MASTER

The design of a decision support system of an integrated return acceptance and replenishment policy

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The Design of a Decision Support System of an Integrated Return Acceptance and Replenishment Policy

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ABSTRACT

In this study, a decision support system is developed for a coordinated return acceptance and replenishment policy for spare parts at Grundfos Distribution Service. This system is developed to decrease the cost of the return acceptance process. The decision support system is modeled to decide on returns to accept and replenishments to do in an integrated way. This is modeled by a periodic review order-up-to level control system under non-stationary demand and return. The decision support system determines the optimal starting and stopping time for accepting returns. These variables are found by a hierarchical heuristic algorithm. In addition to the proposed system, different acceptance scenarios are modeled to compare the performance of the proposed system respectively. Furthermore, a sensitivity analysis is done to evaluate the performance of the proposed system with respect to different demand and return rates.

Keywords: Return acceptance, periodic review order-up-to level control system, spare parts, non-stationary demand

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MANAGEMENT SUMMARY

This study has been carried out at Grundfos Distribution Service (GDS) which is the distribution center for Grundfos, the Danish water pump manufacturing company. GDS mainly focuses on the distribution of the spare parts from the manufacturing companies to the customers of GDS (e.g. the sales offices), exception handling and return process for the spare parts. This study focuses on the return process of the spare parts from the sales offices back to GDS.

The return process at GDS arises because the sales offices want to adjust their stocks by sending back the slow-moving or obsolete spare parts. This return process is initiated and motivated by a general slow-moving policy (Appendix 1) which aims to reduce the inventory levels at the sales offices. The current return acceptance policy at GDS shows that the cost of accepting returns is higher than doing replenishments. Moreover, it is observed that there are more returns accepted than needed regarding the demand rates. Furthermore, one of the disadvantageous aspects of the current system is that the replenishments are done without considering the accepted returns. All of these aspects, increases the current cost of return acceptance and replenishment. Moreover, return acceptance becomes not economically reasonable as an alternative to cheaper replenishments.

In order to solve these problems, the following research questions are formulated: How should a return acceptance policy be designed such that acceptance of returns becomes an economically feasible source alternative to replenishments and how long should GDS accept the returns in order to recover the costs? In order to reach these objectives a decision support system for the integrated return acceptance and replenishment policy is designed.

This decision model is used to decide on the amount of returns to accept and to decide on the amount of replenishments under a cost-efficient integrated inventory policy. This policy is modeled as a periodic order-up-to review system under non-stationary stochastic demand and stationary return rates. The optimal period for accepting returns is found by developing an optimization model. This model determines the time to start and stop accepting returns with minimum cos. The performance of the model is evaluated by doing both a numerical analysis and sensitivity analysis. Both of the analysis involves 5 scenarios that are used to evaluate the performance of integration and return acceptance policy.

The numerical study is done for 20 different spare parts. According to this study, the following conclusions are made:

- The integrated return acceptance policy performs better than the current acceptance system and doing only replenishments.
- The integrated return acceptance policy reduces the buy-back, handling, cleaning and repacking costs by accepting returns in an optimal period.
- The proposed policy rejects 40% of the returns.
- High buy-back price for returns play an important role in deciding on when to accept returns.
- As an alternative policy, all returns can be accepted with an integration of the replenishments. This policy also performs better than the current system. However, this alternative under the investigated spare parts is not economically feasible when the demand rate is decreasing and the return rate is higher than the demand rate.

- The performance of accepting returns under the proposed policy without an integration is also investigated. This alternative is not economically reasonable because there is no integration with the replenishments. As GDS have enough infrastructure for the integration, this scenario can hardly be an alternative.

The final aim of this study is to evaluate the responsiveness of the performance of the proposed system with respect to varying spare parts, return, demand patterns and cleaning, repacking probabilities. The sensitivity analysis suggests that:

- The proposed system's performance is robust regarding the fast moving or slows moving spare parts with decreasing or increasing rate of demands, return rates and unit purchase prices.
- The alternative method of accepting all of the returns with integration performs better for the spare parts with an increasing rate of demand. The proposed method performs better under decreasing rate of demand.
- GDS should motivate the sales offices to send less spare parts that need to be cleaned and repacked to decrease the cost.

The proposed decision support system can be easily implemented by using an Excel Spreadsheet while making forecasts of the return request and the demand rates. The decision support system can be used whenever a return request arrives at GDS. It should be updated every month while forecasting the demand and return rate for 12 months. The optimal starting and stopping decision should be made until the end of the planning horizon.

