anymore. These STAPs are only hold because they might be required at the central spare parts warehouse in the future. There are mainly two reasons for the accumulation of STAPs at the factory. First of all, every part which is left from the production phase automatically gets the material status “Stand Alone” when the corresponding machine is not manufactured anymore. As soon as the part changes its material status, it is transferred directly to the STAP stock. The second reason for the stock accumulation of STAPs is related to the minimum order quantities which many external suppliers require for STAPs and which are often higher than the quantities ordered by BAAS (cf. section 5.1.2.2). Nevertheless, if BAAS orders parts which are coming from these suppliers, the factory has to order the minimum quantities, has to ship the needed quantities to Metz and has to add the excess quantities to the STAP stock. However, there is usually no future demand for the excess quantities and after a final evaluation they have to be scrapped at the expenses of the factory.

5.2.5.2.2 Ordering Process

Obviously, the factory spends more time and efforts to fulfill BAAS orders for parts which it has not on stock than for parts which it has on stock. Besides of the actual ordering of these parts from the different external suppliers, the factory has to take care of expediting and invoice issues. Furthermore, the employees of the inbound area have to check all arriving shipments which contain parts which were ordered by the factory on behalf of BAAS. The following subsections analyze these different activities in more detail.

Ordering Parts

In NV, one employee of the purchasing department is mainly engaged in placing POs towards external suppliers for parts which are not on stock at the factory and which are needed at the central warehouse in Metz. At a first view, the administrative ordering of these parts seems to be a basic task but in reality this can be a quite complex and extensive business. The purchaser has access to all orders and requisitions from BAAS and tries to consolidate them if they refer to the same part or to the same supplier. This is necessary because the respective BAAS planner usually places aggregated orders towards the factory for parts which are coming from different external suppliers. When the planner orders, he focuses mainly on the factory as an internal supplier and often does not know exactly which parts correspond to which external suppliers. Sometimes the purchaser also tries to consolidate BAAS orders and factory orders for parts which are coming from the same supplier.

Often, not all needs of the BAAS orders can be completely satisfied by the external suppliers and the purchaser has to interact with both to get the best out of the situation. E.g. the order quantities of BAAS sometimes do not correspond with the required minimum order quantities of the suppliers (cf. section 5.2.5.2.1) or the delivery date which BAAS requests might not be feasible. Even after an order was placed and the factory already received an order confirmation, problems occur quite frequently. Agreed terms like the order quantity, the price or the delivery date are often subsequently changed by the suppliers which can lead to discrepancies between the order confirmation and the actual performance of the supplier. These discrepancies should be avoided and have to be followed up by the purchaser. This part of the purchaser’s job is called expediting. Van Weele (2010) defines expediting as “Following up on a purchase order to make sure that the supplier is going to perform as it has confirmed through his purchase order confirmation” (van Weele 2010, p. 9). According to van Weele’s purchasing process model (cf. section 5.3.2), expediting is the second step after the actual ordering which belongs to the order function.

Receiving Parts

All ordered parts finally arrive at the inbound area of the factory. The most important suppliers of the factory have more or less fixed delivery times and many of them are delivering the factory every week and during the high season even twice a week. After the spare parts were unpacked, their content has to be controlled. This first control step represents rather a quantity control with visual checks and counting of the parts than a sophisticated quality control. It has to be checked if the delivery note fits with the delivered parts and if the shipped quantity is equivalent to the ordered quantity of parts. There are all types of discrepancies possible. Sometimes the delivered quantity is too low or some parts are completely missing but it could also occur that too many parts are delivered or parts which were not ordered at all. All discrepancies which could be determined during the quantity control have to be followed up by the factory. Very obvious problems with the quality of parts might also be detected at this stage, but an advanced quality control of parts ordered from Metz is only executed in special cases (cf. next section). After having figured out which parts actually arrived at the inbound area, they also have to be registered digital and their goods receipts have to be noticed in the SAP system. Shortly after the parts have arrived at the factory, the suppliers send invoices to the factory which have to be paid after they were compared with the actual received materials. As described in the last section, sometimes, aggregated orders which consist of orders for factory parts and of orders for warehouse parts are placed. When these orders arrive at the factory, the respective employee at the inbound area has to check which parts can stay at the factory and which parts have to be shipped to Metz. The parts for the factory are stored in the production warehouse or they are carried directly to the assembly line when they are needed urgently or when they belong to the Kanban system. The parts for BAAS are either stored temporarily at the STAP stock or they just stay at the inbound area until they are picked up and carried to the outbound area.

Quality Control

Parts which were ordered on behalf of BAAS are usually not controlled on quality aspects at the factory. They only experience a quantity control but the materials are not tested on their technical specifications and conditions (cf. last section). However, there are some exceptions which are related to the performance of the external suppliers according to the internal quality control report of the factory. All claims about the quality of parts which initially arrived at the factory are collected in a database. The database does not only include quality problems which could be detected at the factory but also all claims of further downstream located stages of the Kverneland supply chain. The factory ranks its suppliers based on a ratio between incoming goods and quality claims into four different categories from A to D where A corresponds with the highest and D with the lowest reliability. Parts coming from suppliers with an A ranking are usually not controlled at all on quality aspects. It would be very time-consuming to really control every single incoming part and hence the factory assumes that A suppliers are only delivering high quality parts. Currently, almost every supplier of the factory in NV receives an A grading. However, the ranking is monthly updated and an increasing amount of claims could quickly lead to a different supplier grading. The higher the grade is the higher will be the amount of quality controls for parts which are coming from the respective supplier. When a supplier receives a C or D grading, all parts which are coming from this supplier have to be controlled. This dynamic approach is a very good characteristic of the quality control report because it allows the factory to adjust its quality control activities quickly to the actual performance of its suppliers. Before a quality control can be executed, a transfer order has to be placed and the respective part has to be carried from the inbound area to the quality control department. Some quality control activities require specific tools or instruments and an experienced workforce which executes the control. These resources are only available at the factory but not at the warehouse. Therefore, it is not possible to execute an advanced quality control at the warehouse in the current setting.

5.2.5.2.3 Shipping Process

All parts which can be picked up from stock and all parts which have to be ordered from external suppliers are finally carried to the outbound area of the factory where they are prepared for the delivery to Metz. Every Monday, there is a truck going from NV to the central warehouse but the shipment has to be organized already until Thursday evening the week before. All parts which have been consolidated until Thursday evening are packed into packages and handling units which are suitable for the transportation to Metz (e.g. pallets or boxes). Before the materials are packed, a factory employee looks critically at the different parts but no structural quality control is executed. In case of express orders the parts have to be delivered as fast as possible towards the warehouse and they are sent separately and independently from the weekly trucks. When a customer needs a spare part very urgently and it is crucial to the functionality of his machine, also direct deliveries from the factory to the final customer are possible. However, in the current setting, direct shipments from external suppliers to the central warehouse or from external suppliers to dealers or final customers do not take place very often.

5.2.5.2.4 Conclusion

The current purchasing process of spare parts in NV is only suboptimal and reveals some difficulties and risks for the business of the factory which are summarized and analyzed in this section. Most of these problems could be reduced or completely avoided with a change from the current to the proposed purchasing strategy (cf. section 5.3.3.2) but even if the purchasing strategy would not be changed, the factories should consider some adjustments of the current setting.

Obviously, the Kanban system is a tool to optimize and control the stock of production parts and can lead to substantial savings when implemented and organized in a proper way (Johnson et al. 2011). However, the current purchasing strategy of KvG leads to situations where the Kanban system is not really used in the most efficient way. Every day, Kanban parts have to be picked up manually from the bins at the assembly line because they are needed at the warehouse in Metz. The factory employee who is responsible for following up the transfer orders spends around two hours each day only to pick up Kanban parts on behalf of BAAS what is completely against the initial time saving intention of the system. With a change to the proposed purchasing strategy, the Kanban system would not be affected by the demand of BAAS anymore but only by the consumption of the factory.

According to the manufacturing manager in NV, the STAP stock of the factory currently has a total value of around 200,000€. Additionally, he explained that the factory tries to control the STAP stock regularly and scraps parts which are probably not needed anymore. Nevertheless, the stock ties up considerable amounts of capital and space. In the future, these resources should be used for more factory related tasks instead of for spare parts. Furthermore, in the future, the factory's purchasers should try to agree upon smaller and more flexible minimum order quantities when they sign the initial supply contracts with the external suppliers. Moreover, all information about minimum order sizes should be forwarded to the inventory optimization system of the warehouse and should be taken into account in the warehouse planning.

At the factory in NV, the purchaser has access to all POs and PRs of BAAS (cf. section 5.2.5.2.2). POs serves as official purchasing documents between BAAS and the factory which state that the factory has to procure the parts and BAAS has to buy them. PRs however only suggest placing POs at a specific time towards a specific supplier (cf. section 5.2.4.3). Nevertheless, the factory purchaser sometimes places POs based on PRs towards external suppliers. When the purchaser converts a PR of BAAS into a PO towards an external supplier, the factory takes a risk because before there was no PO placed between BAAS and the factory. Additionally, BAAS requisitions sometimes do not take the lead times between external suppliers and the factory into account and request final delivery dates at the central warehouse which are not feasible. Therefore, parts which were ordered based on BAAS requisitions often arrive too late at the factory and at a date when BAAS does not need them anymore. However, since PRs do not serve as official purchasing documents, BAAS does not have to take them and the factory has to keep the parts.

The current purchasing process of spare parts which have to be ordered from external suppliers shows that the total lead times between the initial PO from BAAS and the final goods receipt in Metz does not only consists of the sum of both lead times between SS and PC and between PC and WH but additionally of the time spend in between the two shipments (cf. section 5.2.5.2.3). Depending on the goods receipt date at the factory, this time takes at least four days and at most ten days.[26] Obviously, in the current setting the total lead times are not only unnecessarily high because of the time-consuming detour via the factory but also because of the additional time spend in between the two shipments. In the future setting, the total lead times could be reduced to the lead times between SS and WH. The impact of shorter lead times on the SPSC performance is examined further in the sections 5.3.4.4 and 6.2.

5.2.6 External Suppliers

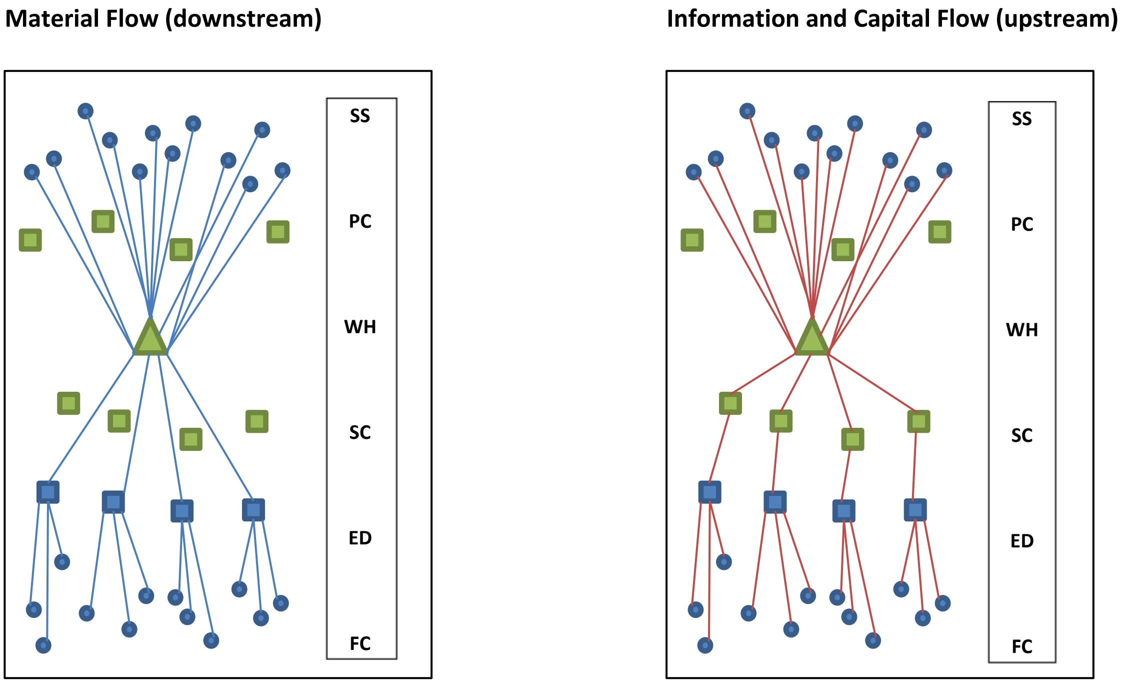
Most of the external suppliers of the Kverneland factories are specialized in the production of agricultural components and technology. The factories purchase parts from external suppliers because they are not equipped with the necessary resources and competences to manufacture them in-house or because the suppliers can produce or source these parts cheaper and faster than the factories (cf. section 5.2.5.1.2). Since every Kverneland factory is specialized in developing and producing specific agricultural machinery for only one of the five different BAs (cf. section 4.2.1) and the factory types can differ substantially (cf. section 5.2.5.1), every production company has its own suppliers which usually do not overlap. Many suppliers are located more or less close to the factories or at least in the same country but some suppliers are also located in foreign countries. Some of the suppliers are even located closer to the central spare parts warehouse in Metz than to the respective Kverneland factories.

[26] The time spend in between the two shipments takes at least four days if the goods receipt date is a Thursday and the parts are shipped on the following Monday and at most ten days if the goods receipt date is a Friday and the parts are shipped on the Monday after next.

5.3 Future Kverneland Spare Parts Supply Chain

This section deals with the proposed purchasing strategy of spare parts within KvG and its consequences for the production companies and BAAS as the two main players of the future Kverneland SPSC (cf. 2. RQ). As Figure 5.3 indicates, the spare parts would be ordered directly by BAAS from the external suppliers and they would be delivered directly from the external suppliers to the central warehouse in Metz.

FIGURE 5.3: FUTURE KVERNELAND SPARE PARTS SUPPLY CHAIN



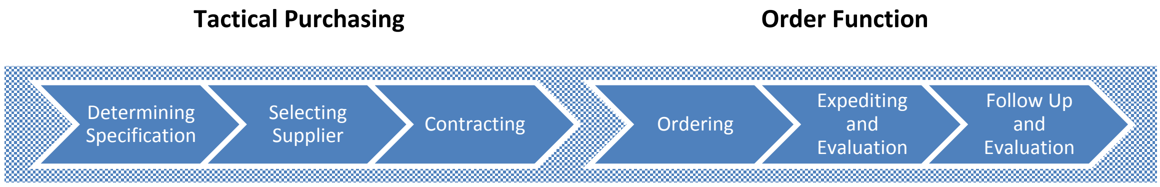
5.3.1 Changes of Current Spare Parts Supply Chain

The top management of KvG wants to improve the performance of its SPSC and considers making some adjustments of the current setting. The future setting would lead to some changes especially for the further upstream located stages of the SPSC, namely BAAS, the production companies and the external suppliers. The changes would concern the procurement process of standard spare parts which are produced by external suppliers and which are needed at the central warehouse in Metz. The procurement process of parts which are manufactured in-house or which have to be modified at the factories would not change (cf. section 5.1.2.3). In the future setting, BAAS would agree with the external suppliers upon direct supply contracts for materials which are used and needed as spare parts at the central warehouse (cf. section 5.3.4.1). The BAAS planners would not contact the factories anymore when the warehouse needs spare parts but they would place POs directly towards the external suppliers. The external suppliers would deliver the parts directly to the warehouse instead of shipping them first to the factories. The future setting would result in shorter total lead times between the external suppliers and the warehouse since the spare parts could skip the time-consuming detour via the factories (cf. section 5.3.4.4 and section 6.2). Furthermore, many administrative ordering and physical order handling activities which are currently executed by the factories on behalf of BAAS could be dropped in the future setting. Obviously, there is a lot of double handling involved in the current procurement process of spare parts because many activities which have to be executed between the factories and the external suppliers have to be executed between BAAS and the factories as well (cf. section 5.2.5.2). According to the future setting, this double handling could be reduced or completely avoided because BAAS would interact and communicate directly with the external suppliers and not with the factories anymore (cf. section 5.3.3.2). However, there are many different aspects to consider in the evaluation of the current and proposed situation and the future setting would have many different consequences for the whole SPSC and in particular for the factories and BAAS. The following sections first analyze the proposed purchasing strategy based on a purchasing process model and afterwards focus on the most important consequences for both the factories and BAAS in more detail. While the following sections serve more as a qualitative analysis, chapter 6 represents a more quantitative analysis of the current and proposed purchasing process. In section 6.1, possible time and cost savings are estimated based on a detailed process overview of 25 different steps in the current and 12 different steps in the proposed purchasing process.

5.3.2 Purchasing Process Model

Van Weele (2010) developed a purchasing process model which visualizes the core elements within the purchasing function of a company and which can be used to compare the current and the proposed purchasing process within KvG.

FIGURE 5.3.2: PURCHASING PROCESS MODEL[27]



As Figure 5.3.2 shows, the different purchasing process elements are grouped into tactical purchasing which refers to sourcing-related tasks and order function which encompasses all supply activities. Purchasing process elements of tactical purchasing represent determining specification, selecting supplier and contracting whereas the order function involves ordering, expediting & evaluation and follow-up & evaluation. According to the current Kverneland purchasing strategy all these tasks should be executed by the purchasing departments of the factories (cf. section 5.2.5.2). This applies to the purchasing of all external procurement parts which are needed in the production at the factories but also to the purchasing of all parts which are only needed as spare parts at the central warehouse. The proposed setting however, would lead to some changes in responsibilities for the different steps. In the following, let us take a closer look at the characteristics of the six different steps and how they should be managed in the future setting. The factories should be still entirely in charge of the first two steps, determining specification and selecting supplier. Since every production company manages an own R&D competence center (cf. section 4.2.1), it is obvious that the factories have the most advanced knowledge of the technical specifications and requirements of the parts which are needed for the production of Kverneland machines. Therefore, the factories should stay responsible for the determination of qualitative specifications towards external suppliers. This is also true for parts which are not needed in the production anymore but which are only used as spare parts. Selecting the best supplier is heavily linked with the determination of specifications and belongs to the core business of the factories. As a R&D manager of the factory in NV explained, it is very important to choose suppliers on the basis of quality issues and reliability and not purely based on financial aspects. The financial consequences of choosing a cheap supplier who delivers parts of a poor quality could be much more severe than choosing an expensive supplier who

[27] Cf. van Weele 2010

delivers high quality parts. If customers realize that production parts within Kverneland machines or spare parts provided by Kverneland are of a poor quality, they would not buy Kverneland products again. This would cost the group far more than choosing an expensive supplier who could offer high quality parts. Contracting as the third step would have to be divided between the factory and BAAS. The supplier contracts which are currently limited to the factories would have to be expanded to group contracts so that the established agreements between the suppliers and the factories would also be valid for business activities between the suppliers and the warehouse (cf. section 5.3.4.1). In the current setting, all steps which are part of the order function towards external suppliers are executed by the factories. Additionally, when spare parts are needed at the warehouse the same order function activities have to be executed by BAAS towards the factories as well. In the future setting the order function towards external suppliers should be completely in the responsibility of BAAS when the warehouse needs spare parts and should be completely in the responsibility of the factories when they need production parts. As a result the order function activities between BAAS and the factories could be reduced to a minimum and the factories could limit their order function activities to production parts.

5.3.3 Consequences for Production Companies

In this section the most important consequences of the proposed setting for the Kverneland factories are presented. Besides of the financial consequences, all relevant aspects regarding administrative ordering, physical order handling and shipping are analyzed in more detail (cf. 3. RQ).

5.3.3.1 *Financial Consequences*

The Kverneland factories benefit from the current setting because they sell the external procurement spare parts at internal transfer prices (TP1) towards the warehouse which are higher than the corresponding purchase prices (DC1 (Direct Cost)) which they pay towards the external suppliers. If we assume that there are no additional costs related to the spare parts business of the factories except of paying the DC1 towards the external suppliers, the factory in NV achieves an average margin of more than 50% with its yearly spare parts sales (cf. section 6.3.1). In the future setting, the warehouse would buy these spare parts directly from the external suppliers and not from the factories anymore. This would result in lower total profits for the factories because the total amount of spare parts sales where the factories achieve relatively high margins would decrease considerably. However, the proposed setting would also lead to financial savings at the factories because the administrative ordering activities and the physical order handling of spare parts on behalf of BAAS could be reduced and less spare parts would have to be bought and paid. Nevertheless, the total profits of the factories would decrease and they would suffer from the future setting. Hence, the top management of KvG wants to implement the proposed purchasing strategy only if the factories would not suffer from a change to the future setting and if they would be compensated for lost sales. Therefore, BAAS should pay reasonable design fees towards the factories when the warehouse would source spare parts directly from external suppliers. That way, the factories could be compensated for the financial losses of the future setting and they could be convinced of the advantages which the proposed purchasing strategy would have on the group's SPSC performance. The design and development of the compensation fees is part of a later chapter in the analysis chapter of this thesis (cf. section 6.3.3).

In the daily business of the factories, not only the profits but also the turnovers play a very important role. The yearly business plans and the factory budgets are based on the planned turnovers which consist not only of the planned turnovers of Kverneland machines but also of the planned turnovers of spare parts. Every factory manager is anxious that his factory achieves the planned turnovers and is accountable for the realization of the business plans and budgets. Therefore, a change from the current to the proposed purchasing strategy should be realized at the beginning of a new financial year and should be taken into consideration when setting up new business plans and budgets. Additionally, the proposed purchasing strategy and its impact on the factory turnovers should also be in line with the strategy and vision of the top management of KvG (cf. section 4.2.2) and should be agreed upon with its owners (Kubota) who determine and authorize the business plans and budgets.

5.3.3.2 Purchasing Process of Spare Parts

In the future setting, the administrative ordering and physical order handling activities which are currently executed by the factories on behalf of BAAS (cf. section 5.2.5.2) could be reduced to some special cases. Hence, the factories could focus more on their core business which is the development and production of machines and not the ordering and handling of spare parts. All available resources should be used to support the core business of the factories and ordering and handling activities should be limited to parts which are needed in the production of machines. In the following, some particular examples are presented which show how a change to the proposed setting would influence the work and the conditions of the factories (cf. section 5.2.5.2.4).

Less ordered parts would lead to less picking activities for the factory employee who follows up the transfer orders. Especially the time-consuming and counterintuitive picking of Kanban parts from the assembly line could be avoided. It would be more efficient if the BAAS planners would order these parts directly from external suppliers and the Kanban system would be only affected by the demand and consumption of the respective factory.

In the future, the factories would not have to order excess quantities of STAPs anymore and they would not have to scrap parts ordered on behalf of BAAS anymore. Hence, the factories could reduce their STAP stocks considerably. In case of the factory in NV, this could lead to substantial space savings because the STAPs currently occupy a whole storage hall on the factory premises which should be rather used for factory purposes (e.g. storing of production parts) than for storing spare parts on behalf of the central warehouse.

According to the proposed purchasing strategy, the purchasing departments of the factories would not have to consolidate orders and requisitions for the factories and BAAS anymore but could completely focus on their own factory needs. Moreover, the risk that spare parts are not needed anymore by BAAS when they arrive at the factories could also be reduced.

Less ordered parts would also lead to less arriving shipments at the inbound areas of the factories and to less physical order handling of arriving parts. A reduction of arriving goods also implies a reduction of quantity and quality discrepancies which have to be followed up at the factories. However, in the future setting these activities would have to be executed by the warehouse which might require technical support from the factories in special cases (cf. section 5.3.4.5). Furthermore, in the future, mainly production parts would arrive at the factories and it would not have to be differentiated anymore if parts could stay at the factories or if they have to be shipped to Metz.