When the complete study is evaluated, the following recommendations are made for GDS:

- If GDS hesitates to reject returns from the sales offices, then GDS should accept all the returns with integration with replenishments.
- GDS should increase the reduction percentages in buy-back prices.
- GDS should use the order-up-to levels that are used for replenishments also for accepting the returns.
- GDS should consider the accepted returns while replenishing. This can be complex because SAP has no integration with returns. However, this can be solved by putting returns into SAP under blocked stock as soon as they are accepted. Thus, the stock levels will be updated accordingly.
- The company should take all the cleaning, and repackaging costs of returns from the sales offices in order to cover the cost of returns.

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List of Abbreviations

BTO: Buy-to-Order
BTS: Buy-to-stock
GDS : Grundfos Distribution Service
(R,S): Periodic review order-up-to level control system for inventory Replenishment
SKU: Stock keeping unit
3PL: Third Party Logistics

List of Definitions

Base Stock: The minimum inventory level that is necessary to maintain cost effective replenishment decisions.

Credit for the returns: The purchasing percentage for the returns with respect to the selling price of the spare part to the sales office. (100%- discount of the return due to age)

Non-Stockable item: an item that is produced or bought after the arrival of the demand

Order-up-to-level inventory replenishment Policy: an inventory replenishment policy which indicates to order up to level (S) whenever the inventory position falls below this level.

Order acceptance process: The process where the returns that are requested by the sales offices are confirmed to be returned back to the distribution center.

Planning horizon: The time interval where an organization analyzes the future of the market for a specific part when preparing a strategic plan.

Reverse logistics: is the process of moving goods from the end customers back to the manufacturers and distributors for the purpose of capturing value, or proper disposal.

Spare parts: Parts that are used for service operations which have low-demand and low-value.

Stochastic non-stationary demand: demand whose behavior is non-deterministic in that a system's subsequent state is determined by a random element and the state can change from one period to another.

Stockable item: an item that can be put on stock before the demand arrival from the customer

1 Introduction

Logistic decisions related to spare parts become more complex as the range of spare parts, customers and vendors increases. Currently, the return of spare parts back to the distributor or manufacturer becomes an important issue. By the help of reverse logistics, a returned part can be considered as a source for a spare part. One of the reasons for returns is the stock adjustments by returning the excess stock at various stock points in the supply chain to distribution centers and manufacturing facilities. The stock adjustments are taken care of via a return process at the spare parts distribution center for Grundfos Group, which is Grundfos Distribution Service.

Grundfos Distribution Service (GDS) has started the return process after the initiation of slow-movers return policy. This policy states that the sales offices can return the slow-movers back to GDS for a refund (Appendix 1). After the application of this policy, the sales offices have accelerated the process to identify non-movers and slow-movers and return them back to GDS to recover value. Such a return of the spare parts can usually be considered as advantageous with respect to more expensive replenishments. However, the current return process of GDS is more expensive than replenishments. This makes acceptance of returns not economically reasonable under the current system. As a trade-off GDS cannot reject all of the return requests from the sales offices.

So far, there is no action taken to make these current returns process economically feasible so that returns can be a reasonable alternative to replenishments. The main concern of GDS is to make the acceptance of returns economically feasible until return requests from the sales offices diminish. The current return policy in GDS depends on only following the rules that are determined by Grundfos management under the slow-moving policy. However, it has never been analyzed that whether the current return process is beneficial for not only the sales offices but also for GDS. Considering this issue GDS would like to reduce all the possible negative impacts of return acceptance on GDS which causes GDS to lose money. Regarding these issues, the initial assignment of the thesis project is to first get insight about the current cost of returns at GDS and to have a new return acceptance system which is economically feasible.

In order to reach this aim, this study focuses first on the analysis of the current return process of GDS by analyzing the current cost of the system and its profitability. Then, in order to reduce the costs of GDS for returns and improve efficiency, a decision support system for an integrated return acceptance and replenishment system is developed. By using this system, the optimal values for the decision variables will be found in order to have an economically feasible return system. The decision variables are about the amount of returns to accept, the amount of replenishments to do and how long a return process should take place. These are analyzed by a mathematical model while the model is solved by a hierarchical heuristic.

The structure of the thesis is as follows: In the first section, the company and the current return process will be described. Furthermore, the replenishment and return process of GDS will be described in this section. The cost of return handling and replenishment will be computed in section 1.4. According to the results of the cost analysis and process description, in section 2, the problem will be analyzed in detail and the components within the return process that should be improved will be determined. The solution approaches in the literature will be discussed in section 3. An efficient return acceptance policy will be suggested in section 4. In section 4.4, regarding the proposed policy, a mathematical model will be developed. In section 5, a numerical analysis will be done regarding the model and the results will be discussed. Then, the results will be compared with the cost of the current system at GDS. Following this, in section 6, a sensitivity analysis will be done to see how the proposed system behaves in varying environments. An implementation plan will be given in section 7. Finally, a summary of the main results will be given as well as suggestions for future work in section 8.

1.1 Company Description

Grundfos is a Danish water pump manufacturing company that was founded in 1945. Approximately sixteen million pumps are produced annually. The product types are mainly pumps and motors for nine different categories: heating, air-conditioning, pressure boosting, groundwater supply, waste water, domestic water, industrial applications, dosing and disinfection.

The major values of the Grundfos Group are “Be Responsible, Think Ahead and Innovate”. With these values, the company considers its responsibility to create innovative solutions and ideas with a foresight to reach its mission of being world’s leading pump manufacturer.

Within Grundfos AG, there are 50 Grundfos sales offices, 12 production companies, 5 business companies and 4 management companies with a total of 71 companies in 45 countries. The manufacturing plants are located in Brazil, China, Denmark, Finland, France, Germany, Hungary, Italy, Switzerland, Taiwan, United Kingdom and the United States.

According to the organization matrix of Grundfos AG, the company is composed of 4 different groups, namely: business services, operations, business development and sales (Appendix 2). Business services involve corporate finance, information services and communication departments. The operations group consists of corporate manufacturing, group logistics, group purchase, quality and corporate social responsibility. The business development group involves the innovative solutions, research and development and new business areas. Moreover, all the sales offices function under the sales group. The thesis project will take place at Grundfos Distribution Service (GDS) which is the spare parts distribution center of the Grundfos group functioning by the group logistics.

The supply chain of Grundfos AG includes the goods flow from the manufacturing companies and external vendors to the end customers and the returns flow from the end customers to the manufacturing companies (Appendix 3). The supply chain process is as follows: first, the parts needed for production are purchased from the vendors. Then, the production of both spare parts and the pumps is done at the Grundfos manufacturing companies. These pumps are then transported to regional DC’s where they are stocked and distributed to the sales companies. Furthermore, within the supply chain of Grundfos there can be returns from the end customers till back to the manufacturing companies.

The spare part’s goods flow is managed differently at Grundfos. The spare parts are transported from the Grundfos manufacturing companies or from the external vendors to Grundfos Distribution Service (GDS). The function of GDS is to transport the spare parts to the sales offices. Then, the sales offices sell the spare parts to end-consumers or repair services. Also, the return of the spare parts is handled from the sales offices back to GDS.

1.2 Description of the Grundfos Distribution Service (GDS)

GDS was founded in 2003 to centralize Grundfos spare parts inventory. The target is to establish a high level of spare part availability and to increase the range of different types of spare parts without increasing inventory levels at the sales offices.

GDS is considered as the central stock location for the spare parts of Grundfos considering the whole world. The vision of GDS is to be a part of a spare part supply chain using modern principles and systems that make it convenient for customers to choose Grundfos as a supplier of pump systems.

The main processes that take place at GDS are as follows:

- Order Exception Handling: This process mainly consists of the management of the exceptions occurring during transportation of the parts to the customer.
- Spare Parts Replenishment: As GDS can be considered as the distribution point for the sales offices, most of the spare parts demanded by the sales offices are replenished by GDS from the vendors according to customer requests or GDS's inventory policy.
- Transportation Mode Selection: According to the customer request, GDS chooses the transportation mode for orders.
- Return Handling: This activity involves accepting the return requests from the sales offices back to GDS.

GDS works with 3rd party logistics providers to manage the physical warehouse activities and transportation to the sales offices. Ceva Logistics is responsible for the stocking and the handling of the spare parts at a warehouse in Eindhoven. Ceva Logistics has specialized in inbound logistics (for the collection of parts from suppliers to storage of products); outbound logistics (for the delivery of products to customers); spare-parts logistics (storage and distribution of spare parts to the aftermarket). The logistics carrier, TNT is responsible for the transportation of the spare parts to the sales offices.