5.3.3.3 Shipping Process

Even in the future setting, there would be trucks going from the factories to the warehouse because all parts which are manufactured in-house and all parts which have to be modified at the factories would have to be shipped from the factories to the warehouse when needed by BAAS. The same applies to all parts which have to undergo a quality control which can only be executed at the factories (cf. section 5.1.2.3). In total, less parts would have to be shipped from the factories to the warehouse and less parts would have to be shipped from external suppliers to the factories but on the other hand more parts would have to be sent from external suppliers to the warehouse. According to the procurement manager of the central spare parts warehouse, the total shipping costs would be approximately the same in both settings and shipping does not represent an important savings potential of the proposed purchasing strategy. Therefore and to narrow down the scope of this investigation, it was decided that the calculation of the total shipping costs is not considered relevant for the purpose of this thesis.

5.3.4 Consequences for Business Area After Sales

There are a lot of different aspects to consider when analyzing the consequences of the proposed purchasing strategy for BAAS. This section deals with the most important consequences for BAAS in terms of supply contracts, purchase prices, administrative ordering, physical order handling, lead times and quality control.

5.3.4.1 Supply Contracts

Before the proposed purchasing strategy could be realized, the procurement manager of the central warehouse would have to agree with the respective external suppliers upon direct supply contracts. One of the most important conditions of these contracts would concern the purchase prices of spare parts (DC1). In case of IUPs, both the factories and the warehouse would have to order parts from external suppliers and both should pay the same DC1 as the factories in the current setting. In case of STAPs, only the warehouse would have to order spare parts from external suppliers[28] but should also pay the same DC1 as the factories in the current setting. KvG has to convince its external suppliers that the total group volumes of spare parts would remain the same irrespective of the two settings and hence also the DC1 should remain the same. The only difference for the external suppliers would be one additional delivery address (central warehouse) compared to the current setting. Furthermore, the procurement manager should try to agree upon smaller and more flexible minimum order quantities than in the current setting when he signs the initial supply

[28] This does not apply to all parts which have to be modified or can only be controlled at the factories since these parts still have to be send from external suppliers to the factories.

contracts with the external suppliers. As described in section 5.2.5.2.1, the current minimum order quantities are often higher than the quantities of parts which BAAS actually needs.

5.3.4.2 Purchase Prices

In the current setting, the warehouse pays fixed internal transfer prices (TP1) to the factories for each spare part which is delivered from the factories to the warehouse. The TP1s consist of the DC1 which the factories pay to the external suppliers and markups on the DC1 designed for the factories. In the future setting, the warehouse would buy spare parts directly from the external suppliers and would therefore only pay the DC1. As the director of the central warehouse explained, the lower purchase prices would also have a positive impact on the capital tied up in inventory because the calculation of the value in inventory is based on moving average prices. If the purchase prices would decrease, the moving average prices would also decrease over time and consequently less capital would be tied up in inventory at the warehouse. Furthermore, the warehouse would sell the spare parts which were ordered by its customers at the same transfer prices as in the current setting (TP2) and since the warehouse would only have to pay the DC1 for these parts, it would automatically achieve very high margins and profits with each spare part sale. These profits would be approximately equivalent to the sum of the profits which the factories and the warehouse achieve in the current setting if we assume that there are no additional costs related to the spare parts business except of paying the respective spare parts price to the actor who is located one stage further upstream in the supply chain. This would be very beneficial for the warehouse but is not in the interest of the factories which would lose the margins and profits of their current spare parts sales to the warehouse and would have to plan with lower turnovers. Moreover, this is also not in the group interest since the top management wants to implement the proposed purchasing strategy only if the factories would not suffer from a change to the future setting and if they would be compensated for lost sales. As mentioned in section 5.3.3.1, this aspect as well as the design and development of adequate compensation fees will be discussed in more detail in section 6.3.

5.3.4.3 Purchasing Process of Spare Parts

In this section, necessary changes from the current to the future setting which concern administrative ordering and physical order handling activities of BAAS are presented.

The future setting would lead to some changes for the work of the BAAS planners because they would stay in direct contact with an increasing amount of different external suppliers and would have to focus more on typical purchasing activities like expediting. Besides, ordering and following up orders towards external suppliers is usually more time-consuming than towards internal suppliers. Thus, an increasing amount of external suppliers could result in the need for an additional BAAS planner at the "IS & Planning" department.

In the future setting, BAAS could not order any arbitrary quantity of parts anymore but would have to order in quantities determined by the external suppliers (cf. section 5.2.5.2.1). These minimum order quantities would be probably higher than the quantities which BAAS would prefer to order and they would lead to increasing stock levels for some parts. From the group perspective, it does not make a huge difference if the excess quantities are stored at the factories or at the warehouse but nevertheless, in contrast to the factories, the warehouse is highly specialized in storing spare parts. At the same time, higher order quantities would also lead to a lower order frequency because instead of ordering the same parts several times, BAAS could just take them from the increased inventories when needed. A lower order frequency would consequently also lead to lower total ordering costs.

An increasing amount of direct orders towards external suppliers would consequently also lead to an increasing amount of direct shipments which arrive at the warehouse. This is because in the current setting, all shipments from external suppliers are first delivered to the respective factories and then the different parts are delivered in consolidated shipments towards the warehouse. However, for most parts the total number of PO lines would stay the same in the future setting and for some parts it could even be lowered if the order frequency could be decreased as just mentioned above. This is important to consider because BAAS pays fixed prices per PO line for the inbound activities of its subcontractor. Hence, the total costs for handling arriving PO lines would not be higher in the future setting even if more shipments would arrive at the warehouse than in the current setting.

In the future setting, the required spare parts would have to be shipped only one time instead of two times and they would not have to be handled in between the two shipments at the factories (cf. section 5.2.5.2). That would reduce the risk of transportation damages and the risk of quantity and quality discrepancies because as the current setting shows, not only discrepancies between the external suppliers and the factories take place but sometimes also discrepancies between the factories and the warehouse occur.

Another positive aspect of the future setting would be the direct communication between BAAS and the external suppliers. In cases of quantity or quality discrepancies at the warehouse, the external suppliers could be contacted directly and it would not have to be investigated if the external suppliers or the factories would be responsible for the discrepancies.

Furthermore, the warehouse often needs documents from its suppliers which are needed for the transportation of parts to further upstream located stages of the SPSC (e.g. certificate of origin of spare part).[29] The documents are usually required very urgently because the parts are not allowed to be shipped without them. In the current setting, the warehouse has to contact the factories as the internal suppliers to get these documents but in many cases they cannot respond and have to contact the external suppliers who produced these parts. It can take a lot of time until the warehouse finally receives the needed documents and can ship the parts to its customers. In the future setting, the warehouse would know exactly which external suppliers produced which parts and could contact them directly when important documents are required. This would speed up the whole process and the parts could be shipped earlier to the next stages.

5.3.4.4 Lead Times

One of the most important aspects to consider when comparing the current purchasing strategy with the proposed one is the impact of direct deliveries from external suppliers to the central warehouse on the lead times of spare parts which are ordered by the warehouse planners. Lead times have a big influence on inventory planning and replenishment policies and lead time savings can be very beneficial for the business of a warehouse and the performance of a SPSC (de Treville et al. 2004). Hiller and Liebermann (2001) regard unnecessarily long lead times as a form of waste and minimizing or avoiding waste as a key component of superior inventory management. In the current setting, three stages of the SPSC are involved in the purchasing process of standard external procurement spare parts which are needed at the warehouse but which are not on stock at the factories. In the future setting, only two stages of the SPSC would be involved in the procurement process. Obviously, both the physical flow and the information flow of the spare parts could be

[29] These documents are especially required for shipments to countries in CEE which represents one of the main future target markets of KvG (cf. section 4.2.2).

reduced in the future setting since the time-consuming detours via the factories could be completely skipped and the parts could be delivered directly from the external suppliers to the warehouse. The direct communication between BAAS as the stage which is in need of parts and the external suppliers as the stage which produces parts could additionally reduce lead times. The warehouse planners would contact the external suppliers immediately when parts would be required and they would not have to wait until the factories would contact them. That way, the time between the POs from BAAS towards the factories and the POs from the factories towards the external suppliers could be saved. As agreed upon with the procurement manager of the warehouse in Metz, one can assume that the lead time between a specific external supplier and the respective factory in the current setting would be approximately equivalent to the lead time between the same external supplier and the warehouse in the future setting. In some cases the lead time could even be shortened e.g. when the supplier is located closer to the warehouse than to the respective factory.

The lead time reductions which could be realized with a change from the current to the proposed purchasing strategy would lead to several improvements for the warehouse planning which are presented in the following. Shorter lead times would facilitate a more flexible and customer oriented planning and would lead to a reduction of uncertainty. According to the BAAS planners, this uncertainty could be reduced especially in the context of forecasting the demand during the lead time. Obviously, the lead time demand forecasts would be more accurate when the lead times could be reduced because the shorter the demand period which has to be forecasted is, the more precise will be the forecast.[30] In addition, shorter lead times would consequently lead to lower demands during the lead time and would result in less variability. Lower lead time demands, less variability and a reduction of uncertainty would automatically reduce the necessary safety stocks at the warehouse. Hence, shorter lead times would also result in a reduction of average inventories, reorder levels and order up-to levels. Decreasing average inventories imply less capital tied up in inventory and higher stockturns. Moreover, less average inventories mean less inventory holding costs. The head of the BAAS planning department mentioned two additional positive aspects of shorter lead times. Firstly, large and unexpected sales orders can easily lead to stockout situations at the central warehouse which imply the great risk of

[30] E.g. a forecast for a period of one month is usually more precise than a forecast for a period of two months.

lost sales. The length of these stockout situations and the risk of lost sales could be reduced with shorter lead times because the stock could be refilled faster. Secondly, he made the observation that the longer the fixed lead time between the warehouse and the factories is, the higher will be the probability that the parts will not arrive on time. *E.g. a part with a fixed lead time of 90 days will often be delivered too late because the factories postpone its procurement or production whereas a part with a fixed lead time of 20 days will often be delivered on time because the factories start with its procurement or production shortly after they received the order.* Moreover, shorter lead times in the upstream part of the supply chain could also have positive effects on the downstream part of the supply chain and could improve the customer service and the entire SPSC performance. In section 6.2, the prevailing inventory planning and replenishment policies of the central spare parts warehouse in Metz are modeled and explained in more detail. Furthermore, one specific supplier is chosen as an example to estimate possible stock reductions at the warehouse based on the above described lead time savings which could be realized with a change from the current to the proposed purchasing strategy.

5.3.4.5 Quality Control

Sometimes, parts have to be controlled on quality aspects after they have been delivered from an external supplier towards KvG. In the current setting, all parts are first shipped to the factories and when a quality control has to be executed, the quality department of the respective factory takes care of it. Some quality control activities require specific resources which are only available at the factories but not at the warehouse. Therefore, it is not possible to execute an advanced quality control at the warehouse in the current setting (cf. section 5.2.5.2.2). But also in the future setting it is not necessary to establish an advanced quality control at the warehouse since the majority of parts which arrive at the factory and which are delivered to Metz are also not controlled in the current setting. In the future setting, the warehouse in Metz should have access to the quality control report of the factory. As long as the warehouse only purchases parts from “A suppliers”, it is not necessary to execute a quality control. When a supplier receives a worse grading, it has to be decided case by case if a quality control has to be executed. In theory, there are four different options possible in such a situation. First of all, the warehouse could acquire some of the resources which are necessary to execute more basic quality controls. This is in line with a current warehouse project of improving the local quality control and aligning it with the quality control of the factories. Secondly, the receiving parts could be controlled by external quality control specialists. Thirdly, parts which require an advanced quality control could be sent to the factories for inspection. And finally, in special cases and for suppliers who have been unreliable over a longer period of time the old setting could be reintroduced until their grading gets better.

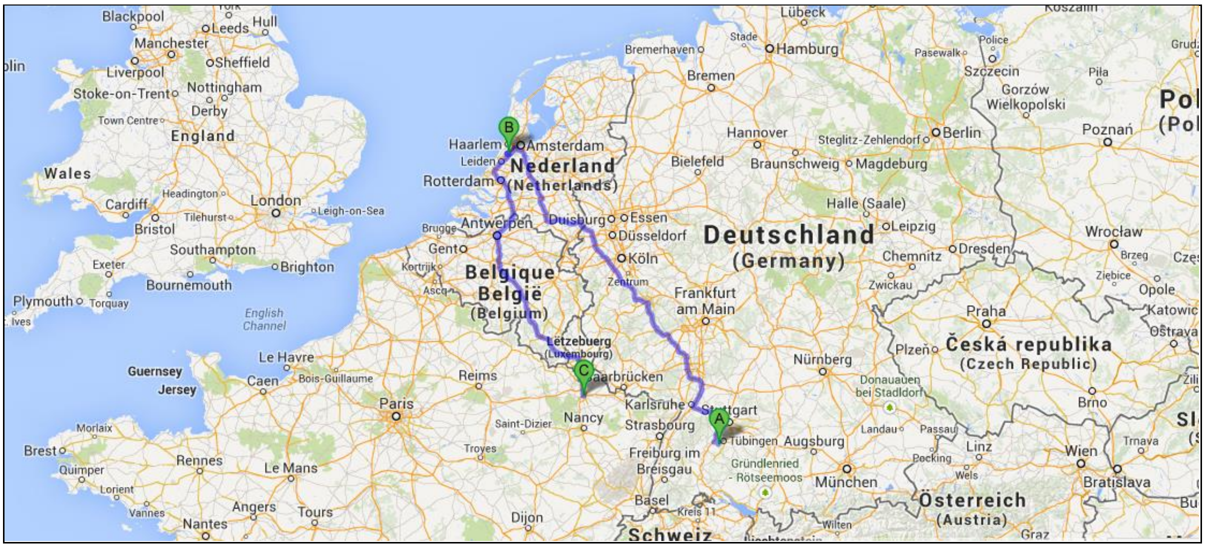
6 Analysis

This chapter represents the analysis part of this thesis. As described in the introduction, the analysis is divided into three main sections. Section 6.1 deals with the current double handling at the production companies and how the proposed purchasing strategy would affect the business processes at the factories (cf. 3. RQ). Section 6.2 investigates which impact the future setting would have on the stock levels and the capital tied up in inventory at the central spare parts warehouse (cf. 4. RQ). Section 6.3 finally examines how the Kverneland factories could be compensated for the lost turnovers which they would experience when the central warehouse would source spare parts directly from external suppliers (cf. 5. RQ). Before the actual analysis part of this study commences, let us first introduce one specific external supplier of the factory in NV to narrow down the scope of this thesis. Together with the procurement manager of the central warehouse in Metz, it was decided to take a closer look at supplier 4 which serves as an interesting case to illustrate the main findings of the sections 6.1 and 6.2. Supplier 4 is mainly delivering hydraulic materials like pumps for the sprayers which are assembled at the factory in NV and was chosen first of all, because it is one of the most important suppliers of the factory in terms of total ordered value, total number of POs and total number of PO lines (especially for STAPs). Additionally, the purchasing department of the factory places more PO lines towards this supplier for parts which are needed as spare parts in Metz than for parts which are needed as production parts in NV.[31] This implies that there is a high savings potential related to the introduction of the proposed purchasing strategy for parts which are coming from supplier 4 because the majority of orders could be placed directly from BAAS towards the supplier and the factory could reduce its order activities to parts which are needed for production purposes. Hence, many costs regarding the administrative ordering but also regarding the physical order handling of spare parts from supplier 4 could be saved at the factory (cf. section 6.1). Furthermore, supplier 4 delivers many different parts with a relatively high

[31] Cf. Appendix 6.A: Supplier 4 represents 6.15% of the total ordered value of all suppliers (3rd), 2.93% of all POs (5th) and 7.37% of all PO lines (3rd). Furthermore, supplier 4 represents 34.59% of all PO lines for STAPs (1st) and 49.22% of the total ordered value of STAPs. Additionally, more than two thirds (68.52%) of all PO lines towards supplier 4 correspond to STAPs.

material value compared to the common spare parts values[32] which implies that there is a high savings potential related to stock reductions for spare parts which are coming from supplier 4 and which are hold on stock at the warehouse in Metz (cf. section 6.2). Finally, supplier 4 is located closer to the central spare parts warehouse in Metz than to the factory in NV since it is based in South West Germany. This means that the shipping distance and the lead time between supplier 4 and the warehouse is shorter than between the supplier and the factory which again demonstrates the suboptimal character of the current purchasing strategy. The following figure indicates the locations of supplier 4 (A), the factory in NV (B) and the warehouse in Metz (C).[33]

FIGURE 6: LOCATIONS OF SUPPLIER 4, FACTORY NIEUW-VENNEP AND CENTRAL WAREHOUSE METZ



The following shipping distances between the three locations could be identified with the help of Google Maps: $A \rightarrow B = 677km$, $A \rightarrow C = 329km$, $B \rightarrow C = 467km$.[34] Hence, the

[32] Cf. Appendix 6.B: In the current setting, supplier 4 delivers 25 of the 90 spare parts with the highest value which the warehouse planners have to order from the factory in NV.

[33] Figure 6 is part of a screenshot of the following Google Maps URL: Google. <https://maps.google.de/maps?saddr=Rottenburg&daddr=Nieuw-Vennep+to:Metz&hl=de&ll=50.625073,10.788574&spn=7.23573,21.643066&sll=50.429518,6.70166&sspn=7.265702,21.643066&geocode=FZy74wIdlW2IACn7bX3D9v2ZRzGwe9-lt2sfBA%3BFVx8HQMd-axGACkp0dvIq8LFRzEcmoLQbfV6KQ%3BFbKB7QIdiUBeACmptnRgG9yURzFpprs1tuRrWQ&mra=ls&t=m&z=6> (12/15/2013).

current shipping distance for spare parts which are coming from supplier 4 and which are needed at the central warehouse in Metz is 1,144 km and the shipping distance in the future setting would be only 329 km which corresponds to a reduction of 71.24%.

6.1 Double Handling at Production Companies

As noticed in section 5.3.1, there is a lot of double handling involved in the current purchasing process of external procurement spare parts which are needed at the central warehouse and which have to be ordered by BAAS from the respective Kverneland factories. Many administrative ordering and physical order handling activities are executed both at the factories and within BAAS. The proposed purchasing process would lead to a reduction of double handling since BAAS would order the required spare parts directly from external suppliers and the factories would be excluded in the procurement process (cf. 3. RQ). Thus, the factories could focus more on their core business which is the development and production of machines and not the ordering and handling of spare parts. In the following subsections, all important steps which are part of the current and proposed purchasing process of STAPs and IUPs are presented by the example of the factory in NV. While section 6.1.1 deals with the different procurement steps and the respective time and cost figures in the case of STAPs, section 6.1.2 analyzes the same aspects regarding IUPs. Both sections serve as a basis for the final process overview document which can be found in Appendix 6.1.1 and Appendix 6.1.2. In section 6.1.3 the main findings of the preceding savings analysis and the savings based on direct costs are presented.

6.1.1 Stand Alone Parts

This section illustrates the complex purchasing process of STAPs with the help of a process overview of 25 different steps in the current setting and 12 different steps in the future setting. For most of the different steps, time and cost figures per PO line could be estimated after various company visits and discussions with key managers of the central warehouse in Metz, the planning department in Klepp and the factory in NV. So far, nobody within KvG has ever written down these different purchasing processes and settings and nobody has ever

[34] Cf. Google. <https://maps.google.com/maps?hl=de&tab=wl> (12/15/2013). and insert $A = Rottenburg$, $B = Nieuw\text{-}Vennep$ and $C = Metz$

made any calculations regarding this subject. The final document can be used to estimate possible group savings which could be realized with a change from the current to the proposed purchasing process.

6.1.1.1 Identification of Processes

STAPs are not used in the production of Kverneland machines and they are usually not on stock at the factory anymore. Therefore, one underlying assumption of the process overview is that the factory has to order STAPs from the respective external suppliers on behalf of BAAS. As Table 6.1.1.1.A shows, there are 25 different steps which have to be executed after an order for STAPs was triggered at BAAS.

TABLE 6.1.1.1.A: CURRENT PURCHASING PROCESS OF STAND ALONE PARTS

Step	Activity
1	BAAS sends order to NV
2	BAAS takes care of expediting towards NV
3	NV gets order from BAAS and creates new order
4	NV sends order to SS
5	NV takes care of expediting towards SS
6	SS gets order from NV and confirms it
7	SS ships parts to NV
8	NV receives and unpacks parts
9	NV registers parts
10	NV counts and controls parts
11	NV stores parts at inbound or stock for BAAS
12	SS sends invoice to NV
13	NV registers and pays invoice from SS
14	NV creates picking list
15	NV picks parts from inbound or stock for BAAS
16	NV packs parts
17	NV creates inbound documentation and sends it to BAAS
18	BAAS receives inbound documentation and updates system
19	NV ships parts to BAAS
20	BAAS receives and unpacks parts
21	BAAS registers parts
22	BAAS counts and controls parts
23	BAAS stores parts
24	NV sends invoice to BAAS
25	BAAS registers and pays invoice from NV

The first two steps are related to the ordering of spare parts from BAAS towards the factory. The BAAS planner sends the respective PO via SAP to the factory (1) and takes care of the expediting issues between the factory and BAAS until the parts finally arrive at the warehouse (2). The next 15 steps are carried out by the factory on behalf of BAAS. They belong to the ordering process of parts from the factory towards the external supplier and to the handling activities of parts which arrive at the factory and which have to be delivered to Metz. After receiving the order from BAAS, the factory purchaser creates a new PO which should be consistent with the request of the BAAS order (3). This PO is then sent to the respective external supplier (4). The factory purchaser takes care of all expediting issues between the supplier and the factory until the parts arrive at the factory (5). The expediting activities are based on the discrepancies between the order confirmation which the supplier sends after he has received the PO (6) and his actual performance. The next step is the actual shipping of the parts from the external supplier to the factory (7). After the parts have arrived at the inbound area of the factory, four different steps have to be executed successively. First, the arriving parts are unpacked from the packages in which they were shipped from the supplier to the factory (8). Then, they are registered into the SAP system to document their goods receipt (9). Thereafter, the parts are counted and sometimes measured to check if the right quantity of the right parts was delivered (10).[35] However, a sophisticated quality control does usually not take place for parts which are going to Metz. After the quantity control, the parts either stay at the inbound area or they are stored at the STAP stock (11). After the actual parts have arrived at the factory, the external supplier sends the invoice for the respective parts to the factory (12). The factory registers the arriving invoice and pays it, given that the quantity control was successful and the right quantity of the right parts was delivered (13). The next steps refer to the work which has to be executed at the factory before the parts are shipped to the central warehouse. First, a picking list is created (14) which serves as a guideline for the factory employee who picks up the parts from the inbound area of the factory or from the STAP stock (15). Thereafter, the picked parts are carried to the outbound area of the factory where they are packed and prepared for the shipment to the warehouse (16). Before the parts are finally shipped from the factory to the central warehouse in Metz, a factory employee creates a document which basically lists all

[35] Since the process overview describes the standard case, it is assumed that always the right quantity of the right parts is delivered and the factory does not have to follow up any discrepancies.

materials which are part of the next shipment (17). This document is sent automatically via SAP from the factory to the warehouse and can be accessed by the warehouse subcontractor before the parts arrive (18). The parts are then shipped from the factory to the warehouse (19) and the subcontractors' staff takes care of the inbound process. They unpack the parts (20) and register them into the SAP system at the warehouse to document their goods receipt (21). Additionally, they count the parts and control if the arriving parts correspond with the information of the inbound document (22). The last step of the inbound process is to store the parts at their respective stocking location within the warehouse (23). The last two steps of the purchasing process concern the financial transactions between the factory and the warehouse. The factory sends the invoice for the parts via SAP to the warehouse (24) and BAAS finally pays the invoice after it was registered (25) and the parts were controlled.