This thesis project focuses on the return handling process of GDS. In order to analyze the current return handling process and to define possible problems, it is essential to describe the spare parts and the processes at GDS which will be done in the following section.

1.3 GDS Current Process Description for Replenishment and Return Acceptance

1.3.1 Spare parts

In order to have a clear understanding of the processes done at GDS, it is necessary to describe the properties of the spare parts. There are over 47,800 different types of spare parts in GDS. Each type of spare part can be found at GDS in one of the two groups which are kits and individual spare parts. The service kits contain one or more spare parts and special tools needed for a specific repair. Individual spare parts, on the other hand, include only one component.

The shelf-life of spare parts varies from 2 to 5 years. After the end of the shelf life, the spare parts become not suitable for use. From a stock keeping point of view, the spare parts are categorized into stockables and non-stockables. Stockables are the spare parts that are managed by a Buy-To-Stock (BTS) policy. Within the BTS policy, the spare parts are subdivided in 5 categories:

SKU – Spare parts, which are defined as stockable in GDS and had sales in the past;
NEW SKU - Spare parts, which are defined as stockable in GDS currently but not stockable in the past
SEED SKU - Spare parts which GDS has decided to be kept in stock to support sales company business.
GUARANTEE - Spare parts that are no longer produced by the production companies
PHASE-OUTS - items part of a phase out strategy.

Non-stockables, on the other hand, are the parts that are directly purchased from a vendor after the customers order without keeping any stocks. So, the non-stockables are managed by a Buy-to-Order (BTO) policy. These spare parts have either a very low consumption rate or these spare parts are produced specially for the customer. The percentages of the amount of BTO and BTS spare parts at GDS are given in Figure 1.

In the thesis project, stockable spare parts will be analyzed because only the spare parts that are stocked at GDS can be returned back to GDS. As the percentage of stockables is increasing, the management of returns has become a crucial issue.

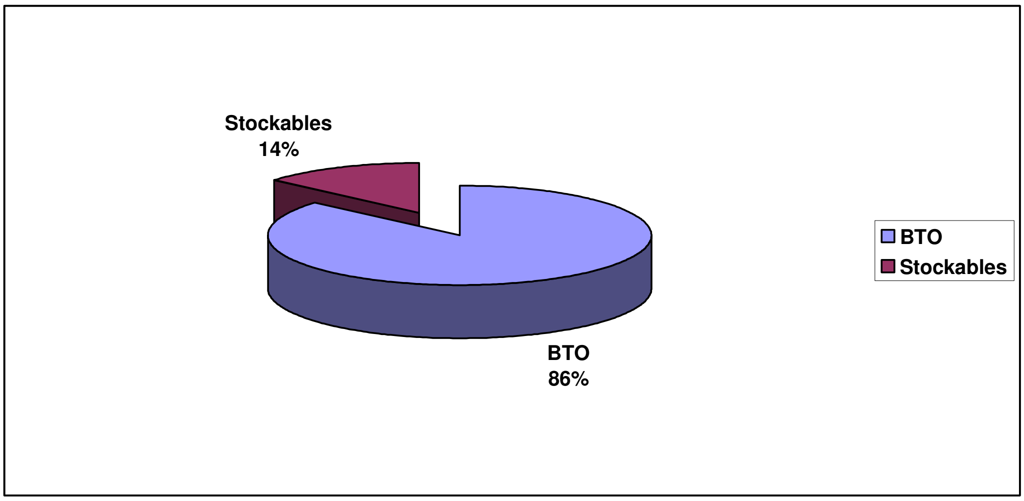

Figure 1. The ratio of number of BTO and stockable parts with respect to total number of spare parts which is retrieved from SAP on 14th March 2009

1.3.2 Detailed Process Description

The process of GDS can be divided in two parts: forward supply chain process and return process.

The goods flow in the forward supply chain process for Buy-to-Stock parts is represented in Figure 2. The spare parts are produced by the vendors which can be either external or internal vendors. The internal vendors are Grundfos' manufacturing companies. These spare parts are transported and consolidated at the warehouse in Eindhoven which is outsourced to Ceva Logistics. In case of a customer order, these spare parts are transported to the sales offices by a third party logistics provider (TNT). The sales offices of Grundfos sell these spare parts to installers and wholesalers. All the orders and information sharing are handled by SAP.

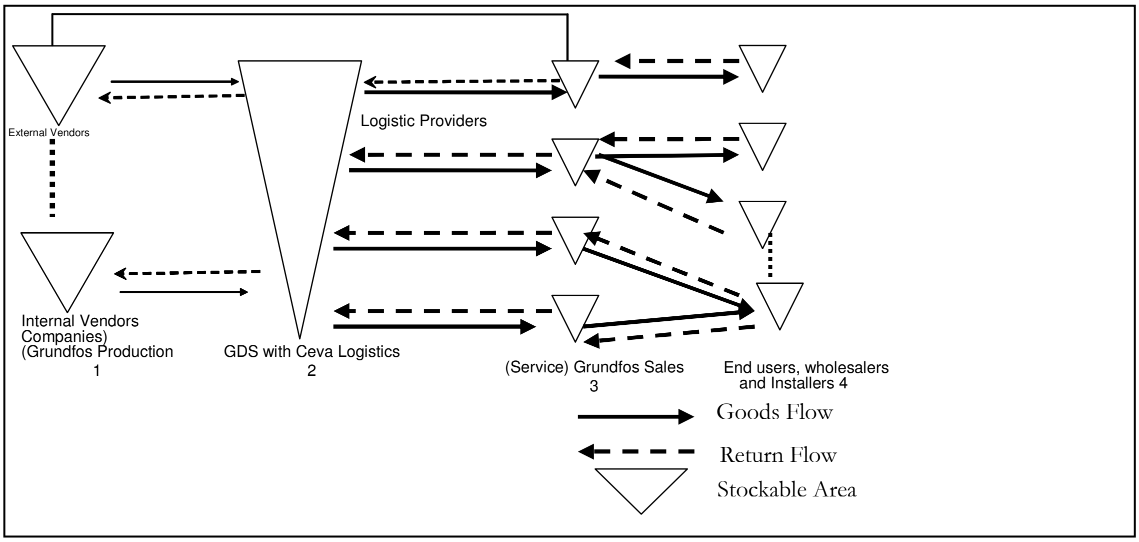

Figure 2. Goods flows and return flows for the spare parts that are stockable

1.3.3 Current Inventory Replenishment Policy

The stockable units are managed under a BTS policy as explained in section 1.3.1. The inbound flow of the BTS items is closely related to the inventory policy of GDS. GDS makes inventory decisions according to a (R,S) policy where the parameters of order-up-to level and safety stock are updated on a rolling horizon basis. The base stock is calculated according to the lead time of replenishments from the vendors and the customer service level. The service level is defined as the non-stock-out probability with a target of 0.98. The base stock is determined by:

$$S = \mu * R + ss$$

$$ss = k * \sigma * \sqrt{(\mathrm{L}+\mathrm{R})}$$

where

μ = Mean sales per month according to the past 1 year data

R = Review Period

ss = Safety Stock of the spare part

k = Safety factor

L = The Lead Time from a supplier

As an important remark, the order-up-to level is determined by the mean demand during the review time. The vendor lead time is not included in this expression. This can create problems when the lead time is longer than the review period. Furthermore, the demand is assumed to be mutually independent for consecutive months which may not be the case in real life.

The lead time is determined by the vendor. The lead time ranges between 2-3 weeks. By the inventory replenishment system described above, the order-up-to levels and the safety stocks are set for each spare part individually. These calculations do not take into account the returns.

1.3.4 Current Return Process

In a general perspective, the recovery process for returned parts consists of collection of the spare parts where product acquisition, transportation, and storage take place. Then, the collected parts/products undergo inspection with testing. Afterwards, the products are refurbished, i.e. cleaning and packaging operations, so that they can be reused. The non-recoverable products are disposed by scrapping and the transformed products are sold to the same market as new with the normal selling price.

The reverse logistics process in Grundfos concerns only the returns for spare parts from the sales offices to GDS.

There are several causes for the returns to GDS (which are shown in detail at Appendix 4 in the cause-effect diagram):

- Stock Adjustments of sales offices to decrease the inventory of slow movers and obsolete spare parts
- Cancellations of orders from the end customers
- The return of spare parts that have quality issues
- The return of damaged spare parts during transportation
- The return of wrongly delivered parts
- The return of kits with missing parts

Among these returns, returns due to stock adjustments of slow-movers and non-movers are the most frequent ones as stated by GDS logistics planners. (Quantitative data of the returns apart from stock adjustments is not available as they are not stored in the system). Therefore, the focus of the study will be on the returns due to stock adjustments of the sales offices.