The next section summarizes all the different steps which are part of the proposed purchasing process of external procurement STAPs. As Table 6.1.1.1.B indicates, the 25 steps of the current setting can be reduced to 12 different steps in the future setting.

TABLE 6.1.1.1.B: PROPOSED PURCHASING PROCESS OF STAND ALONE PARTS

Step	Activity
1	BAAS sends order to SS
2	BAAS takes care of expediting towards SS
3	SS gets order from BAAS and confirms it
17	SS creates inbound documentation and sends it to BAAS
18	BAAS receives inbound documentation and updates system
19	SS ships parts to BAAS
20	BAAS receives and unpacks parts
21	BAAS registers parts
22	BAAS counts and controls parts
23	BAAS stores parts
24	SS sends invoice to BAAS
25	BAAS registers and pays invoice from SS

In the future setting, the BAAS planner places the purchase order not towards the factory but directly towards the respective external supplier (1). Furthermore, he is now responsible for all expediting issues between the external supplier and the warehouse (2). These two tasks are basically the same activities that the factory purchaser carries out in the current setting in step 4 and 5. This change in responsibilities leads to more work or at least a different kind of work for the BAAS planner because expediting towards the external supplier is more time-consuming and more extensive than the current expediting activities towards the factory. At the same time, the future setting leads to a reduction of the expediting activities of the factory purchaser who can now focus more on tasks that are related to the procurement of parts which are needed for production purposes. Of course, all steps which are part of the current setting and concern activities which are executed by the factory on behalf of the warehouse (cf. Table 6.1.1.1.A, step 3-17) can be skipped completely in the future setting. After the external supplier has received the PO from the BAAS planner, he confirms it (3) and before the parts are finally shipped to the warehouse, he sends the inbound document to BAAS (17). The inbound document cannot be sent automatically via SAP because the external supplier is not electronically linked to the warehouse but it has to be sent by e-mail. When the list of shipped materials arrives at the warehouse it has to be typed in manually into the SAP system by a warehouse employee (18). This can be very time-consuming depending on the number of PO lines of the arriving shipment. Afterwards, the list has to be transferred to the warehouse subcontractor and the actual shipment from the external supplier to the warehouse can take place (19). The following inbound process at the warehouse is the same in both settings (20-23) but now BAAS receives an invoice from the external supplier and not from the factory (24). Hence, the last step of the proposed purchasing process is that BAAS pays the invoice to the supplier (25).

6.1.1.2 Identification of Time and Cost Figures

Table 6.1.1.2.A shows the estimated time and cost figures for the current situation. In total, Kverneland personnel spends 40.5 minutes on each PO line which corresponds to total costs of 45.17€ per PO line. The different underlying figures and its sources are explained in more detail further below.

TABLE 6.1.1.2.A: CURRENT PURCHASING PROCESS OF STAND ALONE PARTS WITH TIME AND COST FIGURES

Step	Activity	Time (min.)	Cost (€)
1	BAAS sends order to NV	1.00	2.10
2	BAAS takes care of expediting towards NV	2.50	5.25
3	NV gets order from BAAS and creates new order	1.50	3.15
4	NV sends order to SS	1.00	2.10
5	NV takes care of expediting towards SS	5.00	10.51
6	SS gets order from NV and confirms it	-	-
7	SS ships parts to NV	-	-
8	NV receives and unpacks parts	5.50	2.48
9	NV registers parts		
10	NV counts and controls parts		
11	NV stores parts at inbound or stock for BAAS		
12	SS sends invoice to NV	-	-
13	NV registers and pays invoice from SS	2.00	4.20
14	NV creates picking list	-	-
15	NV picks parts from inbound or stock for BAAS	8.50	3.83
16	NV packs parts	4.00	1.80
17	NV creates inbound documentation and sends it to BAAS	1.00	2.10
18	BAAS receives inbound documentation and updates system	0.00	0.00
19	NV ships parts to BAAS	-	-
20	BAAS receives and unpacks parts	6.50	3.44
21	BAAS registers parts		
22	BAAS counts and controls parts		
23	BAAS stores parts		
24	NV sends invoice to BAAS	-	-
25	BAAS registers and pays invoice from NV	2.00	4.20
Total		40.50	45.17

The time figures for the five different order steps (1-5) were provided by the procurement manager of the warehouse in Metz. The values were chosen based on his experience and figures which he obtained from a similar calculation in the past. The same applies to the time figures for registering and paying the invoice (13, 25). Furthermore, a calculation was made at the warehouse to find out how long it takes per PO line to update the SAP system manually with the information of the inbound document (18). All these steps represent administrative ordering activities and it was difficult to get concrete cost figures for them. Nobody within the factory has ever made a detailed calculation in this field and the factory could not provide a specific value for administrative order cost per PO line. BAAS however, uses 15€ administrative order cost per PO line and these costs cover the steps 1, 2, 20-23 and 25. The time and cost figures for the inbound activities at the warehouse (20-23) were easy to obtain since these costs have to be paid to the subcontractor of the warehouse who executes these activities on behalf of BAAS. For the missing three steps, time figures could be estimated which sum up to 5.5 minutes per PO line. This leads to the conclusion that it costs the company 2.10€ per minute ($\frac{15-3.44}{5.5} = 2.10$) to execute an administrative ordering activity. Based on this calculation the cost figures for all other administrative ordering activities could be estimated (3-5, 13, 17-18). The time figure for step 17 could be estimated with the help of the factory employee who creates the inbound document. He explained that it takes on average 3 hours to complete the list of material and it was observed that one list corresponds to around 180 order lines. The time figures for the physical order handling activities (8-11, 15-16) were provided by the manufacturing manager of the factory in NV. He additionally explained that the factory works with direct costs of 27€ per hour which made it possible to calculate the respective cost figures for the different order handling steps (e.g. step 15: $8.5 * \frac{27}{60} = 3.83$).

The following table shows the estimated time and cost figures for the proposed situation. In total, Kverneland personnel spends only 15 minutes on each PO line which corresponds to total costs of only 21.31€ per PO line. This leads to time savings of 25.5 minutes and cost savings of 23.86€ per PO line compared to the current setting which corresponds to relative time savings of 62.96% and relative cost savings of 52.83% per PO line. While the factory saves 30.17€ and 28.5 minutes per PO line, BAAS has additional costs of 6.31€ and spends 3 minutes more per PO line in the future setting. The sources for the different underlying figures are the same as in the estimation of the current situation.

TABLE 6.1.1.2.B: PROPOSED PURCHASING PROCESS OF STAND ALONE PARTS WITH TIME AND COST FIGURES

Step	Activity	Time (min.)	Cost (€)
1	BAAS sends order to SS	1.00	2.10
2	BAAS takes care of expediting towards SS	5.00	10.51
3	SS gets order from BAAS and confirms it	-	-
17	SS creates inbound documentation and sends it to BAAS	-	-
18	BAAS receives inbound documentation and updates system	0.50	1.05
19	SS ships parts to BAAS	-	-
20	BAAS receives and unpacks parts	6.5	3.44
21	BAAS registers parts		
22	BAAS counts and controls parts		
23	BAAS stores parts		
24	SS sends invoice to BAAS	-	-
25	BAAS registers and pays invoice from SS	2.00	4.20
Total		15.00	21.31

6.1.1.3 Data Analysis

Since we are interested in total yearly savings, the next important step is to find out how many PO lines of STAPs are usually ordered by the factory in NV on behalf of BAAS per year. An extract of the SAP system of the factory which shows all POs which were placed from the factory towards the external suppliers during the year 2012 serves as underlying data.[36] Unfortunately, NV does not use the same PO numbers as BAAS but creates new POs with new PO numbers and it is not clearly evident which POs from NV towards the external suppliers correspond to which POs from BAAS towards NV. However, since the purchasing department of the factory divides the ordered parts into different purchasing groups, it was possible to separate the parts which were ordered on behalf of BAAS from the parts which

[36] Appendix 6.A illustrates the most important information which could be gathered from this SAP extract.

were ordered for production. It was assumed that all parts which belong to the purchasing group SA5 (NV Stand Alone) were ordered on behalf of BAAS. A first look into the data showed that in total, 169 different external suppliers delivered parts to the factory in the year 2012. Out of this total number of 169 external suppliers, 103 suppliers delivered STAPs and 33 suppliers exclusively delivered STAPs. However, most of these 33 suppliers delivered only very small numbers of POs and PO lines. The total number of POs was 3,653 and it was observed that there are three different types of POs: POs only for IUPs (2,592), POs both for IUPs and STAPs (120) and POs only for STAPs (941). This shows that 25.76% of all POs which the factory created in 2012 were exclusively placed on behalf of BAAS. However, we are more interested in the number of PO lines since the time and cost figures in the process overview are based on PO lines. The total number of PO lines was 17,070 whereof 85.4% were PO lines for production parts and 14.6% were PO lines for STAPs (2,492). Additionally, the data revealed that the total ordered value of all STAPs was 931,490€ (DC1) which corresponds to 4.12% of the total ordered value of all parts (22,614,608€).

6.1.1.4 Estimation of Savings

Now, we have all required figures to calculate the total savings which could be realized within KvG when all STAPs would be delivered directly from the external suppliers to the central warehouse in Metz. Further above, we estimated time savings of 25.5 minutes and cost savings of 23.86€ per PO line. Since the total number of order lines in 2012 was 2,492, the total time savings would sum up to 63,546 minutes (1,059.1 hours or 132.39 working days[37]) and the total cost savings would correspond to 59,468.18€. One interesting example to look at is supplier 4 (cf. section 6). If Kverneland would decide to change the current purchasing strategy only for STAPs which are coming from supplier 4, this would already result in group savings of 21,981 minutes and 20,570.45€.

6.1.2 In Use Parts

Obviously, there is a high savings potential related to the proposed purchasing strategy of STAPs. Additionally, it should be also considered which group savings could be achieved if

[37] It is assumed that one working day corresponds to 8 hours.

BAAS would order IUPs directly from the respective external suppliers instead of ordering them from the factory.

6.1.2.1 Identification of Processes and Time and Cost Figures

Table 6.1.2.1 shows the 15 different steps of the current purchasing process of IUPs. It is basically a short version of the further above described current purchasing process of STAPs because in both settings, the same steps have to be carried out except of the activities which are executed between the factory and the external supplier in the case of STAPs (cf. Table 6.1.1.1.A, step 4-13). This is because IUPs do not have to be ordered by the factory on behalf of BAAS since they are already available at the factory and they can just be picked up from the Kanban system or from the factory stock when needed (15). Hence, also the respective time and cost figures for the different steps of the current purchasing process of IUPs can be taken from the "Stand Alone" process overview. As the table shows, the current purchasing process leads to total costs of 25.88€ per PO line and Kverneland employees have to spend 27 minutes in total for ordering and handling one "In Use" PO line.

TABLE 6.1.2.1: CURRENT PURCHASING PROCESS OF IN USE PARTS

Step	Activity	Time (min.)	Cost (€)
1	BAAS sends order to NV	1.00	2.10
2	BAAS takes care of expediting towards NV	2.50	5.25
3	NV gets order from BAAS	1.50	3.15
14	NV creates picking list	-	-
15	NV picks parts from Kanban or stock for NV	8.50	3.83
16	NV packs parts	4.00	1.80
17	NV creates inbound documentation and sends it to BAAS	1.00	2.10
18	BAAS receives inbound documentation and updates system	0.00	0.00
19	NV ships parts to BAAS	-	-
20	BAAS receives and unpacks parts	6.50	3.44
21	BAAS registers parts		
22	BAAS counts and controls parts		
23	BAAS stores parts		
24	NV sends invoice to BAAS	-	-
25	BAAS registers and pays invoice from NV	2.00	4.20
Total		27.00	25.88

The proposed purchasing process and the corresponding time and cost figures are exactly the same for both STAPs and IUPs (cf. Table 6.1.1.2.B). Hence, the 15 steps of the current setting of IUPs can be reduced to 12 steps and the future setting leads to relative time savings of 44.44% and relative cost savings of 17.67% per PO line. This is equivalent to time savings of 12 minutes and cost savings of 4.57€ per PO line. While the factory benefits from the future setting and saves 10.88€ and 15 minutes per PO line, BAAS has again additional costs of 6.31€ and needs 3 minutes more time than in the current setting.

6.1.2.2 Data Analysis and Estimation of Savings

The final step is now to calculate the total time and cost savings which could be realized with a change from the current to the proposed purchasing strategy of IUPs. A SAP extract was used to find out how many PO lines of production parts were needed at the warehouse in 2012.[38] The data shows that 3,677 PO lines for IUPs were required in 2012. Using the calculated savings values from the last section (12 minutes and 4.57€ per PO line) we can estimate total time savings of 44,124 minutes (735.4 hours or 91.93 working days) and total cost savings of 16,818.93€.[39] Regarding the example of supplier 4 and the case of IUPs, the time savings would correspond to 6,696 minutes and the cost savings to 2,552.34€.[40]

6.1.3 Main Findings of Savings Analysis

Now, we can finally calculate which total group savings could be achieved when the factory in NV would change from the current to the proposed purchasing process in the case of both STAPs and IUPs. The resulting time savings would sum up to 107,670 minutes (1794.5 hours or 224.31 working days) and the cost savings would amount to 76,287.11€. If the factory in NV would decide to introduce the proposed purchasing strategy for both types of parts of supplier 4, total group savings of 28,677 minutes and 23,122.80€ could be achieved. Appendix 6.1.3 summarizes the main findings of the savings analysis which were presented and discussed in the preceding sections of this chapter. The final process overview document which serves as a basis for the savings analysis and the resulting main findings can be found in Appendix 6.1.1 and Appendix 6.1.2.

6.1.3.1 Savings based on Direct Costs

As explained in section 6.1.1.2, it was difficult to determine concrete cost figures for the administrative ordering activities (steps 1-5, 13, 17-18 and 25). The factory could not

[38] The SAP extract contains all PO lines which were placed from the warehouse towards the factory in NV between 01/2012-01/2013 and which were closed until 04/2013. All relevant information of the SAP extract can be found in Appendix 6.1.2.2.

[39] In reality, as with STAPs, many IUPs have to be ordered by the factories from the external suppliers on behalf of BAAS and cannot be picked up from stock at the factories when needed at the central warehouse (cf. section 5.1.2). However, since it was not clearly evident how many of the 3,677 PO lines for IUPs could be picked up from stock and how many had to be ordered, it was assumed that all of them could be picked up. Thus, the real total time and cost savings are probably higher than according to this minimum estimation.

[40] This estimation is based on the 558 PO lines for IUPs from supplier 4 which were placed from the warehouse towards the factory in NV in the year 2012 (cf. Appendix 6.1.2.2).

provide a specific value for administrative order cost per PO line and nobody within the factory has ever made a detailed calculation in this field. Hence, it was decided to estimate the cost figures for all administrative ordering activities based on the 15€ which BAAS uses as administrative order cost per PO line. This calculation resulted in cost of 2.10€ per minute to perform an administrative ordering activity. An alternative approach was suggested by the manufacturing manager of the factory in NV. According to his approach, the cost figures for all administrative ordering activities could be estimated based on the 27€ which the factory uses as direct cost per hour to execute a physical order handling activity. As indicated in section 6.1.1.2, this calculation implies cost of 0.45€ per minute to perform an administrative ordering activity. Obviously, an estimation based on direct costs leads to lower savings than an estimation based on order costs. However, the real savings are probably higher than according to the calculation based on the direct costs because the real cost per minute to perform an administrative ordering activity should be higher than the direct cost per minute to execute a physical order handling activity. Nevertheless, the results of the savings calculation based on the direct costs can serve as a minimum estimation of the total savings. In Appendix 6.1.3.1.A and Appendix 6.1.3.1.B the current and proposed purchasing process of STAPs and IUPs as well as all corresponding time and cost figures based on the direct cost approach can be found. The resulting main findings of the savings analysis based on the direct costs are summarized in Appendix 6.1.3.1.C which can be directly compared with the results of the order cost approach which were presented in the last section (cf. Appendix 6.1.3).

6.2 Stock Reductions at Central Warehouse

As described in section 5.3.4.4, the proposed purchasing strategy would lead to shorter lead times for spare parts which are needed at the central warehouse in Metz and which are produced by external suppliers.[41] Shorter lead times result in lower safety stocks and consequently a reduction of average inventories hold at the central spare parts warehouse (cf. 4. RQ). Stock reductions automatically lead to higher stockturns, lower inventory holding

[41] Let us define lead time as the time in calendar days between the date when an order was created and the date when the respective goods were receipted at the inbound area of the location for which the order was placed. Furthermore, let us assume that one month is equivalent to 30 days which means that a lead time of e.g. 45 days corresponds to a lead time of 1.5 months.

costs and less capital tied up in inventory. Money which is invested in inventory cannot be used in other productive ways but less capital tied up in inventory facilitates alternative uses of money (Hiller and Liebermann 2001). As we will see later in this section, lead times have a high influence on the inventory management of spare parts and a lead time reduction implies a lower demand during the lead time as well as a lower demand uncertainty during the lead time (expressed as standard deviation of demand during the lead time). Furthermore, shorter lead times result in lower reorder levels and order up-to levels since these two parameters decrease with a decrease in safety stock.

In the following subsections, the current inventory management practices at BAAS regarding the determination of order quantities (cf. section 6.2.1), reorder levels and order up-to levels (cf. section 6.2.2) are modeled and the lead time as one of the most crucial input factors is decreased from its current duration to its possible future length to illustrate the effect of lead time reductions on average inventories. In section 6.2.3, an overview of the estimated stock reductions which could be realized with a change from the current to the proposed purchasing strategy can be found. The focus of the calculations is mainly set on average inventory in units per year since average inventory is one of the most important inventory-related metrics that influence supply chain performance (Chopra and Meindl 2010, chapter 3). We use the fixed lead times (PDT) which BAAS and the Kverneland factory in NV agreed upon as the current lead times because these are the lead times which also the SAS inventory optimization system at BAAS actually uses in its calculations and requisitions (cf. section 5.2.4.3). As described in section 5.3.4.4 and agreed upon with the procurement manager of the warehouse in Metz, we use the averages of the current lead times between the external suppliers and the factory in NV as the future lead times between the same external suppliers and the warehouse since these two lead times would be approximately equivalent.[42] The impact of lead time reductions on the stock at the central warehouse will be demonstrated for spare parts which are produced by supplier 4 (cf. section 6). It was decided to take a closer look at nine different spare parts to narrow down the scope of this thesis. Lead time reductions are especially beneficial for spare parts with a relatively high demand

[42] The average lead times between the external suppliers and the factory in NV were calculated based on the real lead times of all orders which were created between 01/2011-01/2013 and which were closed between 01/2011-06/2013. For the majority of spare parts, only a few different real lead times which were not highly fluctuating could be identified. Therefore, we do not take lead time uncertainty into account but assume that the lead times are constant and not variable.

and stock reductions are especially beneficial for spare parts with a relatively high value. Hence, spare parts with both a relatively high demand and a relatively high value were chosen as objects of investigation. The following table gives an overview and presents the main characteristics of the nine spare parts which were chosen as examples for the inventory calculations. Appendix 6.2 serves an extended version of the overview with demand figures for each month of the year.[43]

TABLE 6.2: EXAMINED SPARE PARTS[44]

Spare Part	Description	C (€)	D	σ_D	fr	L_{old}	L_{new}
RG00034744	Qv-Reglerkörper Mit Elektr.Regelung	500.09	2.50	2.60	0.98	1.93	0.73
RG00037241	Pump 120l/min	331.00	1.33	1.93	0.98	1.93	0.80
RG00037242	Pump 140 l/min	529.92	1.10	1.28	0.98	1.93	1.17
RG00039683	Pump 200 l/min Suct.=Ri-Press=Le	497.06	2.67	2.44	0.98	1.93	1.07
RG00062998	Pump 200 l/min Suct.= Le.	496.99	5.00	4.52	0.98	2.67	1.30
VNB4203478	Pump 200L P=L / Z=R	498.38	0.19	0.53	0.92	2.67	1.27
VNB4294378	ERM Trailed	502.56	1.48	1.74	0.98	2.93	1.90
VNB4294778	ERM D2	432.51	0.29	0.54	0.92	2.93	1.90
VNB4457478	Pump 250L	679.34	2.06	2.24	0.98	2.93	2.07

6.2.1 Determination of Order Quantities - EOQ Model

As we have seen in section 5.2.4.2, BAAS developed some rules to determine which spare parts should be hold on stock at the central warehouse and which service levels should be realized for these parts. The corresponding fill rates range between 92%-98% which means that most of the spare parts demand has to be satisfied directly from stock whenever it

[43] All demand figures concerning the examined spare parts are based on demand data at the central spare parts warehouse in Metz for the months 01/2009-05/2013. Furthermore, it is assumed that the demand in the different months is independent and neither positively nor negatively correlated.

[44] The following abbreviations were used: $C = moving\ avg\ price$, $D = average\ demand\ per\ month$, $\sigma_D = standard\ deviation\ of\ demand\ per\ month$, $fr = fill\ rate$, $L_{old} = current\ lead\ time\ (months)$ and $L_{new} = future\ lead\ time\ (months)$

arrives. This implies that BAAS has to anticipate and forecast the spare parts demand and has to order and stock the parts already before the sales orders from the customers arrive. Before we consider the stock holding policies of the BAAS planning department and the determination of the stock and safety stock levels at the central warehouse in Metz, we have to check how the respective order quantities are generated.[45] The head of the BAAS planning department explained that the order quantities are determined with the help of the following formula which the planning department calls “Optimal order quantity”:

$$optimal\ order\ quantity = \sqrt{\frac{2 * order\ cost * forecast}{moving\ avg\ price * 0.15}}$$

Formula 6.2.1[46]

This formula is basically the same as the traditional EOQ formula (cf. Formula A.6.2.1.E in Appendix 6.2.1) which is commonly and widely used in practice and theory and hence can be found in most of the relevant textbooks (Chopra and Meindl 2010, chapter 10; Erlenkotter 1990; Nahmias 2009; Silver 1999; Tempelmeier 2006). The derivation of the EOQ formula, a sample calculation and the effect of an increasing order quantity on the total annual costs can be found in Appendix 6.2.1. One of the main assumptions of the EOQ formula is a known fixed demand rate (deterministic demand) for which it provides optimal results. However, even in the case of uncertain stochastic demand, the EOQ formula serves as a good approximation.[47] Fortunately, the EOQ formula has been found to be robust in the sense that it generally still provides nearly optimal results even when its assumptions are not entirely satisfied (Hiller and Liebermann 2001).

6.2.2 Determination of Average Inventories based on (s, S) Replenishment System

Let us now consider the management of spare parts inventories and safety stocks at the central warehouse and the prevailing replenishment policies of BAAS. Since the purpose of

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[45] For reasons of clarity and comprehensibility, let us assume in the following that BAAS can order any arbitrary quantity of parts and does not have to take minimum order quantities into account.

[46] Cf. Kverneland Group Business Area After Sales. 2010. SAS Season Prep Team Kerteminde. PowerPoint presentation.

[47] This is also the case for the continuous review policy which is applied in the succeeding sections.

section 6.2 is to estimate possible stock reductions at the central spare parts warehouse which could be realized with the help of decreasing lead times, we first have to find out how average inventory is commonly determined. In most of the relevant textbooks, it can be found that average inventory is calculated as follows (Chopra and Meindl 2010, chapter 11):

$$average\ inventory = safety\ stock + cycle\ inventory = ss + \frac{Q}{2}$$ **Formula 6.2.2.A**

While cycle inventory can easily be determined as the half of the respective economic order quantity Q, the calculation of the safety stock ss is more complex and requires different input factors. The safety stock ss is defined as the difference of the reorder level s (often referred to as the reorder point (ROP)) and the average demand during the lead time $D_{L:}$

$$ss = s - D_L$$ **Formula 6.2.2.B**

The average demand during the lead time D_L is given as the product of the average demand per period D (e.g. per month or per year) and the lead time L (stated in periods):

$$D_L = D * L$$ **Formula 6.2.2.C**

Before we demonstrate how to obtain the appropriate reorder level s subject to four different demand assumptions, we now present the prevailing replenishment policies of BAAS. According to an IS manager, BAAS uses the (s, S) replenishment system subject to a service level constraint (fill rate) for all spare parts which are hold on stock at the warehouse in Metz. The (s, S) or min-max system is based on a continuous review of the stock level of a spare part and determines that as soon as the inventory of a specific spare part is less than or equal to a predefined reorder level s, BAAS has to order a specific quantity of this spare part to reach a fixed order up-to level S (as soon as inventory ≤ s, order up to S). For the purpose of this study, let us assume that the reorder level s is always reached exactly and that the inventory level cannot drop below s at a reorder instance. This implies that the inventory is monitored continuously and each individual customer order is for one unit. Basically, this approach is very similar to a (s, Q) system where a fixed quantity Q has to be ordered whenever the inventory is less than or equal to s (as soon as inventory ≤ s, order Q). In our case, let us determine the values for s and Q as in a standard (s, Q) replenishment system and set $S = s + Q$. This approach to obtain the appropriate value for S is applied among others by Guajardo et al. (2012) who examined and improved the min-max inventory system of a large energy company and producer of oil and gas. From the relevant textbooks, we know that it is common to use the EOQ formula to determine the fixed quantity Q (cf. section 6.2.1). The next step is the calculation of the appropriate reorder level s. As we will see in section 6.2.2.1, we apply a similar sequential approach to obtain the appropriate value for s as among others Guajardo et al. (2012). The sequential computation of s and $S = s + Q$ is a common approach in the literature of inventory control (Porras and Dekker 2008; Silver 1999; Vereecke and Verstraeten 1994) and will be explained in more detailed further below. Guajardo et al. (2012) evaluate the fill rate (ß) consecutively, starting from $s = 0$ and introduce $\widetilde{ß}_s$, the approximated fill rate achieved for a given reorder level s. If the service level ß is not satisfied, i.e. if $\widetilde{ß}_s <$ ß, they try $s = s + 1$ and so on, until they find the lowest value of s such that $\widetilde{ß}_s \geq$ ß.[48]

In the following four sections, four different assumptions about the spare parts demand are made and the determination of the corresponding replenishment parameters is explained. At the end of each section, the resulting safety stock and average inventory levels for all nine examined spare parts based on both the current (old) lead time and the future (new) lead time are presented. The four different demand assumptions refer to normal distributed demand without seasonality (cf. section 6.2.2.1), Poisson distributed demand without seasonality (cf. section 6.2.2.2), normal distributed demand with seasonality (cf. section 6.2.2.3) and Poisson distributed demand with seasonality (cf. section 6.2.2.4). We first assume a normal distributed demand without seasonality to demonstrate the basic calculations behind the determination of the reorder level s and the resulting safety stocks and average inventories. Thereafter, we assume that the non-seasonal demand for the spare parts is Poisson

48 Furthermore, they point out that “For purposes of implementation, an upper bound on s could be set as the maximum allowable reorder point. In [their] experience with spare parts, this iterative evaluation procedure finishes quickly, especially for slow-moving items for which the reorder points are relatively low.” (Guajardo et al. 2012, p. 8).

distributed. In the inventory management literature, this is a traditional and commonly used assumption for demand modeling of slow-moving items like spare parts as it has proven to be effective in case studies (Chopra and Meindl 2010, chapter 11; Porras and Dekker 2008). Kalchschmidt et al. (2003) who studied an integrated system for managing inventories in a multi-echelon SPSC point out that it is often much more appropriate to use the Poisson distribution instead of the normal distribution to model the spare parts demand. This is especially the case when many different customers are responsible for the demand peaks. Finally, we drop the assumption that the spare parts demand is non-seasonal. In practice, spare parts demand is often very seasonal with the average demand and the standard deviation of demand varying by the time of the year (cf. section 5.1.3). In the presence of seasonality, it is not appropriate to select an average demand and a standard deviation of demand over the whole year to evaluate fixed reorder levels and order up-to levels. Fixed reorder levels and order up-to levels may lead to stockouts during the peak season and overstocks during the low-demand season. Therefore, one should adjust the spare parts inventory policies over the year if demand is seasonal (Chopra and Meindl 2010, chapter 11).

6.2.2.1 Normal Distributed Demand without Seasonality

We start with the determination of the reorder level s under the assumption of normal distributed demand without seasonality. For the calculation of the appropriate reorder level, different input factors are required. One important input is the standard deviation of demand during the lead time σ_L which can be calculated with the help of the standard deviation of demand per period σ_D and the lead time L as follows (cf. Formula 2.1.3 in section 2.1.3):

$$\sigma_L = \sigma_D * \sqrt{L}$$ **Formula 6.2.2.1.A**

Furthermore, a desired fill rate fr has to be given which measures the proportion of customer demand that is satisfied from available inventory. The fill rate is defined as follows:

$$fr = 1 - \frac{ESC}{Q}$$ **Formula 6.2.2.1.B**

where ESC represent the expected shortage per replenishment cycle which is the average units of demand that are not satisfied from inventory in stock per replenishment cycle. With a given fill rate fr (e.g. 98%) and an economic order quantity of Q, the value of ESC can be easily determined. In general, ESC is defined as:

$$ESC = \int_{x=s}^{\infty} (x - s)\, f(x)\, dx$$

Formula 6.2.2.1.C

where f(x) refers to the density function of the demand distribution during the lead time. When the demand during the lead time is normal distributed, Formula 6.2.2.1.C can be written equal to:

$$ESC = -ss * \left[1 - F_S\left(\frac{ss}{\sigma_L}\right)\right] + \sigma_L * f_S\left(\frac{ss}{\sigma_L}\right)$$

Formula 6.2.2.1.D

which can be expressed with the help of Excel as:

$$ESC = -ss * \left[1 - NORMSDIST\left(\frac{ss}{\sigma_L}\right)\right] + \sigma_L * NORMDIST\left(\frac{ss}{\sigma_L}, 0, 1, 0\right)$$

Formula 6.2.2.1.E

After applying all formulas which were presented in section 6.2 so far, we can now calculate the resulting ESC values and fill rates fr based on the given input factors (D, σ_D, L and Q) for each positive integer $0 \leq s \leq 50$ with the help of an Excel spreadsheet (cf. sequential approach as described in section 6.2.2). As soon as the fill rate is greater than or equal to the required target value (0.92 or 0.98) we have found the appropriate reorder level s. Finally, we can check with the help of the Excel spreadsheet which safety stock and average inventory levels correspond to the appropriate reorder level. Let us now consider spare part RG00062998 as an example for the determination of the reorder level and the resulting safety stock and average inventory levels.

EXAMPLE 6.2.2.1: DETERMINATION OF S, SS AND AVERAGE INVENTORY FOR SPARE PART RG00062998

Data: $D = 5$ (per month), $\sigma_D = 4.5185$, $L = 2.6667$ (months), $Q = 5$ (cf. Example A.6.2.1 in Appendix 6.2.1) and $cycle\ inventory = 2.5$

Plugging in these values in Formula 6.2.2.C and Formula 6.2.2.1.A, gives us $D_L = 13.3333$ and $\sigma_L = 7.3786$. In Appendix 6.2.2.1, all necessary Excel formulas as well as all the resulting calculated values of the above described sequential computation of the appropriate reorder level s, the order up-to level S, the safety stock ss and the average inventory can be found for spare part RG00062998 as an example. It can be observed that $fr \geq 0.98\ \forall\ s \geq 27$. As Table A.6.2.2.1.B indicates, the reorder level $s = 27$ corresponds with $S = 32$, $ss = 13.6665$ and $average\ inventory = 16.1665$. For spare part RG00062998, a current lead time of 80 days ($\frac{80}{30} = 2.6667$ months) and a future lead time of 39 days (1.3. months) could be estimated (cf. section 6.2). If we now again apply the sequential approach based on the new lead time, we get the following results: $fr \geq 0.98\ \forall\ s \geq 16$, $\mathrm{s} = 16$, $\mathrm{S} = 21$, $ss = 9.5$ and average inventory $= 12$. Hence, the average inventory of spare part RG00062998 could be reduced by 25.77% and 2,070.71€ less capital would have to be tied up in inventory at the central warehouse according to the proposed setting ($(16.1665 - 12) * 496.99€ = 2{,}070.71€$).

The following table illustrates the appropriate average inventory (avg inv) and safety stock levels as well as the corresponding replenishment parameters (s and S) for all nine examined spare parts under the assumption of normal distributed demand without seasonality based on both the old and new lead time. The necessary demand data and all other required information about the nine spare parts can be found in Appendix 6.2.

TABLE 6.2.2.1: RESULTS NORMAL DISTRIBUTED DEMAND WITHOUT SEASONALITY

Spare Part	old				new			
	s	S	ss	avg inv	s	S	ss	avg inv
RG00034744	11	15	6.1667	8.1667	5	9	3.1667	5.1667
RG00037241	7	11	4.4222	6.4222	4	8	2.9333	4.9333
RG00037242	5	8	2.8653	4.3653	4	7	2.7118	4.2118
RG00039683	11	15	5.8444	7.8444	7	11	4.1556	6.1556
RG00062998	27	32	13.6667	16.1667	16	21	9.5000	12.0000
VNB4203478	2	3	1.5000	2.0000	1	2	0.7625	1.2625
VNB4294378	10	13	5.6611	7.1611	7	10	4.1896	5.6896
VNB4294778	2	4	1.1444	2.1444	1	3	0.4458	1.4458
VNB4457478	13	16	6.9500	8.4500	10	13	5.7375	7.2375

Table 6.2.2.1 shows that the safety stock and average inventory levels as well as the two replenishment parameters could be reduced considerably for all nine spare parts with a change from the current to the proposed purchasing strategy. The reason for this finding is the underlying lead time reduction.

6.2.2.2 Poisson Distributed Demand without Seasonality

Now, we assume that the non-seasonal demand for the spare parts is Poisson distributed. Under the assumption of Poisson distributed spare parts demand, ESC can be expressed as follows (Guajardo et al. 2012):

$$ESC = \sum_{x = s + 1}^{\infty} (x - s) * P(x)$$

Formula 6.2.2.2.A

where P(x) can be expressed with the help of Excel as:

$P(x) = POISSON\ (x, D_L, 0)$ **Formula 6.2.2.2.B**

Regarding the demand data of the nine spare parts which we want to analyze, it is sufficient to set $\infty = s + 50$ because when $x > s + 50$, P(x) is very close to zero. Hence, we can use the following formula for the calculation of ESC:

$$ESC = \sum_{x=s+1}^{s+50} (x - s) * POISSON\ (x, D_L, 0)$$

Formula 6.2.2.2.C

Now, we can again calculate the resulting ESC values and fill rates fr based on the given input factors for each positive integer $0 \leq s \leq 50$ with the help of an Excel spreadsheet (cf. section 6.2.2.1). The following table indicates the appropriate average inventory and safety stock levels as well as the corresponding replenishment parameters for all nine examined spare parts under the assumption of Poisson distributed demand without seasonality based on both the old and new lead time. As the table shows, we obtain the same finding as under the assumption of normal distributed demand without seasonality (cf. Table 6.2.2.1): The lead time reduction would result in lower safety stocks and average inventories as well as in lower replenishment parameters.

TABLE 6.2.2.2: RESULTS POISSON DISTRIBUTED DEMAND WITHOUT SEASONALITY

Spare Part	old				new			
	s	S	ss	avg inv	s	S	ss	avg inv
RG00034744	9	13	4.1667	6.1667	4	8	2.1667	4.1667
RG00037241	5	9	2.4222	4.4222	3	7	1.9333	3.9333
RG00037242	5	8	2.8653	4.3653	3	6	1.7118	3.2118
RG00039683	9	13	3.8444	5.8444	6	10	3.1556	5.1556
RG00062998	20	25	6.6667	9.1667	11	16	4.5000	7.0000
VNB4203478	2	3	1.5000	2.0000	1	2	0.7625	1.2625
VNB4294378	8	11	3.6611	5.1611	6	9	3.1896	4.6896
VNB4294778	2	4	1.1444	2.1444	1	3	0.4458	1.4458
VNB4457478	11	14	4.9500	6.4500	8	11	3.7375	5.2375

Obviously, the replenishment parameters and the calculated average inventory values are significantly lower under the assumption of Poisson distributed demand than under the assumption of normal distributed demand. In the next two sections, we will see that most of these values can be reduced even further if we assume that the spare parts demand is seasonal.

6.2.2.3 Normal Distributed Demand with Seasonality

So far, we assumed that the spare parts demand is non-seasonal. In practice, however, spare parts demand is often very seasonal and companies should adjust their spare parts inventory policies over the year as indicated in section 6.2.2. Therefore, let us now assume that the spare parts demand is normal distributed and seasonal. To reflect the seasonality and the changing demand pattern of the nine examined spare parts, we first have to calculate the average demand and the standard deviation of demand for each month of the year as done in Appendix 6.2. Based on the monthly demand data, we can then apply the sequential approach (cf. section 6.2.2.1) to determine the appropriate order quantities[49], reorder levels and order up-to levels for each month of the year. Finally, the corresponding monthly safety stock and average inventory levels can be identified and a yearly average can be calculated. Let us now again take a closer look at spare part RG00062998 as an example to illustrate the impact of demand seasonality on safety stock and average inventory. The figures in Table E.6.2.2.3 are based on the current lead time (2.6667 months) and the monthly demand data which can be found in Appendix 6.2.

[49] It is important to use the same time units for the holding cost rate h and the demand D when applying the EOQ formula (Chopra and Meindl 2010, chapter 10). Therefore, the correct EOQ formula based on monthly demand D is as follows: $Q^* = \sqrt{\frac{2 * D * S}{\frac{h}{12} * C}}$

EXAMPLE 6.2.2.3: DETERMINATION OF S, SS AND AVERAGE INVENTORY FOR SPARE PART RG00062998

The following table shows that the spare parts demand is relatively high from November until June with demand peaks in March, April (maximum) and May. As described in section 5.1.3, the Kverneland spare parts demand is generally very high in spring when the farmers are actively working with Kverneland machines in the fields because this is the season when most parts break down. Furthermore, dealers are usually filling up their stocks in winter before their high season starts and make use of the low season discounts offered by BAAS.

TABLE E.6.2.2.3: RESULTS NORMAL DISTRIBUTED DEMAND WITH SEASONALITY FOR SPARE PART RG00062998

Month	D	D_L	σ_D	σ_L	Q	s	S	ss	avg inv
Jan	3.8000	10.1333	3.1875	5.2051	5	20	25	9.8667	12.3667
Feb	4.8000	12.8000	1.9391	3.1665	5	19	24	6.2000	8.7000
Mar	10.2000	27.2000	4.4000	7.1852	8	39	47	11.8000	15.8000
Apr	12.4000	33.0667	3.1369	5.1225	8	41	49	7.9333	11.9333
May	9.0000	24.0000	4.3012	7.0238	7	36	43	12.0000	15.5000
Jun	5.7500	15.3333	1.9203	3.1358	6	20	26	4.6667	7.6667
Jul	1.5000	4.0000	0.5000	0.8165	3	5	8	1.0000	2.5000
Aug	1.5000	4.0000	1.1180	1.8257	3	7	10	3.0000	4.5000
Sep	2.5000	6.6667	1.8028	2.9439	4	12	16	5.3333	7.3333
Oct	2.5000	6.6667	1.8028	2.9439	4	12	16	5.3333	7.3333
Nov	4.0000	10.6667	4.2426	6.9282	5	24	29	13.3333	15.8333
Dec	3.5000	9.3333	4.0927	6.6833	5	22	27	12.6667	15.1667
Year								7.7611	10.3861

As the table indicates, the monthly demand has a high influence on the safety stock and average inventory levels as well as on the order quantity and the replenishment parameters. In months with high demands, all other parameters which were considered in the table show relatively high values compared to months which are characterized by low demands since all these parameters increase with an increase in monthly demand. If we now recalculate the replenishment parameters based on the new lead time, we obtain a yearly average safety stock of 5.1763 and a yearly average inventory of only 7.8013 which corresponds to a stock reduction of 24.89% and 1,284.65€ less capital tied up in inventory compared to the old setting. Notice that the replenishment parameters vary widely over the year but the calculated yearly average inventory is significantly lower under the assumption of seasonal demand (10.3861) than under the assumption of non-seasonal demand (16.1665).

If we now apply the above described sequential approach for all nine examined spare parts under the assumption of normal distributed demand with seasonality, we obtain the results illustrated in Table 6.2.2.3. The safety stocks and average inventories are calculated based on the old and new lead times and it can be observed again that the lead time reduction would result in lower safety stock and average inventory levels.

TABLE 6.2.2.3: RESULTS NORMAL DISTRIBUTED DEMAND WITH SEASONALITY

Spare Part	old		new	
	ss	avg inv	ss	avg inv
RG00034744	3.0508	4.8425	1.6658	3.4575
RG00037241	2.9706	4.5539	1.7867	3.3700
RG00037242	2.2633	3.5133	1.6833	2.9333
RG00039683	3.5250	5.4833	2.3500	4.3083
RG00062998	7.7611	10.3861	5.1763	7.8013
VNB4203478	0.6111	1.1111	0.5694	1.0694
VNB4294378	5.1700	6.7950	4.0675	5.6925
VNB4294778	0.5733	1.1983	0.5371	1.1621
VNB4457478	3.5633	5.1050	2.9158	4.4575

6.2.2.4 Poisson Distributed Demand with Seasonality

The same approach as in section 6.2.2.3 can also be applied under the assumption of Poisson distributed demand with seasonality. As Table 6.2.2.4 shows, it can be concluded again that the lead time reduction would result in a decrease in safety stock and average inventory for all nine examined spare parts.

TABLE 6.2.2.4: RESULTS POISSON DISTRIBUTED DEMAND WITH SEASONALITY

Spare Part	old		new	
	ss	avg inv	ss	avg inv
RG00034744	3.4675	5.2592	2.0825	3.8742
RG00037241	2.7206	4.3039	1.5367	3.1200
RG00037242	2.5133	3.7633	1.8500	3.1000
RG00039683	3.9417	5.9000	2.8500	4.8083
RG00062998	6.1778	8.8028	4.0096	6.6346
VNB4203478	0.6944	1.1944	0.4861	0.9861
VNB4294378	4.0033	5.6283	3.1508	4.7758
VNB4294778	0.7400	1.3650	0.5371	1.1621
VNB4457478	4.3967	5.9383	3.7492	5.2908

6.2.3 Overview - Reduction of Average Inventories

This section serves as an overview of the estimated stock reductions which could be realized with a change from the current to the proposed purchasing strategy. The next two tables summarize the results of the average inventory calculations which were made for the nine examined spare parts and demonstrate that significant stock reductions could be achieved with the help of shorter lead times. Table 6.2.3.A and Table 6.2.3.B show which average inventories should be hold on stock to satisfy the required fill rates based on the old and new lead times. It was found that the average inventories could be reduced considerably by the implementation of the proposed purchasing strategy. Furthermore, it could be observed that less capital would have to be tied up in inventory in the new setting (cf. 4. RQ).[50] The calculations were made based on four different assumptions about the spare parts demand[51]

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[50] In Table 6.2.3.A and Table 6.2.3.B "savings %" refers to the savings of average inventory from the old to the new setting in percentage terms and "savings €" refers to the savings of tied up capital in €.

[51] The following assumptions about the spare parts demand were considered:

$NDNS = normal\ distributed\ demand\ without\ seasonality$

$PDNS = poisson\ distributed\ demand\ without\ seasonality$

which were presented in the preceding sections (cf. sections 6.2.2.1-6.2.2.4). The order quantities were calculated based on the EOQ model (cf. section 6.2.1) and the replenishment parameters were calculated based on the (s, S) replenishment system (cf. section 6.2.2).

TABLE 6.2.3.A: STOCK REDUCTIONS NON-SEASONAL DEMAND

Spare Part	NDNS				PDNS			
	avg inv		savings		avg inv		savings	
	old	new	%	€	old	new	%	€
RG00034744	8.17	5.17	36.73	1,500.27	6.17	4.17	32.43	1,000.18
RG00037241	6.42	4.93	23.18	492.82	4.42	3.93	11.06	161.82
RG00037242	4.37	4.21	3.52	81.33	4.37	3.21	26.42	611.25
RG00039683	7.84	6.16	21.53	839.48	5.84	5.16	11.79	342.42
RG00062998	16.17	12.00	25.77	2,070.79	9.17	7.00	23.64	1,076.81
VNB4203478	2.00	1.26	36.88	367.56	2.00	1.26	36.88	367.56
VNB4294378	7.16	5.69	20.55	739.53	5.16	4.69	9.14	236.97
VNB4294778	2.14	1.45	32.58	302.16	2.14	1.45	32.58	302.16
VNB4457478	8.45	7.24	14.35	823.70	6.45	5.24	18.80	823.70

$NDS = normal\ distributed\ demand\ with\ seasonality$

$PDS = poisson\ distributed\ demand\ with\ seasonality$

TABLE 6.2.3.B: STOCK REDUCTIONS SEASONAL DEMAND

Spare Part	NDS				PDS			
	avg inv		savings		avg inv		savings	
	old	new	%	€	old	new	%	€
RG00034744	4.84	3.46	28.60	692.62	5.26	3.87	26.33	692.62
RG00037241	4.55	3.37	26.00	391.87	4.30	3.12	27.51	391.87
RG00037242	3.51	2.93	16.51	307.35	3.76	3.10	17.63	351.51
RG00039683	5.48	4.31	21.43	584.05	5.90	4.81	18.50	542.62
RG00062998	10.39	7.80	24.89	1,284.65	8.80	6.63	24.63	1,077.57
VNB4203478	1.11	1.07	3.75	20.77	1.19	0.99	17.44	103.83
VNB4294378	6.80	5.69	16.23	554.07	5.63	4.78	15.15	428.43
VNB4294778	1.20	1.16	3.03	15.68	1.37	1.16	14.87	87.76
VNB4457478	5.11	4.46	12.68	439.87	5.94	5.29	10.90	439.87

The focus of the preceding calculations was mainly set on average inventory in units per year, a metric which should be as low as possible if companies want to achieve a high supply chain performance. As an alternative important inventory-related metric, inventory turns in units per year (stockturns) could have been considered, a metric which should be as high as possible. Inventory turns is defined as follows if we assume that the total average demand of spare parts per year D can be entirely sold to the customers:

$$inventory\ turns = \frac{sales}{average\ inventory} = \frac{D}{average\ inventory}$$ **Formula 6.2.3**

As Formula 6.2.3 indicates, inventory turns obviously increases with a decrease of average inventory and hence we would obtain the same findings with both metrics, i.e. that lead time reductions are beneficial for the supply chain performance (Chopra and Meindl 2010, chapter 3). The same observations can be made with regard to Example 6.2.3.