The return process of the slow-movers and the non-movers is initiated by the slow-moving policy of Grundfos (Appendix 1). The sales offices are decentralized in decision making and order from GDS independently. As there is no centralization in decision making, sales offices prefer holding excess amount of safety stocks in their inventory. In the course of time, these stocks may become slow-movers or obsolete parts. Then, it becomes essential to return these spare parts to GDS to reduce the stocks of the sales offices. Thus, in order to adjust their stocks sales offices have started to return these spare parts back to GDS under the slow-moving policy.

Under the stock adjustments, the return policy states that sales offices can return the spare parts that do not have demand within 6 months back to GDS (these spare parts are called slow movers). The sales offices are getting paid for the returns with the reduction percentages as defined in the slow-moving policy. Thus, the sales offices are motivated to return back the slow movers and the obsolete parts in their stocks. GDS is given the responsibility to accept these returns according to the constraints as stated below:

- GDS should accept the returns if they stock the returned items at GDS.
- The spare parts that are damaged must be scrapped by the sales offices.
- GDS should not accept motors and pump heads older than 2 years. These parts must be scrapped by the sales offices.
- GDS should not accept spare parts containing electrical parts older than 3 years. These parts must be scrapped by the sales offices.

- GDS should buy back the spare parts from the sales offices according to the percentage reductions in the selling prices of the part. The reduction percentages are given in Table 1.

The return process is shown in figure 3: (The goods flow information is obtained from the supervisor from GDS and by the observations done on following the flow of returns at GDS and CEVA Logistics)

- Firstly, the sales office identifies the spare parts that are needed to be returned (number 1 and 2, Figure 3)
- The sales office sends GDS a return request containing the spare part's name, amount, and its date of production (number 3, Figure 3).
- Then, GDS planners determine a reduction percentage and the quantity to be returned according to the age and the stockability of the return as stated in Table 1. This information is then sent to the sales office.

Age Reduction	
Age	Reduction in the selling price
0-6 months	5%
6-12months	20%
12-24 months	45% (except motors, pump heads)
24-36 months	55% (except motors, pump heads ,electrical parts)
Older than 3 years	90%
Condition Reduction	
Condition	Additional Reduction
Need to be repacked	-20%
Need to be repacked and cleaned	-35%
damaged	No credit

Table 1. The crediting percentages for returns of spare parts

- After acceptance, the returns are transported to the warehouse (number 4, Figure 3). The maximum lead-time for returning to the warehouse is 2 weeks.
- After the arrival of the returns in the warehouse, Ceva checks whether repackaging or cleaning is needed (number 6, Figure 3).If the spare part has to be cleaned or repacked, these operations are executed as soon as possible (number 8 and 9, Figure 3). Furthermore, it can be the case that the sales office returns old and unusable spare parts (number 5, Figure 3). For these parts, the scrapping is done by Ceva Logistics.
- According to the information from the quality check operation, the reduction percentages are updated and the sales offices are informed. (If this is the case, there is more reduction from the buyback price of the spare part as indicated in the Table 1)
- The spare parts, except the ones that will be scrapped, are put on stock before they become physically available (number 12, Figure 3).
- The invoice with the reduction percentages is sent to the sales office where GDS pays the value of the returned spare part.
- The returned items that are put on stock are sold to the sales offices at a normal selling price (number 13, Figure 3). The returned spared part is sold as new without any consideration of the age of the spare part. The sales offices do not know whether they bought a returned item or a new item.