EXAMPLE 6.2.3: DETERMINATION OF INVENTORY TURNS FOR SPARE PART RG00062998

If we now again take spare part RG00062998 as an example and assume a Poisson distributed demand with seasonality, we obtain inventory turns of 6.816 with the old lead time and inventory turns of 9.0435 with the new lead time. This corresponds to an increase of 32.68% in inventory turns only because of a shorter lead time.

6.3 Compensation Fee for Production Companies

This section deals with the current and future information and capital flow within the Kverneland SPSC as well as with compensation fees which BAAS should pay towards the production companies when the warehouse would source spare parts directly from external suppliers (cf. 5. RQ). In total, four different approaches for the design and development of compensation fees will be presented. In Appendix 6.3, a spreadsheet with Excel formulas and three input cells can be found to study the consequences of the four approaches on the profits of the factories and the warehouse.

6.3.1 Current Information and Capital Flow

This section deals with the current information and capital flow which represents an important part of the purchasing process of spare parts within the Kverneland SPSC. As Figure 6.3.1.A indicates, the final customer (FC) places an order towards his local dealer (ED) when he notices that he needs spare parts. The external dealer orders spare parts from the respective Kverneland sales company (SC) which operates on a national level. The sales company contacts BAAS which is in charge of the central spare parts warehouse (WH). When the warehouse is out of stock, BAAS has to place an order towards the respective Kverneland production company (PC). Since most of the spare parts are not manufactured in-house at the factory but procured externally, the production company usually has to purchase the spare parts from an external supplier (SS). After the successful delivery of the spare parts to the further downstream located actor of the supply chain, the financial transactions take place. The capital flow proceeds in the same way as the information flow, upstream the SPSC and every actor has to be compensated according to his efforts. The final customer pays the global retail price (GRP) to his dealer who has to pay the dealer net price (DN) to the sales company. Within the group, Kverneland works with two different transfer prices: BAAS charges the sales company a transfer price (TP2) while the factory charges BAAS a transfer price (TP1).[52] Furthermore, the factory has to pay a purchase price (DC1) to its supplier.

FIGURE 6.3.1.A: CURRENT INFORMATION AND CAPITAL FLOW (UPSTREAM)[53]

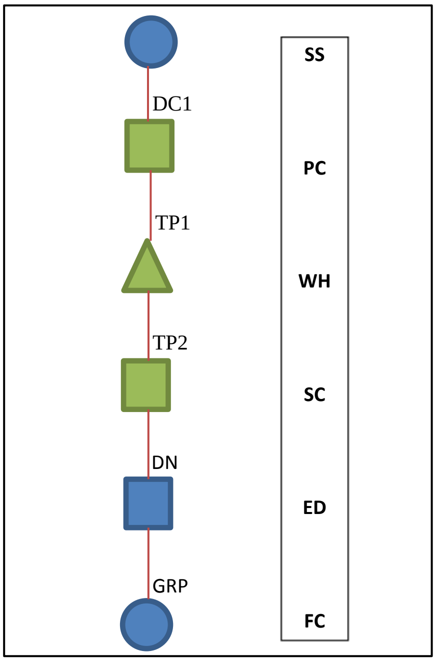


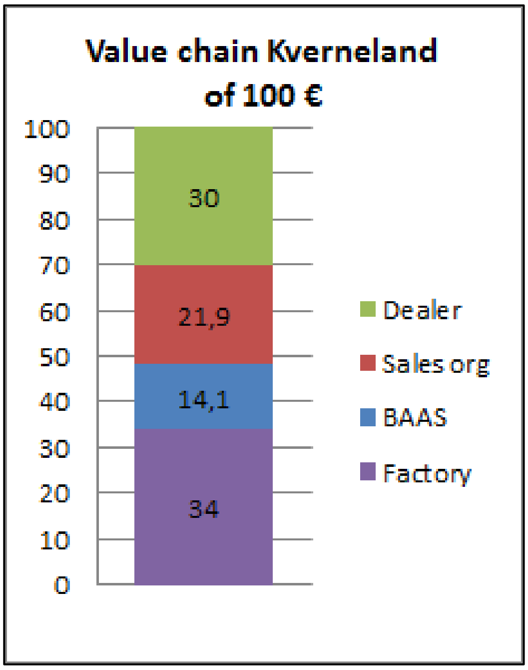
Figure 6.3.1.B reveals how the five different prices of the spare parts are generated. The DC1 is always given since it is the result of the negotiations between the factory's purchaser and the supplier. The GRP is calculated as the product of the DC1 and a markup. The level of the markup depends on the competitiveness of the market segment to which the respective spare part belongs. In highly competitive market segments the markup is relatively low compared to market segments with a low competitiveness. In the case of highly competitive market segments, the GRP is given as the prevailing market price and therefore also the markup is given but in market segments with less competition, Kverneland can decide about the level of the markup independently and hence can also set the GRP autonomously. Let us now consider an example of a spare part with a DC1 of 20€ and a markup of the factor 5

[52] A great introduction to the methods and consequences of internal transfer pricing can be found at Bergstrand 2009

[53] Cf. Figure 5.2

(400% markup). As Figure 6.3.1.B shows, the resulting GRP is 100€ whereof 34% minus the DC1 are dedicated to the factory, 14.1% to BAAS, 21.9% to the sales company and 30% to the dealer. This leads to a TP1 of 34€, a TP2 of 48.1€ and a DN of 70€ (cf. Appendix 6.3).

FIGURE 6.3.1.B: VALUE CHAIN KVERNELAND[54]



If we now assume that there are no additional costs related to the spare parts business except of paying the respective spare parts price to the actor who is located one stage further upstream in the supply chain, we obtain the following margins: $PC = 41.18\%$, $WH = 29.31\%$, $SC = 31.29\%$ and $ED = 30\%$ (cf. Appendix 6.3). The margins for BAAS, the sales company and the dealer are independent of the level of the markup and hence they stay the same even if the markup would be changed. The margin for the factory however depends highly on the level of the markup and increases with an increase in the markup. E.g. with a markup of the factor 6, the factory would obtain a margin of 50.98% in our example while the margins for the other actors of the SPSC would remain the same. Since the markup and the factory margin vary a lot between the different Kverneland spare parts, it was decided

[54] Figure 6.3.1.B is part of Kverneland Group Business Area After Sales. 2013. Pricing Strategies and Methods. PowerPoint presentation.

together with the procurement manager of the warehouse in Metz to calculate an average of all margins which the factory in NV could achieve with its yearly spare parts sales to Metz. As Table 6.3.1 shows, the average margin amounted to 50.07% in 2011 and to 52.03% in 2012.

TABLE 6.3.1: SPARE PARTS SALES BETWEEN FACTORY NIEUW-VENNEP AND WAREHOUSE METZ[55]

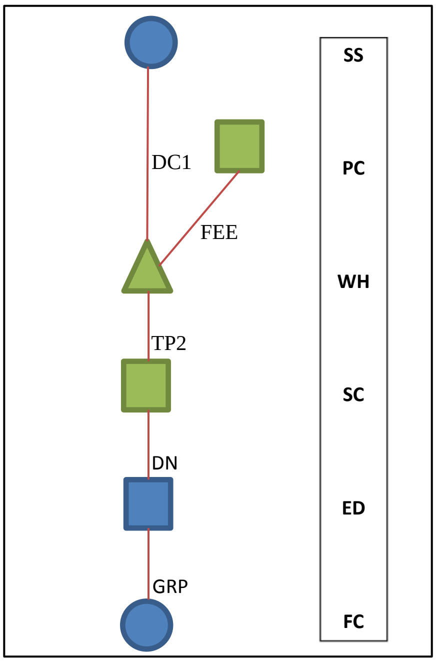
	2012		2011	
	Total	**Total**	**Total**	**Stand Alone**
Different Part Numbers	2,851	2,851	3,244	1,280
Total Cost (DC1)	2,055,168	2,055,168	2,064,086	968,143
Total Turnover (TP1)	4,284,394	4,284,394	4,134,052	1,788,690
Total Profit	2,229,226	2,229,226	2,069,965	820,548
Average Margin	52.03%	52.03%	50.07%	45.87%

6.3.2 Future Information and Capital Flow

According to the proposed purchasing strategy (cf. Figure 6.3.2), BAAS would order the spare parts which are needed at the central warehouse directly from the external supplier and thus would only have to pay the DC1. Since the further downstream located part of the SPSC would remain exactly the same in the future setting, the proposed strategy would automatically lead to a high increase in the warehouse margin and profit. In the future, BAAS would still charge the sales company the TP2 but it would not have to pay the TP1 anymore but only the DC1, since the factory would be excluded in the purchasing process.

[55] Based on all POs which were placed from the warehouse towards the factory between 01/2011-01/2013

FIGURE 6.3.2: FUTURE INFORMATION AND CAPITAL FLOW (UPSTREAM)[56]



If we now reconsider the further above described example, we obtain the following margins in the future setting: $PC = 0\%$, $WH = 58.42\%$, $SC = 31.29\%$ and $ED = 30\%$ (cf. Appendix 6.3). Obviously, this strategy would lead to a very high warehouse margin but to no margin at all for the production company. However, the top management of KvG wants to implement the proposed purchasing strategy only if the factories would not suffer from a change to the future setting and if they would be compensated for lost sales. Therefore, BAAS should pay reasonable design fees towards the factories when the warehouse would source spare parts directly from external suppliers. The design and development of adequate compensation fees is content of the next section (cf. 5. RQ).

6.3.3 Design and Development of Compensation Fee

After multiple discussions with various managers in different positions and from different locations within KvG, it was found that, in principle, there are three different approaches possible in developing a compensation fee which the warehouse has to pay to the respective factory when it sources spare parts directly from an external supplier. The first approach is

[56] Cf. Figure 5.3

based on the whole amount of parts which the warehouse actually purchases from the supplier[57] (x1), the second approach is based on the amount of parts which the warehouse actually needs and would have ordered from the factory in the current setting (x2) and the third approach is based on the amount of parts which the warehouse finally sells to its customers and where it actually achieves a very high margin (x3). These three amounts could be the same if the minimum order quantity which the supplier dictates would be less than or equal to the quantity which the warehouse needs and if all of these parts could be sold to the warehouse customers. They could be also the same if there would be no minimum order quantity and the warehouse could sell all parts which it needs. Furthermore, the first two amounts could be identical but higher than the third amount if the warehouse would need a quantity greater than or equal to the minimum order quantity (or if there would be no minimum order quantity) but could not sell the whole quantity to its customers. However, in many cases the minimum order quantity is higher than the quantity which is needed at the warehouse and quite often also the initially needed quantity is higher than the quantity which is finally sold to the customers. In summary, there are four different settings possible regarding the quantities of the three further above described amounts (x1, x2 and x3):

1. Setting: $x1 = x2 = x3$
2. Setting: $x1 = x2 > x3$
3. Setting: $x1 > x2 = x3$
4. Setting: $x1 > x2 > x3$

Let us now take again the further above described spare part as an example to illustrate and discuss the current and proposed purchasing strategy and the three different approaches based on the “4. Setting” which is probably the most common. Please also consider Appendix 6.3, where all figures and calculations which are used and mentioned in the following as well as all corresponding Excel formulas can be found. Let us assume that the warehouse needs 75 parts (x2) but the supplier requires a minimum order quantity of 100

[57] This amount often has to be greater than or equal to a minimum order quantity.

parts (x1). Furthermore, after a certain period of time, the warehouse can only sell 70 parts (x3) to its customers and the excess quantity of 5 parts has to be scrapped.[58]

- According to the current setting, the factory orders 100 parts and sells the 75 required parts to BAAS. The remaining 25 parts are put on stock at the factory and after a certain period of time they are scrapped since they are not needed again. The 75 parts are put on stock at the warehouse whereof 70 are sold and 5 are scrapped after a certain period of time. This setting leads to a factory profit of 550€ and to a warehouse profit of 817€.
- According to the future setting, the warehouse would order 100 parts and would put all of them on stock. After a certain period of time 70 parts would be sold and 30 parts would have to be scrapped. This setting would lead to a warehouse profit of 1,367€ and to no profit at all for the factory.
    - According to the first approach, the warehouse should pay a fee of 1,400€ ($\boldsymbol{x1} * (TP1 - DC1)$) to the factory. This approach would lead to a factory profit of 1,400€ and to a warehouse loss of 33€.
    - According to the second approach, the warehouse should pay a fee of 1,050€ ($\boldsymbol{x2} * (TP1 - DC1)$) to the factory. This approach would lead to a factory profit of 1,050€ and to a warehouse profit of 317€.
    - According to the third approach, the warehouse should pay a fee of 980€ ($\boldsymbol{x3} * (TP1 - DC1)$) to the factory. This approach would lead to a factory profit of 980€ and to a warehouse profit of 387€.
- Notice that in all three approaches, the factory would make a higher profit than in the current setting. Hence, one should also apply a fourth approach where the factory would make exactly the same profit as currently. This implies that the warehouse would have to pay a compensation fee which equals the current profit of the factory. According to the fourth approach, the warehouse should pay a fee of 550€ to the factory. This approach would lead to a factory profit of 550€ and to a warehouse profit of 817€ (cf. current setting).

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[58] For reasons of clarity and comprehensibility, let us assume in the following that there are no additional costs (e.g. scrapping costs) related to the spare parts business except of paying the respective spare parts price to the actor who is located one stage further upstream in the supply chain.

- The costs and turnovers of factory and warehouse would be the same in all future approaches and only the amount of the compensation fee would be different. However, in the current setting, the group turnovers are higher than in the future because according to the proposed purchasing strategy, only the warehouse would make turnovers with spare parts and the factory would be excluded. As described in section 5.3.3.1, turnovers play a very important role within KvG and hence the decreasing factory turnovers should be taken into account when setting up new business plans and budgets.
- The group profit would always remain the same, irrespective of the setting and approach ($PC + WH = 1.367$). Hence, from a group perspective there would not be a difference between the current and the proposed purchasing strategy in terms of total group profit if we neglect the savings which could be realized through less double handling (cf. section 6.1) and stock reductions (cf. section 6.2). Nevertheless, the factory and warehouse profits would differ considerably between the different settings and approaches. However, at the end of the day, it is the decision of the top management of KvG to choose the compensation fee approach which fits best to the local business environment of the company.

The four described approaches focus only on the respective spare parts prices as the costs which the factories and the warehouse have to pay towards the further upstream located actors of the SPSC and the turnovers which they make with their spare parts sales towards the further downstream located actors. In reality, however, there are additional costs related to the spare parts business which have to be paid from the different actors. These are e.g. ordering costs, transportation costs, handling costs, inventory holding costs, stockout costs and scrapping costs. Furthermore, there could be additional savings realized with a change from the current to the proposed purchasing strategy. As we have estimated in section 6.1, for each PO line which BAAS would order directly from an external supplier, the factories could save 30.17€ in case of STAPs and 10.88€ in case of IUPs (both based on order costs). These savings have to be considered and should be deducted from each compensation fee which the warehouse would pay towards the factories. Additionally, it should be taken into account that BAAS would automatically carry the full risk of obsolescence, storage and financing when it would source spare parts directly from external suppliers. These risks are currently carried by Kverneland’s production companies.

7 Conclusions and Recommendations

This last chapter reveals limitations of this study and summarizes and presents the most important conclusions and recommendations which could be drawn within the scope of this thesis.

7.1 Observations and Limitations

As described in section 5.2.5.1, the proposed purchasing strategy would especially affect the business of factories with a focus on assembly like the factory in NV which served as a representative case for all Kverneland production companies in this investigation. The factories with a focus on manufacturing (e.g. Klepp) would not be affected by a large extend and hence were not subject of examination. We focused on all external procurement parts which do not have to be controlled on quality aspects at the factories or which could undergo a quality control at the central warehouse in the future setting. All parts which are manufactured in-house and require Kverneland production know-how and all external procurement parts where value is added at the factories or which can only be controlled at the factories were not part of this study since they cannot be delivered directly from external suppliers to the warehouse. Furthermore, we examined both STAPs and IUPs although the procurement practices of these two part types usually differ (cf. section 5.1.2).

7.2 Conclusions

The main conclusion of this master thesis is that the proposed purchasing strategy of direct deliveries from external suppliers to the central warehouse would be beneficial for the spare parts supply chain performance of the Kverneland Group (cf. 1. RQ). In the following, the most important findings of this study are summarized and presented.

- In the analysis part of this thesis it was found that the future setting would lead to less double handling within KvG and that most of the administrative ordering and physical order handling activities which are currently executed by the factories on behalf of BAAS could be skipped entirely (cf. 3. RQ). Hence, the factories could focus more on their core business which is the development and production of machines and not the ordering and handling of spare parts. In the case of the factory in NV, total time savings of around 225 working days and total cost savings of around 80,000€ (minimum around 50,000€) could be estimated. (cf. section 6.1).

- Furthermore, the future setting would lead to lower total lead times for spare parts which would result in considerable stock reductions in terms of safety stocks and average inventories at the central spare parts warehouse in Metz (cf. 4. RQ). The stock reductions would be especially beneficial for high value parts because KvG aims for less capital tied up in inventory (cf. section 6.2). Moreover, shorter lead times usually facilitate an improved inventory and replenishment planning and reduce uncertainty (cf. section 5.4.4.4).
- Most of the parts which are currently ordered from the factories on behalf of BAAS are not controlled on quality aspects at the factories. Hence, they could also be delivered directly from external suppliers to the central warehouse. Besides, the central warehouse is currently expanding and improving its quality control activities so that in the future setting most of the external procurement parts could also be controlled directly in Metz if necessary (cf. section 5.3.4.5).
- The proposed purchasing strategy would establish a direct communication link between BAAS and the external suppliers. As a result, the BAAS planners would have to focus on more purchasing activities like expediting and would have to place more orders towards an increasing number of suppliers. Regarding quantity and quality discrepancies and the provision of important documents (e.g. certificate of origin), the direct communication between BAAS and the external suppliers would definitely lead to an improvement of the current situation (cf. section 5.3.4.3).
- In the future setting, instead of the factories, BAAS would order from external suppliers and hence would have to take care of minimum order quantities. Since the minimum order quantities would be probably higher than the quantities which BAAS would prefer to order, the stock levels of some parts could increase. However, higher order quantities would also lead to a lower order frequency and consequently to lower total ordering costs. Furthermore, from the group perspective it is more reasonable to store excess quantities of spare parts at the central spare parts warehouse than at the factories (cf. section 5.3.4.3).
- The factories would not have to take the demand of BAAS into account anymore. Thus, their STAP stocks could be reduced considerably and the Kanban system would only be affected by the own consumption of the factories (cf. section 5.3.3.2).

- As described in section 6.3, the factories would lose high amounts of their spare parts turnovers where they currently achieve relatively high margins (around 50%). At the same time, the margins of BAAS' spare parts sales would increase considerably. Since KvG wants to implement the proposed purchasing strategy only if the factories would not suffer from a change to the future setting, the top management has to agree on adequate compensation fees which BAAS should pay towards the factories when the warehouse would source spare parts directly from external suppliers.

7.3 Recommendations

The main recommendation of this master thesis is that the Kverneland Group should implement the proposed purchasing strategy of direct deliveries from external suppliers to the central warehouse because it is beneficial for its spare parts supply chain performance. In the following, the most important recommendations for the group management, for BAAS and for the factories with regards to the implementation of the future setting are summarized and presented.

- Group management
    - The implementation process should consist of three different phases. In the first phase, KvG should focus on the main suppliers of the factory in NV and should introduce the proposed purchasing strategy especially for STAPs. In the second phase, the strategy should be expanded to the IUPs of the main suppliers of the factory in NV. In the final phase, the strategy should be implemented for all relevant factories and suppliers. The relevant suppliers should be determined with the help of a supplier rating which should reveal the yearly number of PO (lines) for both STAPs and IUPs placed from the corresponding factory towards the supplier and the proximity of the supplier to the factory and the central warehouse.
    - One of the most important aspects to consider when implementing the future setting is the development of adequate compensation fees which BAAS should pay towards the factories when the warehouse would source spare parts directly from external suppliers (cf. 5. RQ). Hence, the top management should agree on one of the four different approaches which were discussed in section 6.3.3 and should take the recommendations of the KvG tax managers

and external tax experts into consideration. Furthermore, the decreasing spare parts turnovers of the factories should be taken into account when setting up new budgets and business plans (cf. section 5.3.3.1).

- BAAS and factories
    - Even in the future setting, the factories should stay responsible for the determination of parts specifications and for the selection of appropriate external suppliers. This is because the R&D departments of the factories have the most advanced knowledge of technical specifications of parts. For high quality manufacturers like Kverneland, it is important to choose suppliers based on reliability and not purely based on financial aspects (cf. section 5.3.2).
    - The purchasers of the factories and the procurement manager of the central warehouse should negotiate together with the external suppliers and should expand the current supply contracts of the factories to group contracts. The most important conditions of the future contracts concern the purchase prices and the minimum order quantities. Kverneland has to convince its suppliers that the DC1 prices should remain the same irrespective whether the parts would be sent to the factories or to the central warehouse. Furthermore, KvG should try to agree with its suppliers on minimum order quantities as low as possible when signing new supply contracts (especially for the "Stand Alone" phase). Moreover, Kverneland should emphasize that the external suppliers have to secure shorter and more constant lead times.
    - Besides of specific contract conditions, the purchasers should always try to find alternative or substitute suppliers. For some parts, KvG is very depending on only one specific supplier which represents a risk because in these cases the suppliers can "dictate" the supply contracts and stockouts could occur if the suppliers would not deliver on time.
    - The quality control at the central warehouse should be improved and expanded so that the majority of external procurement parts could be controlled directly at the warehouse if necessary. In the future setting, only in special cases, the parts should be sent to external quality control specialists or factories for inspection.

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APPENDIX 3.1: OVERVIEW OF RESEARCH ACTIVITIES

Visit	Description	Location	Arrival	Departure	Days	Weeks	Research Activity / Discussed Topics	Interviewed Persons	Observations
1	Job Interview Master Thesis	Klepp (Norway)	02/12/13	02/12/13	1		- First meeting - Presentation of company, SPSC and purchasing process - Presentation of research project - Scheduling of first company visits	- MD BAAS and BACC - BAAS Controller	
2	Company Visit BAAS Planning	Klepp (Norway)	02/25/13	03/08/13		2	- Qualitative and quantitative data collection - Semi structured interviews with open discussions - Discussions about inventory management, planning, replenishment, administrative ordering, purchasing, lead times, financial consequences, spare parts pricing, internal and external suppliers, factory types, production of machines and spare parts, machine and spare parts characteristics - Presentation of first findings	- MD BAAS and BAAC - Director IS & Planning - BAAS Controller - Planning Managers - IS Managers - Procurement Manager WH - Factory Employees	- Factory - Factory WH - Offices
3	Company Visit BACC Factory	Nieuw-Vennep (the Netherlands)	03/18/13	03/22/13		1	- Qualitative and quantitative data collection - Semi structured interviews with open discussions - Discussions about first findings, planning, administrative ordering, purchasing, lead times, physical order handling, inbound, quality control, picking, outbound, packing, shipping, financial consequences, factory turnovers, spare parts pricing, internal transfer pricing, compensation fee, external suppliers, factory types, production of machines and spare parts, R&D, machine and spare parts characteristics, spare parts quality	- MD BAAS and BAAC - Factory Controller - R&D Manager - IT Consultant - Factory Purchasers - Procurement Manager WH - Quality Control Manager - Members of Order Desk - Inbound Employee - Outbound Employee - Factory Employees	- Factory - Factory WH - Inbound - Outbound - Qu. Control - R&D - Order Desk - Offices

4	Company Visit Central Warehouse	Metz (France)	04/15/13	04/19/13		1	- Qualitative and quantitative data collection - Semi structured interviews with open discussions - Discussions about inventory management, planning, replenishment, administrative ordering, purchasing, lead times, physical order handling, inbound, quality control, picking, outbound, packing, shipping, order costs, internal and external suppliers, spare parts characteristics, spare parts quality - Scheduling of next company visits and further project outline	- MD BAAS and BACC - Director IS & Planning - Director Warehouse - Planning Manager - IS Managers - Procurement Manager WH	- Central WH - Inbound - Outbound - Offices
5	Transfer Pricing & Inventory Models	Klepp (Norway)	05/23/13	05/24/13	2		- Qualitative and quantitative data collection - Semi structured interviews with open discussions - Discussions about inventory management, planning, replenishment, administrative ordering, purchasing, lead times, financial consequences, factory turnovers, spare parts pricing, internal transfer pricing, compensation fee, order costs	- Director IS & Planning - IS Manager - Tax Analyst	
6	Investigation Ordering Process	Nieuw-Vennep (the Netherlands)	05/27/13	05/30/13	4		- Qualitative and quantitative data collection - Semi structured interviews with open discussions - Discussions about inventory management, planning, replenishment, administrative ordering, purchasing, lead times, physical order handling, inbound, quality control, picking, outbound, packing, shipping, financial consequences, factory turnovers, order costs, direct costs, external suppliers, spare parts quality - Investigation of time and cost figure of adm. ordering and physical order handling activities	- MD BAAS and BAAC - Manufacturing Manager - Factory Purchasers - Procurement Manager WH - Quality Control Manager - Members of Order Desk - Inbound Employee - Outbound Employee - Factory Employees	- Factory - Factory WH - Inbound - Outbound - Order Desk - Offices
7	Presentation Ordering Process	Nieuw-Vennep (the Netherlands)	07/03/13	07/04/13	2		- Presentation of time and cost figure of adm. ordering and physical order handling activities - Discussions about financial consequences, factory turnovers, order costs, direct costs	- Manufacturing Manager - Procurement Manager WH	

8	Presentation Thesis Results	Klepp (Norway)	12/25/13	12/27/13	3	- Presentation of conclusions and discussion about recommendations	- MD BAAS and BAAC - Director IS & Planning - Procurement Manager WH

APPENDIX 6.A: ALL POS AND ALL PO LINES BETWEEN FACTORY NIEUW-VENNEP AND EXTERNAL SUPPLIERS IN 2012

External Supplier	I. PO only IUP		II. PO IUP and STAP			III. PO only STAP		Total Overview				Total Ordered Value (DC1) (€)		
	PO	PO lines	PO	PO lines		PO	PO lines	PO	PO lines			IUP	STAP	Total
				IUP	STAP				IUP	STAP	Total			
Total	2,592	12,219	120	2,359	581	941	1,911	3,653	14,578	2,492	17,070	21,683,117	931,490	22,614,608
Supplier 1	2	2	0	0	0	0	0	2	2	0	2	1,387	0	1,387
Supplier 2	0	0	0	0	0	1	1	1	0	1	1	0	783	783
Supplier 3	130	1,923	20	1,661	24	38	72	188	3,584	96	3,680	4,210,778	23,209	4,233,987
Supplier 4	19	135	36	261	427	52	435	107	396	862	1,258	932,971	458,434	1,391,405
Supplier 5	28	92	1	1	1	5	6	34	93	7	100	62,493	1,292	63,785
Supplier 6	0	0	0	0	0	1	1	1	0	1	1	0	1,270	1,270
Supplier 7	0	0	0	0	0	1	1	1	0	1	1	0	775	775
Supplier 8	1	1	0	0	0	1	1	2	1	1	2	376	125	501
Supplier 9	0	0	0	0	0	1	1	1	0	1	1	0	807	807
Supplier 10	1	2	0	0	0	0	0	1	2	0	2	316	0	316
Supplier 11	0	0	0	0	0	7	8	7	0	8	8	0	3,623	3,623
Supplier 12	0	0	0	0	0	24	78	24	0	78	78	0	21,909	21,909
Supplier 13	17	46	2	2	2	4	5	23	48	7	55	594,273	423	594,696
Supplier 14	0	0	0	0	0	1	1	1	0	1	1	0	66	66
Supplier 15	10	65	0	0	0	0	0	10	65	0	65	13,990	0	13,990
Supplier 16	24	151	0	0	0	6	9	30	151	9	160	39,878	120	39,998
Supplier 17	18	63	2	20	2	22	29	42	83	31	114	641,641	3,080	644,722
Supplier 18	19	34	0	0	0	7	7	26	34	7	41	42,222	22,626	64,848
Supplier 19	0	0	0	0	0	5	5	5	0	5	5	0	1,419	1,419
Supplier 20	4	4	0	0	0	1	1	5	4	1	5	2,539	152	2,691
Supplier 21	0	0	0	0	0	5	6	5	0	6	6	0	401	401
Supplier 22	48	130	0	0	0	4	4	52	130	4	134	322,621	20,000	342,621
Supplier 23	81	248	9	147	22	36	61	126	395	83	478	725,460	52,989	778,450
Supplier 24	30	75	0	0	0	7	8	37	75	8	83	37,315	4,916	42,232
Supplier 25	15	26	11	14	38	40	107	66	40	145	185	596	12,947	13,543
Supplier 26	4	4	3	4	15	32	89	39	8	104	112	200	4,469	4,669
Supplier 27	9	11	0	0	0	0	0	9	11	0	11	39,675	0	39,675

Supplier 28	0	0	0	0	0	5	6	5	0	6	6	0	7,224	7,224
Supplier 29	0	0	0	0	0	1	1	1	0	1	1	0	4	4
Supplier 30	18	32	0	0	0	3	3	21	32	3	35	70,718	207	70,925
Supplier 31	19	33	1	1	1	23	27	43	34	28	62	3,074	1,168	4,242
Supplier 32	20	32	0	0	0	4	4	24	32	4	36	15,838	43	15,881
Supplier 33	8	11	0	0	0	8	9	16	11	9	20	43,485	291	43,775
Supplier 34	0	0	0	0	0	1	2	1	0	2	2	0	1,853	1,853
Supplier 35	0	0	0	0	0	10	14	10	0	14	14	0	3,455	3,455
Supplier 36	6	8	0	0	0	0	0	6	8	0	8	1,210	0	1,210
Supplier 37	0	0	0	0	0	3	3	3	0	3	3	0	227	227
Supplier 38	1	1	0	0	0	0	0	1	1	0	1	1,067	0	1,067
Supplier 39	6	9	0	0	0	0	0	6	9	0	9	744	0	744
Supplier 40	6	10	0	0	0	0	0	6	10	0	10	1,010	0	1,010
Supplier 41	15	17	0	0	0	0	0	15	17	0	17	22,227	0	22,227
Supplier 42	16	22	0	0	0	0	0	16	22	0	22	55,066	0	55,066
Supplier 43	7	12	0	0	0	2	2	9	12	2	14	19,313	398	19,710
Supplier 44	1	1	0	0	0	0	0	1	1	0	1	9,500	0	9,500
Supplier 45	0	0	0	0	0	2	2	2	0	2	2	0	1,579	1,579
Supplier 46	51	191	0	0	0	19	23	70	191	23	214	476,870	3,565	480,435
Supplier 47	13	27	0	0	0	0	0	13	27	0	27	27,686	0	27,686
Supplier 48	2	2	0	0	0	0	0	2	2	0	2	2,059	0	2,059
Supplier 49	2	2	0	0	0	0	0	2	2	0	2	40	0	40
Supplier 50	0	0	0	0	0	4	4	4	0	4	4	0	177	177
Supplier 51	0	0	0	0	0	2	2	2	0	2	2	0	505	505
Supplier 52	4	6	0	0	0	0	0	4	6	0	6	5,072	0	5,072
Supplier 53	12	23	0	0	0	0	0	12	23	0	23	14,702	0	14,702
Supplier 54	14	113	4	52	5	14	14	32	165	19	184	371,217	1,581	372,797
Supplier 55	7	54	0	0	0	0	0	7	54	0	54	147,139	0	147,139
Supplier 56	10	42	0	0	0	0	0	10	42	0	42	19,495	0	19,495
Supplier 57	1	1	0	0	0	1	1	2	1	1	2	35	44	79
Supplier 58	12	23	1	4	2	6	6	19	27	8	35	48,457	668	49,125
Supplier 59	1	2	0	0	0	12	19	13	2	19	21	57	1,220	1,277
Supplier 60	11	12	0	0	0	0	0	11	12	0	12	11,536	0	11,536
Supplier 61	0	0	0	0	0	1	1	1	0	1	1	0	24	24

Supplier 62	12	15	0	0	0	26	46	38	15	46	61	216	768	983
Supplier 63	1	1	0	0	0	0	0	1	1	0	1	26	0	26
Supplier 64	33	217	2	2	2	15	20	50	219	22	241	949,037	6,981	956,018
Supplier 65	35	70	0	0	0	2	2	37	70	2	72	73,868	890	74,758
Supplier 66	1	1	0	0	0	3	3	4	1	3	4	5,790	7,680	13,470
Supplier 67	32	88	0	0	0	1	1	33	88	1	89	16,107	9	16,116
Supplier 68	0	0	0	0	0	1	1	1	0	1	1	0	232	232
Supplier 69	0	0	0	0	0	1	1	1	0	1	1	0	485	485
Supplier 70	53	80	3	8	3	5	5	61	88	8	96	15,262	2,885	18,148
Supplier 71	17	40	0	0	0	2	2	19	40	2	42	38,436	531	38,967
Supplier 72	2	3	0	0	0	0	0	2	3	0	3	4,020	0	4,020
Supplier 73	112	1,171	1	1	1	1	1	114	1,172	2	1,174	3,744,165	1,761	3,745,927
Supplier 74	67	407	0	0	0	10	13	77	407	13	420	129,995	3,159	133,154
Supplier 75	4	4	0	0	0	0	0	4	4	0	4	7,560	0	7,560
Supplier 76	0	0	0	0	0	4	5	4	0	5	5	0	516	516
Supplier 77	17	59	1	1	1	11	14	29	60	15	75	16,591	2,249	18,840
Supplier 78	5	5	0	0	0	0	0	5	5	0	5	2,017	0	2,017
Supplier 79	16	31	0	0	0	0	0	16	31	0	31	477,691	0	477,691
Supplier 80	86	738	0	0	0	0	0	86	738	0	738	73,296	0	73,296
Supplier 81	1	1	0	0	0	0	0	1	1	0	1	485	0	485
Supplier 82	1	4	0	0	0	0	0	1	4	0	4	1,032	0	1,032
Supplier 83	3	5	0	0	0	0	0	3	5	0	5	4,030	0	4,030
Supplier 84	11	28	0	0	0	0	0	11	28	0	28	5,474	0	5,474
Supplier 85	50	125	2	5	2	25	53	77	130	55	185	74,449	16,467	90,916
Supplier 86	3	3	0	0	0	2	2	5	3	2	5	999	489	1,488
Supplier 87	13	16	0	0	0	0	0	13	16	0	16	5,114	0	5,114
Supplier 88	1	1	0	0	0	0	0	1	1	0	1	1,287	0	1,287
Supplier 89	21	42	0	0	0	15	22	36	42	22	64	29,730	7,743	37,472
Supplier 90	3	3	0	0	0	0	0	3	3	0	3	1,497	0	1,497
Supplier 91	9	10	0	0	0	1	1	10	10	1	11	38,205	3,743	41,948
Supplier 92	18	65	0	0	0	1	1	19	65	1	66	65,328	1,031	66,359
Supplier 93	50	236	0	0	0	13	20	63	236	20	256	146,801	8,930	155,730
Supplier 94	1	1	0	0	0	0	0	1	1	0	1	398	0	398
Supplier 95	7	7	0	0	0	0	0	7	7	0	7	2,208	0	2,208

Supplier 96	100	271	0	0	0	1	1	101	271	1	272	1,069,850	508	1,070,358
Supplier 97	11	22	0	0	0	2	2	13	22	2	24	2,656	86	2,742
Supplier 98	48	114	0	0	0	0	0	48	114	0	114	299,169	0	299,169
Supplier 99	20	52	1	31	1	0	0	21	83	1	84	188,871	48	188,919
Supplier 100	12	18	0	0	0	10	11	22	18	11	29	18,774	2,886	21,661
Supplier 101	17	27	0	0	0	1	1	18	27	1	28	10,957	87	11,044
Supplier 102	0	0	0	0	0	1	1	1	0	1	1	0	370	370
Supplier 103	27	113	0	0	0	12	14	39	113	14	127	213,081	6,950	220,031
Supplier 104	8	9	0	0	0	0	0	8	9	0	9	5,014	0	5,014
Supplier 105	6	8	0	0	0	0	0	6	8	0	8	30,750	0	30,750
Supplier 106	11	29	0	0	0	0	0	11	29	0	29	23,901	0	23,901
Supplier 107	60	235	0	0	0	21	25	81	235	25	260	1,013,644	17,490	1,031,134
Supplier 108	7	7	1	1	1	30	70	38	8	71	79	347	2,074	2,421
Supplier 109	26	43	0	0	0	4	4	30	43	4	47	21,799	870	22,669
Supplier 110	19	102	1	3	2	17	27	37	105	29	134	62,655	4,061	66,716
Supplier 111	6	6	0	0	0	1	1	7	6	1	7	1,444	0	1,445
Supplier 112	5	10	0	0	0	0	0	5	10	0	10	6,833	0	6,833
Supplier 113	15	91	0	0	0	0	0	15	91	0	91	20,326	0	20,326
Supplier 114	24	139	0	0	0	9	11	33	139	11	150	247,958	12,392	260,350
Supplier 115	25	70	0	0	0	17	36	42	70	36	106	15,043	9,818	24,861
Supplier 116	2	4	0	0	0	0	0	2	4	0	4	838	0	838
Supplier 117	60	196	0	0	0	9	9	69	196	9	205	201,110	399	201,509
Supplier 118	0	0	0	0	0	8	8	8	0	8	8	0	1,697	1,697
Supplier 119	0	0	0	0	0	1	1	1	0	1	1	0	2	2
Supplier 120	4	4	0	0	0	0	0	4	4	0	4	2,858	0	2,858
Supplier 121	22	81	0	0	0	6	7	28	81	7	88	18,233	2,238	20,470
Supplier 122	4	4	0	0	0	0	0	4	4	0	4	7,120	0	7,120
Supplier 123	16	27	0	0	0	0	0	16	27	0	27	84,961	0	84,961
Supplier 124	11	29	0	0	0	10	11	21	29	11	40	9,720	3,961	13,680
Supplier 125	0	0	0	0	0	3	3	3	0	3	3	0	1,178	1,178
Supplier 126	3	3	0	0	0	4	4	7	3	4	7	1,388	1,116	2,504
Supplier 127	15	19	0	0	0	0	0	15	19	0	19	8,957	0	8,957
Supplier 128	17	30	0	0	0	0	0	17	30	0	30	14,546	0	14,546
Supplier 129	37	113	0	0	0	2	2	39	113	2	115	43,454	191	43,645

Supplier 130	10	10	0	0	0	0	0	10	10	0	10	5,529	0	5,529
Supplier 131	0	0	0	0	0	8	11	8	0	11	11	0	1,069	1,069
Supplier 132	2	5	0	0	0	1	1	3	5	1	6	343	6	349
Supplier 133	3	3	0	0	0	0	0	3	3	0	3	81	0	81
Supplier 134	44	123	1	7	1	3	3	48	130	4	134	117,444	1,191	118,635
Supplier 135	5	6	0	0	0	0	0	5	6	0	6	17,477	0	17,477
Supplier 136	0	0	0	0	0	1	1	1	0	1	1	0	28	28
Supplier 137	8	9	0	0	0	0	0	8	9	0	9	5,790	0	5,790
Supplier 138	17	65	0	0	0	5	9	22	65	9	74	82,720	977	83,697
Supplier 139	3	3	0	0	0	0	0	3	3	0	3	5,656	0	5,656
Supplier 140	24	380	0	0	0	13	14	37	380	14	394	532,853	7,089	539,941
Supplier 141	5	6	0	0	0	0	0	5	6	0	6	5,385	0	5,385
Supplier 142	62	198	4	17	5	2	4	68	215	9	224	238,072	6,610	244,682
Supplier 143	24	56	0	0	0	3	4	27	56	4	60	377,699	7,584	385,283
Supplier 144	37	131	0	0	0	35	58	72	131	58	189	54,320	19,228	73,547
Supplier 145	0	0	0	0	0	27	44	27	0	44	44	0	18,544	18,544
Supplier 146	17	43	0	0	0	0	0	17	43	0	43	4,871	0	4,871
Supplier 147	0	0	0	0	0	3	4	3	0	4	4	0	417	417
Supplier 148	1	1	0	0	0	0	0	1	1	0	1	372	0	372
Supplier 149	1	2	0	0	0	0	0	1	2	0	2	2,470	0	2,470
Supplier 150	18	65	13	116	23	24	61	55	181	84	265	290,455	19,776	310,231
Supplier 151	3	5	0	0	0	0	0	3	5	0	5	1,903	0	1,903
Supplier 152	4	4	0	0	0	0	0	4	4	0	4	439	0	439
Supplier 153	10	10	0	0	0	0	0	10	10	0	10	5,973	0	5,973
Supplier 154	12	23	0	0	0	0	0	12	23	0	23	19,934	0	19,934
Supplier 155	1	1	0	0	0	3	6	4	1	6	7	135	910	1,045
Supplier 156	2	4	0	0	0	0	0	2	4	0	4	27,237	0	27,237
Supplier 157	1	1	0	0	0	0	0	1	1	0	1	1,750	0	1,750
Supplier 158	56	168	0	0	0	27	43	83	168	43	211	583,402	37,453	620,855
Supplier 159	121	1,504	0	0	0	38	83	159	1,504	83	1,587	566,060	9,169	575,229
Supplier 160	27	305	0	0	0	0	0	27	305	0	305	92,938	0	92,938
Supplier 161	9	13	0	0	0	1	1	10	13	1	14	19,620	285	19,906
Supplier 162	7	10	0	0	0	1	1	8	10	1	11	975	42	1,017
Supplier 163	0	0	0	0	0	3	6	3	0	6	6	0	521	521

Supplier 164	2	2	0	0	0	0	0	2	2	0	2	945	0	945
Supplier 165	0	0	0	0	0	2	2	2	0	2	2	0	192	192
Supplier 166	1	1	0	0	0	0	0	1	1	0	1	2,500	0	2,500
Supplier 167	0	0	0	0	0	1	1	1	0	1	1	0	1,926	1,926
Supplier 168	9	11	0	0	0	0	0	9	11	0	11	4,050	0	4,050
Supplier 169	0	0	0	0	0	10	13	10	0	13	13	0	3,439	3,439

Based on all POs which were placed from the factory towards external suppliers between 01/2012-01/2013 and which were closed until 06/2013.

There are three different types of POs:

I. POs only for "In Use" parts

II. POs both for "In Use" parts and "Stand Alone" parts

III. POs only for "Stand Alone" parts

APPENDIX 6.B: THE 90 SPARE PARTS WITH THE HIGHEST VALUE BETWEEN FACTORY NIEUW-VENNEP AND WAREHOUSE METZ IN 2012

Rank	Spare Part	External Supplier	Material Value (DC1) (€)
1	MT00000228	Supplier 73	1,250.00
2	VNB2018494	Supplier 71	952.58
3	VNB2911678	Supplier 114	768.58
4	RG00061126	Supplier 140	754.50
5	VNB4923794	Supplier 71	724.05
6	VNB4923894	Supplier 71	724.05
7	VNB4854094	Supplier 71	709.00
8	VNB4854194	Supplier 71	709.00
9	VNB4853894	Supplier 71	699.00
10	VNB4853994	Supplier 71	699.00
11	RG00055441	Supplier 145	676.68
12	RG00062364	Supplier 85	676.15
13	VNB4926878	Supplier 156	664.31
14	VNB2944378	Supplier 140	662.60
15	RG00061013	Supplier 12	611.87
16	VNB4923994	Supplier 71	593.61
17	VNB4854994	Supplier 71	591.00
18	VNB4866994	Supplier 71	591.00
19	VNB3007594	Supplier 71	561.54
20	VNB3532794	Supplier 71	561.54
21	VNB4924094	Supplier 71	559.61
22	RG00059667	Supplier 145	493.34
23	RG00058080	Supplier 145	472.50
24	RG00056479	Supplier 4	469.62
25	VNB4654878	Supplier 4	435.54
26	VNB4457478	Supplier 4	430.36
27	VNB4457578	Supplier 4	430.36
28	VNB4457678	Supplier 4	430.36
29	VNB4549078	Supplier 4	430.36
30	VNB0460873	Supplier 73	400.74
31	RG00053234	Supplier 2	391.65
32	VN90070768	Supplier 44	380.00
33	RG00051922	Supplier 4	368.23
34	VNB3711878	Supplier 96	360.00
35	RG00053440	Supplier 34	358.13
36	RG00034744	Supplier 4	356.54
37	RG00039683	Supplier 4	340.25
38	RG00062998	Supplier 4	340.25
39	VNB4203478	Supplier 4	340.25
40	VNB0530973	Supplier 73	336.82
41	VNB4134765	Supplier 17	336.58
42	RG00056464	Supplier 4	335.43

43	RG00056478	Supplier 4	335.43
44	VNB3542578	Supplier 4	331.84
45	RG00050622	Supplier 34	327.62
46	VNB4294378	Supplier 4	327.19
47	RG00054422	Supplier 96	327.00
48	VNB4548978	Supplier 4	323.23
49	MT00000583	Supplier 73	322.66
50	VNB4294778	Supplier 4	312.78
51	VN46110020	Supplier 46	309.98
52	VNB4294478	Supplier 4	308.99
53	RG00034754	Supplier 4	299.21
54	VNB0465373	Supplier 73	287.23
55	VNB2926278	Supplier 114	285.74
56	RG00037242	Supplier 4	274.81
57	VNB4548878	Supplier 4	274.81
58	RG00060750	Supplier 46	270.15
59	VNB4679478	Supplier 99	269.32
60	RG00039561	Supplier 114	265.97
61	RG00034746	Supplier 4	265.43
62	VNB3213878	Supplier 54	262.51
63	VNB0545173	Supplier 73	261.33
64	VNB0449673	Supplier 73	255.37
65	VNB0547373	Supplier 73	248.45
66	VNB2801702	Supplier 107	245.00
67	RG00056487	Supplier 145	241.86
68	VNB0461073	Supplier 73	235.94
69	RG00054214	Supplier 46	226.53
70	VNB3935178	Supplier 150	226.50
71	RG00056486	Supplier 145	226.21
72	VNB4007278	Supplier 12	220.00
73	VNB4783878	Supplier 23	215.00
74	VNB4059978	Supplier 23	207.65
75	RG00055451	Supplier 145	206.83
76	VNB1592478	Supplier 64	199.84
77	VNB0441573	Supplier 73	199.15
78	VNB4592478	Supplier 4	196.09
79	VNB4683878	Supplier 99	196.03
80	VNB4598178	Supplier 150	193.56
81	VN79730271	Supplier 73	186.55
82	VNB4295278	Supplier 4	183.70
83	RG00059248	Supplier 145	176.27
84	MT00001356	Supplier 73	175.29
85	VNB4061494	Supplier 23	171.20
86	VN46110017	Supplier 46	171.12
87	RG00063740	Supplier 46	169.57
88	RG00037241	Supplier 4	169.03
89	VNB4166294	Supplier 22	165.60

90	VNB0518973	Supplier 73	164.51

Based on all POs which were placed from the warehouse towards the factory between 01/2012-01/2013 and which were closed until 04/2013.

APPENDIX 6.1.1: PURCHASING PROCESS OF STAND ALONE PARTS (ORDER COSTS)

Step	Current Situation	Proposed Situation	Current Situation Time	Current Situation Cost	Proposed Situation Time	Proposed Situation Cost
	BAAS gets order from customer and confirms it	*same*				
	BAAS gets requisition from SAS and selects it	*same*				
1	BAAS sends order to NV	BAAS sends order to SS	1.00	2.10	1.00	2.10
2	BAAS takes care of expediting towards NV	BAAS takes care of expediting towards SS	2.50	5.25	5.00	10.51
3	NV gets order from BAAS and creates new order	SS gets order from BAAS and confirms it	1.50	3.15	-	-
4	NV sends order to SS	-	1.00	2.10	-	-
5	NV takes care of expediting towards SS	-	5.00	10.51	-	-
6	SS gets order from NV and confirms it	-	-	-	-	-
7	SS ships parts to NV	-	-	-	-	-
8	NV receives and unpacks parts	-	5.50	2.48	-	-
9	NV registers parts	-				
10	NV counts and controls parts	-				
11	NV stores parts at inbound or stock for BAAS	-				
12	SS sends invoice to NV	-	-	-	-	-
13	NV registers and pays invoice from SS	-	2.00	4.20	-	-
14	NV creates picking list	-	-	-	-	-
15	NV picks parts from inbound or stock for BAAS	-	8.50	3.83	-	-
16	NV packs parts	-	4.00	1.80	-	-
17	NV creates inbound documentation and sends it to BAAS	SS creates inbound documentation and sends it to BAAS	1.00	2.10	-	-
18	BAAS receives inbound documentation and updates system	BAAS receives inbound documentation and updates system	0.00	0.00	0.50	1.05
19	NV ships parts to BAAS	SS ships parts to BAAS	-	-	-	-
20	BAAS receives and unpacks parts	BAAS receives and unpacks parts	6.50	3.44	6.50	3.44
21	BAAS registers parts	BAAS registers parts				
22	BAAS counts and controls parts	BAAS counts and controls parts				
23	BAAS stores parts	BAAS stores parts				
24	NV sends invoice to BAAS	SS sends invoice to BAAS	-	-	-	-
25	BAAS registers and pays invoice from NV	BAAS registers and pays invoice from SS	2.00	4.20	2.00	4.20
Total			40.50	45.17	15.00	21.31
	BAAS picks parts	*same*				
	BAAS packs parts	*same*				
	BAAS ships parts to customer	*same*				
	BAAS sends invoice to customer	*same*				
	Customer registers and pays invoice from BAAS	*same*				

Activity performed by BAAS
Activity performed by NV
Activity performed by SS
Physical Order Handling Activity
Administrative Ordering Activity

The time figures are given in minutes per PO line and the cost figures are given in € per PO Line.

APPENDIX 6.1.2: PURCHASING PROCESS OF IN USE PARTS (ORDER COSTS)

Step	Current Situation	Proposed Situation	Current Situation		Proposed Situation	
			Time	Cost	Time	Cost
	BAAS gets order from customer and confirms it	*same*				
	BAAS gets requisition from SAS and selects it	*same*				
1	BAAS sends order to NV	BAAS sends order to SS	1.00	2.10	1.00	2.10
2	BAAS takes care of expediting towards NV	BAAS takes care of expediting towards SS	2.50	5.25	5.00	10.51
3	NV gets order from BAAS	SS gets order from BAAS and confirms it	1.50	3.15	-	-
4	-	-	-	-	-	-
5	-	-	-	-	-	-
6	-	-	-	-	-	-
7	-	-	-	-	-	-
8	-	-	-	-	-	-
9	-	-	-	-	-	-
10	-	-	-	-	-	-
11	-	-	-	-	-	-
12	-	-	-	-	-	-
13	-	-	-	-	-	-
14	NV creates picking list	-	-	-	-	-
15	NV picks parts from Kanban or stock for NV	-	8.50	3.83	-	-
16	NV packs parts	-	4.00	1.80	-	-
17	NV creates inbound documentation and sends it to BAAS	SS creates inbound documentation and sends it to BAAS	1.00	2.10	-	-
18	BAAS receives inbound documentation and updates system	BAAS receives inbound documentation and updates system	0.00	0.00	0.50	1.05
19	NV ships parts to BAAS	SS ships parts to BAAS	-	-	-	-
20	BAAS receives and unpacks parts	BAAS receives and unpacks parts				
21	BAAS registers parts	BAAS registers parts	6.50	3.44	6.50	3.44
22	BAAS counts and controls parts	BAAS counts and controls parts				
23	BAAS stores parts	BAAS stores parts				
24	NV sends invoice to BAAS	SS sends invoice to BAAS	-	-	-	-
25	BAAS registers and pays invoice from NV	BAAS registers and pays invoice from SS	2.00	4.20	2.00	4.20
Total			27.00	25.88	15.00	21.31
	BAAS picks parts	*same*				
	BAAS packs parts	*same*				
	BAAS ships parts to customer	*same*				
	BAAS sends invoice to customer	*same*				
	Customer registers and pays invoice from BAAS	*same*				

Activity performed by BAAS
Activity performed by NV
Activity performed by SS
Physical Order Handling Activity
Administrative Ordering Activity

The time figures are given in minutes per PO line and the cost figures are given in € per PO Line.

APPENDIX 6.1.2.2: ALL PO LINES BETWEEN FACTORY NIEUW-VENNEP AND WAREHOUSE METZ IN 2012 WITH RESPECTIVE EXTERNAL SUPPLIERS

Rank	External Supplier	PO Lines
1	Supplier 4	558
2	Supplier 108	396
3	Supplier 25	230
4	Supplier 3	178
5	Supplier 74	144
6	Supplier 150	128
7	Supplier 159	126
8	Supplier 73	107
9	Supplier 62	106
10	Supplier 23	104
11	Supplier 158	94
12	Supplier 26	89
13	Supplier 64	76
14	Supplier 124	75
15	Supplier 31	64
16	Supplier 115	54
17	Supplier 131	53
18	Supplier 46	41
19	Supplier 54	41
20	Supplier 65	39
21	Supplier 73	39
22	Supplier 180	37
23	Supplier 110	34
24	Supplier 22	33
25	Supplier 17	30
26	Supplier 89	30
27	Supplier 5	29
28	Supplier 16	27
29	Supplier 77	27
30	Supplier 129	27
31	Supplier 79	25
32	Supplier 140	23
33	Supplier 71	22
34	Supplier 174	21
35	Supplier 59	21
36	Supplier 183	21
37	Supplier 91	21
38	Supplier 117	20
39	Supplier 107	18
40	Supplier 32	16
41	Supplier 70	16
42	Supplier 134	15

43	Supplier 30	14
44	Supplier 42	14
45	Supplier 92	14
46	Supplier 121	14
47	Supplier 138	14
48	Supplier 13	13
49	Supplier 103	13
50	Supplier 76	12
51	Supplier 142	11
52	Supplier 100	10
53	Supplier 143	10
54	Supplier 35	9
55	Supplier 58	9
56	Supplier 184	9
57	Supplier 98	9
58	Supplier 123	9
59	Supplier 29	8
60	Supplier 33	8
61	Supplier 188	8
62	Supplier 190	8
63	Supplier 99	8
64	Supplier 144	8
65	Supplier 171	6
66	Supplier 20	6
67	Supplier 40	6
68	Supplier 114	6
69	Supplier 126	6
70	Supplier 137	6
71	Supplier 18	5
72	Supplier 37	5
73	Supplier 47	5
74	Supplier 132	5
75	Supplier 198	5
76	Supplier 173	4
77	Supplier 178	4
78	Supplier 43	4
79	Supplier 56	4
80	Supplier 82	4
81	Supplier 85	4
82	Supplier 93	4
83	Supplier 194	4
84	Supplier 195	4
85	Supplier 160	4
86	Supplier 172	3
87	Supplier 175	3
88	Supplier 55	3
89	Supplier 187	3

90	Supplier 109	3
91	Supplier 111	3
92	Supplier 197	3
93	Supplier 130	3
94	Supplier 204	3
95	Supplier 170	2
96	Supplier 24	2
97	Supplier 36	2
98	Supplier 41	2
99	Supplier 179	2
100	Supplier 182	2
101	Supplier 186	2
102	Supplier 78	2
103	Supplier 87	2
104	Supplier 96	2
105	Supplier 193	2
106	Supplier 112	2
107	Supplier 133	2
108	Supplier 139	2
109	Supplier 199	2
110	Supplier 152	2
111	Supplier 153	2
112	Supplier 202	2
113	Supplier 203	2
114	Supplier 12	1
115	Supplier 14	1
116	Supplier 176	1
117	Supplier 177	1
118	Supplier 44	1
119	Supplier 48	1
120	Supplier 52	1
121	Supplier 181	1
122	Supplier 185	1
123	Supplier 67	1
124	Supplier 189	1
125	Supplier 81	1
126	Supplier 191	1
127	Supplier 84	1
128	Supplier 192	1
129	Supplier 86	1
130	Supplier 101	1
131	Supplier 116	1
132	Supplier 196	1
133	Supplier 118	1
134	Supplier 200	1
135	Supplier 151	1
136	Supplier 201	1

137	Supplier 156	1
Total		3,677

Based on all POs which were placed from the warehouse towards the factory between 01/2012-01/2013 and which were closed until 04/2013.

APPENDIX 6.1.3: MAIN FINDINGS OF SAVINGS ANALYSIS (ORDER COSTS)

			Current Situation	Proposed Situation	Savings
STAP	Per PO Line	Time NV	28.50	0.00	28.50
		Cost NV	30.17	0.00	30.17
		Time BAAS	12.00	15.00	-3.00
		Cost BAAS	15.00	21.31	-6.31
		Time Group	40.50	15.00	25.50
		Cost Group	45.17	21.31	23.86
	Total	Time Group	100,926.00	37,380.00	63,546.00
		Cost Group	112,561.37	53,093.19	59,468.18
	SS 4	Time Group	34,911.00	12,930.00	21,981.00
		Cost Group	38,935.76	18,365.30	20,570.45
IUP	Per PO Line	Time NV	15.00	0.00	15.00
		Cost NV	10.88	0.00	10.88
		Time BAAS	12.00	15.00	-3.00
		Cost BAAS	15.00	21.31	-6.31
		Time Group	27.00	15.00	12.00
		Cost Group	25.88	21.31	4.57
	Total	Time Group	99,279.00	55,155.00	44,124.00
		Cost Group	95,159.09	78,340.16	16,818.93
	SS 4	Time Group	15,066.00	8,370.00	6,696.00
		Cost Group	14,440.79	11,888.44	2,552.34

STAP + IUP	**Total**	**Time Group**	200,205.00	92,535.00	107,670.00
		Cost Group	207,720.46	131,433.35	76,287.11
	SS 4	**Time Group**	49,977.00	21,300.00	28,677.00
		Cost Group	53,376.54	30,253.75	23,122.80

The time figures are given in minutes and the cost figures are given in €.

APPENDIX 6.1.3.1.A: PURCHASING PROCESS OF STAND ALONE PARTS (DIRECT COSTS)

Step	Current Situation	Proposed Situation	Current Situation		Proposed Situation	
			Time	Cost	Time	Cost
	BAAS gets order from customer and confirms it	*same*				
	BAAS gets requisition from SAS and selects it	*same*				
1	BAAS sends order to NV	BAAS sends order to SS	1.00	0.45	1.00	0.45
2	BAAS takes care of expediting towards NV	BAAS takes care of expediting towards SS	2.50	1.13	5.00	2.25
3	NV gets order from BAAS and creates new order	SS gets order from BAAS and confirms it	1.50	0.68	-	-
4	NV sends order to SS	-	1.00	0.45	-	-
5	NV takes care of expediting towards SS	-	5.00	2.25	-	-
6	SS gets order from NV and confirms it	-	-	-	-	-
7	SS ships parts to NV	-	-	-	-	-
8	NV receives and unpacks parts	-	5.50	2.48	-	-
9	NV registers parts	-				
10	NV counts and controls parts	-				
11	NV stores parts at inbound or stock for BAAS	-				
12	SS sends invoice to NV	-	-	-	-	-
13	NV registers and pays invoice from SS	-	2.00	0.90	-	-
14	NV creates picking list	-	-	-	-	-
15	NV picks parts from inbound or stock for BAAS	-	8.50	3.83	-	-
16	NV packs parts	-	4.00	1.80	-	-
17	NV creates inbound documentation and sends it to BAAS	SS creates inbound documentation and sends it to BAAS	1.00	0.45	-	-
18	BAAS receives inbound documentation and updates system	BAAS receives inbound documentation and updates system	0.00	0.00	0.50	0.23
19	NV ships parts to BAAS	SS ships parts to BAAS	-	-	-	-
20	BAAS receives and unpacks parts	BAAS receives and unpacks parts	6.50	3.44	6.50	3.44
21	BAAS registers parts	BAAS registers parts				
22	BAAS counts and controls parts	BAAS counts and controls parts				
23	BAAS stores parts	BAAS stores parts				
24	NV sends invoice to BAAS	SS sends invoice to BAAS	-	-	-	-
25	BAAS registers and pays invoice from NV	BAAS registers and pays invoice from SS	2.00	0.90	2.00	0.90
Total			40.50	18.74	15.00	7.27
	BAAS picks parts	*same*				
	BAAS packs parts	*same*				
	BAAS ships parts to customer	*same*				
	BAAS sends invoice to customer	*same*				
	Customer registers and pays invoice from BAAS	*same*				

Activity performed by BAAS
Activity performed by NV
Activity performed by SS
Physical Order Handling Activity
Administrative Ordering Activity

The time figures are given in minutes per PO line and the cost figures are given in € per PO Line.

APPENDIX 6.1.3.1.B: PURCHASING PROCESS OF IN USE PARTS (DIRECT COSTS)

Step	Current Situation	Proposed Situation	Current Situation		Proposed Situation	
			Time	Cost	Time	Cost
	BAAS gets order from customer and confirms it	*same*				
	BAAS gets requisition from SAS and selects it	*same*				
1	BAAS sends order to NV	BAAS sends order to SS	1.00	0.45	1.00	0.45
2	BAAS takes care of expediting towards NV	BAAS takes care of expediting towards SS	2.50	1.13	5.00	2.25
3	NV gets order from BAAS	SS gets order from BAAS and confirms it	1.50	0.68	-	-
4	-	-	-	-	-	-
5	-	-	-	-	-	-
6	-	-	-	-	-	-
7	-	-	-	-	-	-
8	-	-	-	-	-	-
9	-	-	-	-	-	-
10	-	-	-	-	-	-
11	-	-	-	-	-	-
12	-	-	-	-	-	-
13	-	-	-	-	-	-
14	NV creates picking list	-	-	-	-	-
15	NV picks parts from Kanban or stock for NV	-	8.50	3.83	-	-
16	NV packs parts	-	4.00	1.80	-	-
17	NV creates inbound documentation and sends it to BAAS	SS creates inbound documentation and sends it to BAAS	1.00	0.45	-	-
18	BAAS receives inbound documentation and updates system	BAAS receives inbound documentation and updates system	0.00	0.00	0.50	0.23
19	NV ships parts to BAAS	SS ships parts to BAAS	-	-	-	-
20	BAAS receives and unpacks parts	BAAS receives and unpacks parts	6.50	3.44	6.50	3.44
21	BAAS registers parts	BAAS registers parts				
22	BAAS counts and controls parts	BAAS counts and controls parts				
23	BAAS stores parts	BAAS stores parts				
24	NV sends invoice to BAAS	SS sends invoice to BAAS	-	-	-	-
25	BAAS registers and pays invoice from NV	BAAS registers and pays invoice from SS	2.00	0.90	2.00	0.90
Total			27.00	12.67	15.00	7.27
	BAAS picks parts	*same*				
	BAAS packs parts	*same*				
	BAAS ships parts to customer	*same*				
	BAAS sends invoice to customer	*same*				
	Customer registers and pays invoice from BAAS	*same*				

Activity performed by BAAS
Activity performed by NV
Activity performed by SS
Physical Order Handling Activity
Administrative Ordering Activity

The time figures are given in minutes per PO line and the cost figures are given in € per PO Line.

APPENDIX 6.1.3.1.C: MAIN FINDINGS OF SAVINGS ANALYSIS (DIRECT COSTS)

			Current Situation	Proposed Situation	Savings
STAP	Per PO Line	Time NV	28.50	0.00	28.50
		Cost NV	12.83	0.00	12.83
		Time BAAS	12.00	15.00	-3.00
		Cost BAAS	5.92	7.27	-1.35
		Time Group	40.50	15.00	25.50
		Cost Group	18.74	7.27	11.48
	Total	Time Group	100,926.00	37,380.00	63,546.00
		Cost Group	46,700.08	18,104.38	28,595.70
	SS 4	Time Group	34,911.00	12,930.00	21,981.00
		Cost Group	16,153.88	6,262.43	9,891.45
IUP	Per PO Line	Time NV	15.00	0.00	15.00
		Cost NV	6.75	0.00	6.75
		Time BAAS	12.00	15.00	-3.00
		Cost BAAS	5.92	7.27	-1.35
		Time Group	27.00	15.00	12.00
		Cost Group	12.67	7.27	5.40
	Total	Time Group	99,279.00	55,155.00	44,124.00
		Cost Group	46,569.21	26,713.41	19,855.80
	SS 4	Time Group	15,066.00	8,370.00	6,696.00
		Cost Group	7,067.07	4,053.87	3,013.20

STAP + IUP	Total	Time Group	200,205.00	92,535.00	107,670.00
		Cost Group	93,269.29	44,817.79	48,451.50
	SS 4	Time Group	49,977.00	21,300.00	28,677.00
		Cost Group	23,220.95	10,316.30	12,904.65

The time figures are given in minutes and the cost figures are given in €.

APPENDIX 6.2: EXAMINED SPARE PARTS WITH DEMAND FIGURES FOR EACH MONTH OF THE YEAR

Spare Part	RG00034744	RG00037241	RG00037242	RG00039683	RG00062998	VNB4203478	VNB4294378	VNB4294778	VNB4457478
C (€)	500.09	331.00	529.92	497.06	496.99	498.38	502.56	432.51	679.34
fr	0.98	0.98	0.98	0.98	0.98	0.92	0.98	0.92	0.98
L_{old}	1.93	1.93	1.93	1.93	2.67	2.67	2.93	2.93	2.93
L_{new}	0.73	0.80	1.17	1.07	1.30	1.27	1.90	1.90	2.07
D	2.50	1.33	1.10	2.67	5.00	0.19	1.48	0.29	2.06
σ_D	2.60	1.93	1.28	2.44	4.52	0.53	1.74	0.54	2.24
D_1	1.80	2.40	2.60	4.80	3.80	0.40	1.20	0.20	1.00
σ_{D1}	0.98	2.73	1.02	3.87	3.19	0.80	1.47	0.40	1.55
D_2	3.60	0.80	0.80	6.60	4.80	0.00	2.60	0.40	1.60
σ_{D2}	0.49	0.40	1.60	2.73	1.94	0.00	4.22	0.49	1.02
D_3	5.00	1.80	1.40	5.00	10.20	0.60	0.80	0.60	2.80
σ_{D3}	4.56	2.14	1.50	1.90	4.40	0.80	0.98	0.49	0.75
D_4	6.00	2.20	1.60	2.60	12.40	0.00	4.00	0.00	5.00
σ_{D4}	1.67	2.14	1.74	1.02	3.14	0.00	1.26	0.00	2.00
D_5	3.50	3.75	2.00	5.25	9.00	0.00	2.50	1.00	6.00
σ_{D5}	1.80	2.86	0.71	2.28	4.30	0.00	1.12	0.71	2.74
D_6	2.75	1.75	2.25	4.00	5.75	0.00	2.00	0.00	3.75
σ_{D6}	1.09	0.83	0.83	0.71	1.92	0.00	1.58	0.00	0.83
D_7	0.25	0.25	0.75	0.50	1.50	0.50	1.25	0.25	1.25
σ_{D7}	0.43	0.43	1.30	0.50	0.50	0.87	1.30	0.43	1.30
D_8	1.75	1.00	0.00	0.50	1.50	0.00	1.00	0.50	0.75
σ_{D8}	1.79	1.00	0.00	0.87	1.12	0.00	1.22	0.50	0.43
D_9	1.75	1.00	1.75	1.25	2.50	0.25	0.75	0.50	1.25
σ_{D9}	0.83	1.22	1.09	1.09	1.80	0.43	0.83	0.87	1.09
D_{10}	0.50	0.25	0.00	1.00	2.50	0.25	2.00	0.00	0.75

σ_{D10}	0.50	0.43	0.00	0.71	1.80	0.43	2.92	0.00	0.83
D_{11}	0.50	0.00	0.25	0.75	4.00	0.50	1.75	0.00	1.25
σ_{D11}	0.50	0.00	0.43	0.83	4.24	0.87	2.49	0.00	1.09
D_{12}	1.25	0.50	1.00	2.25	3.50	0.00	0.25	0.00	0.25
σ_{D12}	0.83	0.50	1.22	1.79	4.09	0.00	0.43	0.00	0.43

Based on demand data of the central spare parts warehouse in Metz for the months 01/2009-05/2013.

D_1 and σ_{D1} refer to the average demand and the standard deviation of demand in January, D_2 and σ_{D2} in February, etc.

APPENDIX 6.2.1: DERIVATION OF EOQ FORMULA AND EFFECT OF ORDER QUANTITY ON COSTS

The EOQ formula is based on the total annual cost which requires the following input factors:

$D = annual\ demand\ of\ product$

$S = fixed\ cost\ incurred\ per\ order$

$C = cost\ per\ unit$[1]

$h = holding\ cost\ per\ year\ as\ fraction\ of\ product\ cost$

$Q = order\ quantity$

The total annual cost is the sum of the annual material cost, annual ordering cost and annual holding cost which are given as:

$$annual\ material\ cost = C * D$$ **Formula A.6.2.1.A**

$$annual\ ordering\ cost = number\ of\ orders\ per\ year * S = \left(\frac{D}{Q}\right) * S$$ **Formula A.6.2.1.B**

$$annual\ holding\ cost = cycle\ inventory * h * C = \left(\frac{Q}{2}\right) * h * C$$ **Formula A.6.2.1.C**

Thus, the total annual cost (TC) is given as:

$$total\ annual\ cost = TC = C * D + \left(\frac{D}{Q}\right) * S + \left(\frac{Q}{2}\right) * h * C$$ **Formula A.6.2.1.D**

Since the total annual cost should be minimized, the "Economic Order Quantity" is obtained by taking the first derivative of Formula A.6.2.1.D with respect to Q and setting it equal to 0:

$$economic\ order\ quantity = EOQ = Q^* = \sqrt{\frac{2 * D * S}{h * C}}$$ **Formula A.6.2.1.E**

Let us now consider spare part RG00062998 as an example for the calculation of the economic order quantity.

[1] It is assumed that the cost per unit C is fixed and independent of the order quantity Q.

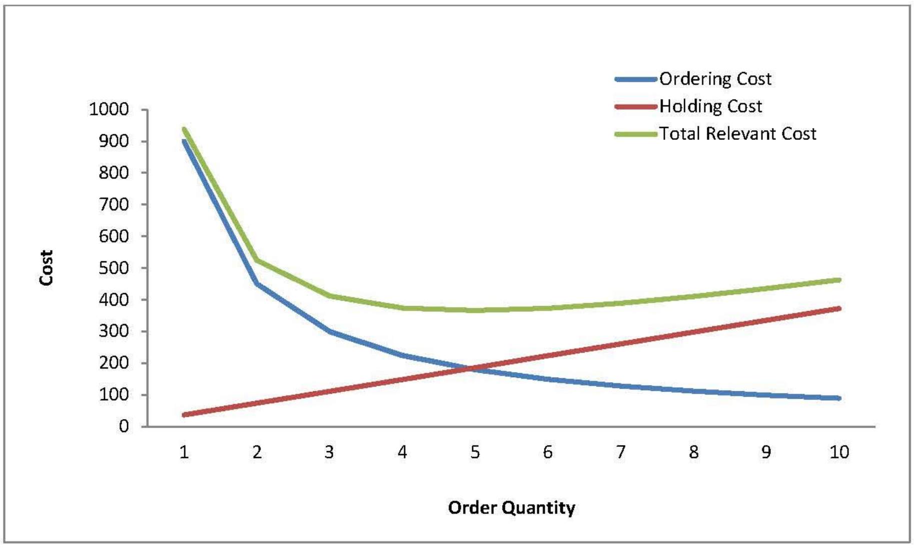
EXAMPLE A.6.2.1: CALCULATION OF EOQ FOR SPARE PART RG00062998

Data: $D = forecast = 60$, $S = order\ cost\ (per\ PO\ line) = 15€$, $C = moving\ avg\ price = 496.99€$ and $h = 0.15$

Plugging in these values in Formula A.6.2.1.E, gives us $Q^* = 4.9138 \approx 5$.[2]

The following figure illustrates the effect of an increasing order quantity on annual ordering cost, annual holding cost and total annual relevant cost taking spare part RG00062998 as an example.

FIGURE A.6.2.1: EFFECT OF ORDER QUANTITY ON COSTS



As Figure A.6.2.1 indicates, the annual ordering cost decreases with an increase in order quantity and the annual holding cost increases with an increase in order quantity. Since the annual material cost is independent of the order quantity we only focus on the sum of the two other costs (total annual relevant cost). The total annual relevant cost first decreases and then increases with an increase in order quantity and is minimized when annual ordering cost and annual holding cost are equal which at the same time generates the appropriate EOQ value (≈5).

[2] As the calculation for spare part RG00062998 indicates, the estimated values for Q should always be rounded up to the next integer to secure that the total demand can be definitely satisfied with the chosen parameters.

APPENDIX 6.2.2.1: DETERMINATION OF S, SS AND AVERAGE INVENTORY FOR SPARE PART RG00062998

TABLE A.6.2.2.1.A: EXCEL FORMULAS

	A	B	C	D	E
1	**D**	5			
2	**σ_D**	4,5185			
3	**L**	2,6667			
4	**Q**	5			
5	**cycle inventory**	=B4/2			
6	**D_L**	=B1*B3			
7	**σ_L**	=B2*SQRT(B3)			
8					
9	**s**	**S**	**ss**	**average inventory**	**fr**
10	0	=A10+$B$4	=A10-$B$6	=C10+$B$5	=1-(-C10*(1-NORMDIST(C10/$B$7;0;1;1))+$B$7*NORMDIST(C10/$B$7;0;1;0))/$B$4
11	1	=A11+$B$4	=A11-$B$6	=C11+$B$5	=1-(-C11*(1-NORMDIST(C11/$B$7;0;1;1))+$B$7*NORMDIST(C11/$B$7;0;1;0))/$B$4
12	2	=A12+$B$4	=A12-$B$6	=C12+$B$5	=1-(-C12*(1-NORMDIST(C12/$B$7;0;1;1))+$B$7*NORMDIST(C12/$B$7;0;1;0))/$B$4
13	3	=A13+$B$4	=A13-$B$6	=C13+$B$5	=1-(-C13*(1-NORMDIST(C13/$B$7;0;1;1))+$B$7*NORMDIST(C13/$B$7;0;1;0))/$B$4
14	4	=A14+$B$4	=A14-$B$6	=C14+$B$5	=1-(-C14*(1-NORMDIST(C14/$B$7;0;1;1))+$B$7*NORMDIST(C14/$B$7;0;1;0))/$B$4
15	5	=A15+$B$4	=A15-$B$6	=C15+$B$5	=1-(-C15*(1-NORMDIST(C15/$B$7;0;1;1))+$B$7*NORMDIST(C15/$B$7;0;1;0))/$B$4
16	6	=A16+$B$4	=A16-$B$6	=C16+$B$5	=1-(-C16*(1-NORMDIST(C16/$B$7;0;1;1))+$B$7*NORMDIST(C16/$B$7;0;1;0))/$B$4
17	7	=A17+$B$4	=A17-$B$6	=C17+$B$5	=1-(-C17*(1-NORMDIST(C17/$B$7;0;1;1))+$B$7*NORMDIST(C17/$B$7;0;1;0))/$B$4
18	8	=A18+$B$4	=A18-$B$6	=C18+$B$5	=1-(-C18*(1-NORMDIST(C18/$B$7;0;1;1))+$B$7*NORMDIST(C18/$B$7;0;1;0))/$B$4
19	9	=A19+$B$4	=A19-$B$6	=C19+$B$5	=1-(-C19*(1-NORMDIST(C19/$B$7;0;1;1))+$B$7*NORMDIST(C19/$B$7;0;1;0))/$B$4
20	10	=A20+$B$4	=A20-$B$6	=C20+$B$5	=1-(-C20*(1-NORMDIST(C20/$B$7;0;1;1))+$B$7*NORMDIST(C20/$B$7;0;1;0))/$B$4
21	11	=A21+$B$4	=A21-$B$6	=C21+$B$5	=1-(-C21*(1-NORMDIST(C21/$B$7;0;1;1))+$B$7*NORMDIST(C21/$B$7;0;1;0))/$B$4
22	12	=A22+$B$4	=A22-$B$6	=C22+$B$5	=1-(-C22*(1-NORMDIST(C22/$B$7;0;1;1))+$B$7*NORMDIST(C22/$B$7;0;1;0))/$B$4
23	13	=A23+$B$4	=A23-$B$6	=C23+$B$5	=1-(-C23*(1-NORMDIST(C23/$B$7;0;1;1))+$B$7*NORMDIST(C23/$B$7;0;1;0))/$B$4
24	14	=A24+$B$4	=A24-$B$6	=C24+$B$5	=1-(-C24*(1-NORMDIST(C24/$B$7;0;1;1))+$B$7*NORMDIST(C24/$B$7;0;1;0))/$B$4

25	15	=A25+$B$4	=A25-$B$6	=C25+$B$5	=1-(-C25*(1-NORMDIST(C25/$B$7;0;1;1))+$B$7*NORMDIST(C25/$B$7;0;1;0))/$B$4
26	16	=A26+$B$4	=A26-$B$6	=C26+$B$5	=1-(-C26*(1-NORMDIST(C26/$B$7;0;1;1))+$B$7*NORMDIST(C26/$B$7;0;1;0))/$B$4
27	17	=A27+$B$4	=A27-$B$6	=C27+$B$5	=1-(-C27*(1-NORMDIST(C27/$B$7;0;1;1))+$B$7*NORMDIST(C27/$B$7;0;1;0))/$B$4
28	18	=A28+$B$4	=A28-$B$6	=C28+$B$5	=1-(-C28*(1-NORMDIST(C28/$B$7;0;1;1))+$B$7*NORMDIST(C28/$B$7;0;1;0))/$B$4
29	19	=A29+$B$4	=A29-$B$6	=C29+$B$5	=1-(-C29*(1-NORMDIST(C29/$B$7;0;1;1))+$B$7*NORMDIST(C29/$B$7;0;1;0))/$B$4
30	20	=A30+$B$4	=A30-$B$6	=C30+$B$5	=1-(-C30*(1-NORMDIST(C30/$B$7;0;1;1))+$B$7*NORMDIST(C30/$B$7;0;1;0))/$B$4
31	21	=A31+$B$4	=A31-$B$6	=C31+$B$5	=1-(-C31*(1-NORMDIST(C31/$B$7;0;1;1))+$B$7*NORMDIST(C31/$B$7;0;1;0))/$B$4
32	22	=A32+$B$4	=A32-$B$6	=C32+$B$5	=1-(-C32*(1-NORMDIST(C32/$B$7;0;1;1))+$B$7*NORMDIST(C32/$B$7;0;1;0))/$B$4
33	23	=A33+$B$4	=A33-$B$6	=C33+$B$5	=1-(-C33*(1-NORMDIST(C33/$B$7;0;1;1))+$B$7*NORMDIST(C33/$B$7;0;1;0))/$B$4
34	24	=A34+$B$4	=A34-$B$6	=C34+$B$5	=1-(-C34*(1-NORMDIST(C34/$B$7;0;1;1))+$B$7*NORMDIST(C34/$B$7;0;1;0))/$B$4
35	25	=A35+$B$4	=A35-$B$6	=C35+$B$5	=1-(-C35*(1-NORMDIST(C35/$B$7;0;1;1))+$B$7*NORMDIST(C35/$B$7;0;1;0))/$B$4
36	26	=A36+$B$4	=A36-$B$6	=C36+$B$5	=1-(-C36*(1-NORMDIST(C36/$B$7;0;1;1))+$B$7*NORMDIST(C36/$B$7;0;1;0))/$B$4
37	27	=A37+$B$4	=A37-$B$6	=C37+$B$5	=1-(-C37*(1-NORMDIST(C37/$B$7;0;1;1))+$B$7*NORMDIST(C37/$B$7;0;1;0))/$B$4
38	28	=A38+$B$4	=A38-$B$6	=C38+$B$5	=1-(-C38*(1-NORMDIST(C38/$B$7;0;1;1))+$B$7*NORMDIST(C38/$B$7;0;1;0))/$B$4
39	29	=A39+$B$4	=A39-$B$6	=C39+$B$5	=1-(-C39*(1-NORMDIST(C39/$B$7;0;1;1))+$B$7*NORMDIST(C39/$B$7;0;1;0))/$B$4
40	30	=A40+$B$4	=A40-$B$6	=C40+$B$5	=1-(-C40*(1-NORMDIST(C40/$B$7;0;1;1))+$B$7*NORMDIST(C40/$B$7;0;1;0))/$B$4
41	31	=A41+$B$4	=A41-$B$6	=C41+$B$5	=1-(-C41*(1-NORMDIST(C41/$B$7;0;1;1))+$B$7*NORMDIST(C41/$B$7;0;1;0))/$B$4
42	32	=A42+$B$4	=A42-$B$6	=C42+$B$5	=1-(-C42*(1-NORMDIST(C42/$B$7;0;1;1))+$B$7*NORMDIST(C42/$B$7;0;1;0))/$B$4
43	33	=A43+$B$4	=A43-$B$6	=C43+$B$5	=1-(-C43*(1-NORMDIST(C43/$B$7;0;1;1))+$B$7*NORMDIST(C43/$B$7;0;1;0))/$B$4
44	34	=A44+$B$4	=A44-$B$6	=C44+$B$5	=1-(-C44*(1-NORMDIST(C44/$B$7;0;1;1))+$B$7*NORMDIST(C44/$B$7;0;1;0))/$B$4
45	35	=A45+$B$4	=A45-$B$6	=C45+$B$5	=1-(-C45*(1-NORMDIST(C45/$B$7;0;1;1))+$B$7*NORMDIST(C45/$B$7;0;1;0))/$B$4
46	36	=A46+$B$4	=A46-$B$6	=C46+$B$5	=1-(-C46*(1-NORMDIST(C46/$B$7;0;1;1))+$B$7*NORMDIST(C46/$B$7;0;1;0))/$B$4
47	37	=A47+$B$4	=A47-$B$6	=C47+$B$5	=1-(-C47*(1-NORMDIST(C47/$B$7;0;1;1))+$B$7*NORMDIST(C47/$B$7;0;1;0))/$B$4
48	38	=A48+$B$4	=A48-$B$6	=C48+$B$5	=1-(-C48*(1-NORMDIST(C48/$B$7;0;1;1))+$B$7*NORMDIST(C48/$B$7;0;1;0))/$B$4
49	39	=A49+$B$4	=A49-$B$6	=C49+$B$5	=1-(-C49*(1-NORMDIST(C49/$B$7;0;1;1))+$B$7*NORMDIST(C49/$B$7;0;1;0))/$B$4
50	40	=A50+$B$4	=A50-$B$6	=C50+$B$5	=1-(-C50*(1-NORMDIST(C50/$B$7;0;1;1))+$B$7*NORMDIST(C50/$B$7;0;1;0))/$B$4
51	41	=A51+$B$4	=A51-$B$6	=C51+$B$5	=1-(-C51*(1-NORMDIST(C51/$B$7;0;1;1))+$B$7*NORMDIST(C51/$B$7;0;1;0))/$B$4
52	42	=A52+$B$4	=A52-$B$6	=C52+$B$5	=1-(-C52*(1-NORMDIST(C52/$B$7;0;1;1))+$B$7*NORMDIST(C52/$B$7;0;1;0))/$B$4
53	43	=A53+$B$4	=A53-$B$6	=C53+$B$5	=1-(-C53*(1-NORMDIST(C53/$B$7;0;1;1))+$B$7*NORMDIST(C53/$B$7;0;1;0))/$B$4
54	44	=A54+$B$4	=A54-$B$6	=C54+$B$5	=1-(-C54*(1-NORMDIST(C54/$B$7;0;1;1))+$B$7*NORMDIST(C54/$B$7;0;1;0))/$B$4

55	45	=A55+$B$4	=A55-$B$6	=C55+$B$5	=1-(-C55*(1-NORMDIST(C55/$B$7;0;1;1))+$B$7*NORMDIST(C55/$B$7;0;1;0))/$B$4
56	46	=A56+$B$4	=A56-$B$6	=C56+$B$5	=1-(-C56*(1-NORMDIST(C56/$B$7;0;1;1))+$B$7*NORMDIST(C56/$B$7;0;1;0))/$B$4
57	47	=A57+$B$4	=A57-$B$6	=C57+$B$5	=1-(-C57*(1-NORMDIST(C57/$B$7;0;1;1))+$B$7*NORMDIST(C57/$B$7;0;1;0))/$B$4
58	48	=A58+$B$4	=A58-$B$6	=C58+$B$5	=1-(-C58*(1-NORMDIST(C58/$B$7;0;1;1))+$B$7*NORMDIST(C58/$B$7;0;1;0))/$B$4
59	49	=A59+$B$4	=A59-$B$6	=C59+$B$5	=1-(-C59*(1-NORMDIST(C59/$B$7;0;1;1))+$B$7*NORMDIST(C59/$B$7;0;1;0))/$B$4
60	50	=A60+$B$4	=A60-$B$6	=C60+$B$5	=1-(-C60*(1-NORMDIST(C60/$B$7;0;1;1))+$B$7*NORMDIST(C60/$B$7;0;1;0))/$B$4

TABLE A.6.2.2.1.B: CALCULATED VALUES

	A	B	C	D	E
1	**D**	5			
2	**σ_D**	4.5185			
3	**L**	2.6667			
4	**Q**	5			
5	**cycle inventory**	2.5			
6	**D_L**	13.3335			
7	**σ_L**	7.3787			
8					
9	**s**	**S**	**ss**	**average inventory**	**fr**
10	0	5	-13.3335	-10.8335	-1.6874
11	1	6	-12.3335	-9.8335	-1.4956
12	2	7	-11.3335	-8.8335	-1.3065
13	3	8	-10.3335	-7.8335	-1.1208
14	4	9	-9.3335	-6.8335	-0.9391
15	5	10	-8.3335	-5.8335	-0.7622
16	6	11	-7.3335	-4.8335	-0.5911
17	7	12	-6.3335	-3.8335	-0.4266
18	8	13	-5.3335	-2.8335	-0.2695
19	9	14	-4.3335	-1.8335	-0.1208
20	10	15	-3.3335	-0.8335	0.0188

21	11	16	-2.3335	0.1665	0.1487
22	12	17	-1.3335	1.1665	0.2683
23	13	18	-0.3335	2.1665	0.3773
24	14	19	0.6665	3.1665	0.4755
25	15	20	1.6665	4.1665	0.5630
26	16	21	2.6665	5.1665	0.6399
27	17	22	3.6665	6.1665	0.7067
28	18	23	4.6665	7.1665	0.7639
29	19	24	5.6665	8.1665	0.8124
30	20	25	6.6665	9.1665	0.8527
31	21	26	7.6665	10.1665	0.8859
32	22	27	8.6665	11.1665	0.9128
33	23	28	9.6665	12.1665	0.9342
34	24	29	10.6665	13.1665	0.9511
35	25	30	11.6665	14.1665	0.9641
36	26	31	12.6665	15.1665	0.9741
37	27	32	13.6665	16.1665	0.9815
38	28	33	14.6665	17.1665	0.9870
39	29	34	15.6665	18.1665	0.9910
40	30	35	16.6665	19.1665	0.9939
41	31	36	17.6665	20.1665	0.9959
42	32	37	18.6665	21.1665	0.9973
43	33	38	19.6665	22.1665	0.9982
44	34	39	20.6665	23.1665	0.9989
45	35	40	21.6665	24.1665	0.9993
46	36	41	22.6665	25.1665	0.9996
47	37	42	23.6665	26.1665	0.9997
48	38	43	24.6665	27.1665	0.9998
49	39	44	25.6665	28.1665	0.9999
50	40	45	26.6665	29.1665	0.9999

51	41	46	27.6665	30.1665	1.0000
52	42	47	28.6665	31.1665	1.0000
53	43	48	29.6665	32.1665	1.0000
54	44	49	30.6665	33.1665	1.0000
55	45	50	31.6665	34.1665	1.0000
56	46	51	32.6665	35.1665	1.0000
57	47	52	33.6665	36.1665	1.0000
58	48	53	34.6665	37.1665	1.0000
59	49	54	35.6665	38.1665	1.0000
60	50	55	36.6665	39.1665	1.0000

APPENDIX 6.3: CURRENT AND FUTURE CAPITAL FLOW

TABLE A.6.3.A: CALCULATED VALUES

	A	B	C	D	E	F	G
1		**DC1**	**Markup**	**Total Margin**	**x1**	**x2**	**x3**
2		20	5	80%	100	75	70
3							
4		**Stage**	SS	PC	WH	SC	ED
5		**Price**	DC1	TP1	TP2	DN	GRP
6							
7		**Price**	20	34	48.1	70	100
8	**Current Setting**	**Profit**		14	14.1	21.9	30
9		**Margin**		41.18%	29.31%	31.29%	30.00%
10							
11		**Price**	20	0	48.1	70	100
12	**Future Setting**	**Profit**		0	28.1	21.9	30
13		**Margin**		0.00%	58.42%	31.29%	30.00%
14							
15		**Stage**	**Cost**	**Turnover**	**Fee**	**Profit**	
16							
17		**PC**	2,000	2,550	0	550	
18	**Current Setting**	**WH**	2,550	3,367	0	817	
19		**PC+WH**	4,550	5,917		1,367	
20							
21		**PC**	0	0	0	0	
22	**Future Setting**	**WH**	2,000	3,367	0	1,367	
23		**PC+WH**	2,000	3,367		1,367	
24							

25		**PC**	0	0	1,400	1,400
26	**1. Approach**	**WH**	2,000	3,367	1,400	-33
27		**PC+WH**	2,000	3,367		1,367
28						
29		**PC**	0	0	1050	1,050
30	**2. Approach**	**WH**	2,000	3,367	1050	317
31		**PC+WH**	2,000	3,367		1,367
32						
33		**PC**	0	0	980	980
34	**3. Approach**	**WH**	2,000	3,367	980	387
35		**PC+WH**	2,000	3,367		1,367
36						
37		**PC**	0	0	550	550
38	**4. Approach**	**WH**	2,000	3,367	550	817
39		**PC+WH**	2,000	3,367		1,367

TABLE A.6.3.B: EXCEL FORMULAS

	A	B	C	D	E	F	G
1		**DC1**	**Markup**	**Total Margin**	**x1**	**x2**	**x3**
2		20	5	=(G7-C7)/G7	100	75	70
3							
4		**Stage**	SS	PC	WH	SC	ED
5		**Price**	DC1	TP1	TP2	DN	GRP
6							
7		**Price**	=B2	=0.34*G7	=(0.34+0.141)*G7	=(0.34+0.141+0.219)*G7	=B2*C2
8	**Current Setting**	**Profit**		=D7-C7	=E7-D7	=F7-E7	=G7-F7
9		**Margin**		=(D7-C7)/D7	=(E7-D7)/E7	=(F7-E7)/F7	=(G7-F7)/G7
10							
11	**Future Setting**	**Price**	=B2	0	=(0.34+0.141)*G11	=(0.34+0.141+0.219)*G11	=B2*C2

12		**Profit**		0	=E11-C11	=F11-E11	=G11-F11
13		**Margin**		0	=(E11-C11)/E11	=(F11-E11)/F11	=(G11-F11)/G11
14							
15		**Stage**	**Cost**	**Turnover**	**Fee**	**Profit**	
16							
17		**PC**	=E2*C7	=F2*D7	0	=D17-C17	
18	**Current Setting**	**WH**	=F2*D7	=G2*E7	0	=D18-C18	
19		**PC+WH**	=SUM(C17:C18)	=SUM(D17:D18)		=SUM(F17:F18)	
20							
21		**PC**	0	0	0	0	
22	**Future Setting**	**WH**	=E2*C7	=G2*E7	0	=D22-C22	
23		**PC+WH**	=SUM(C21:C22)	=SUM(D21:D22)		=SUM(F21:F22)	
24							
25		**PC**	0	0	=E2*D8	=E25	
26	**1. Approach**	**WH**	=E2*C7	=G2*E7	=E25	=D26-C26-E26	
27		**PC+WH**	=SUM(C25:C26)	=SUM(D25:D26)		=SUM(F25:F26)	
28							
29		**PC**	0	0	=F2*D8	=E29	
30	**2. Approach**	**WH**	=E2*C7	=G2*E7	=E29	=D30-C30-E30	
31		**PC+WH**	=SUM(C29:C30)	=SUM(D29:D30)		=SUM(F29:F30)	
32							
33		**PC**	0	0	=G2*D8	=E33	
34	**3. Approach**	**WH**	=E2*C7	=G2*E7	=E33	=D34-C34-E34	
35		**PC+WH**	=SUM(C33:C34)	=SUM(D33:D34)		=SUM(F33:F34)	
36							
37		**PC**	0	0	=F17	=E37	
38	**4. Approach**	**WH**	=E2*C7	=G2*E7	=E37	=D38-C38-E38	
39		**PC+WH**	=SUM(C37:C38)	=SUM(D37:D38)		=SUM(F37:F38)	

All price, profit, cost and turnover figures are given in €.

The yellow shaded areas represent the input cells.