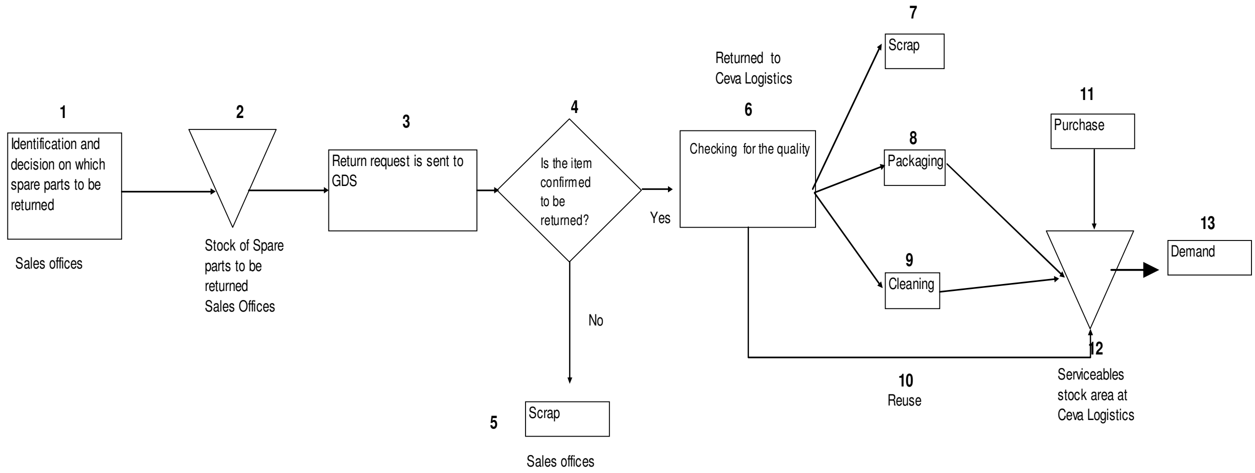

Figure 3. The goods flow diagram for the return process based on own observations and information from GDS).

1.3.5 The acceptance policy of the returns

A return order can consist of several spare parts where the acceptance is done item by item per order. A sales office can create a return order at any time by e-mail before transporting the returns.

The decision whether to accept or refuse the return request depends on the age of the part and on whether the spare part is stockable or not. If the spare part is a BTO spare part, then it is rejected. If not, the age of the spare part is analyzed according to the constraints in section 1.3.4. For the rest of the spare parts, no upper limit for age is determined by Grundfos slow-moving policy. However, there can be returns older than 4 or 5 years which are considered to have low quality, so GDS rejects the spare parts older than 3 years.

If the return request is accepted after the age analysis, then a preliminary buyback price is determined according to Table 1. The buy-back price is calculated as follows:
The reduction percentage based on age* the selling price to the sales company
The selling price is calculated by: (1+profit margin)* the replenishment price.
The profit margin varies from 0% to 20% percentage of the replenishment price of the spare part and is different for each sales company. The return price is calculated based on this selling price. This is one of the reasons that makes the returns more expensive than the replenishments.

After the accepted returns arrive at Ceva Logistics, the checking process is done to determine whether the return needs to be scrapped, cleaned or repackaged. The information concerning these is sent by e-mail to GDS. The repacking and cleaning activities are successfully done and all of the spare parts are directly pushed in to the serviceables inventory. Then, the returns except the scrapped ones are included in the inventory by adding the part numbers to SAP.

First of all, a cost analysis for the current return process is done to see whether GDS is really losing money on returns. Furthermore, it is targeted to analyze the cost components that have the highest impact on the total costs.

1.4 Cost Analysis for Return Acceptance and Handling Process

In order to get insight about the cost of the return handling and acceptance policy, a total cost is computed by using the data from SAP involving the months 10/2008 to 02/2009. These 5 months are selected because the data recording for returns has started on 10/2008. The analysis is done on a weekly level where 19 weeks in 5 months are analyzed.

Another objective of this cost study is to identify the components of the return process that have the highest contribution to the total cost so that the improvement study can be focused on these components. Furthermore, it is crucial to see the proportion of returns that are sold back to the customers after being accepted. With this proportion, it can be shown that there are returns becoming slow-movers at GDS after having been accepted.

1.4.1 The Cost Computation for Return Acceptance Process

The return process cost is calculated at a weekly level in order to have a detailed insight for a limited available data. The calculations are done for the spare parts that are returned in the given 19 weeks. In this analysis, there are 1118 different types of spare parts that are returned.

The total cost is composed of buy-back cost of the returns, return handling cost at the warehouse, weekly inventory holding cost, scrapping, cleaning and packaging cost. In order to compute these, the variables and cost parameters needed. The cost parameters are obtained from the contract of Ceva Logistics and GDS. The necessary variables and cost parameters are as follows:

Variables:
The number of returns that are accepted in week t (R(t))
The number of returns that are scrapped in week t ($q_s(t)$)
The number of returns that are cleaned in week t ($q_c(t)$)
The number of returns that are repacked in week t ($q_p(t)$)
The stock level of the serviceables inventory at the end of the week t (I(t))

Parameters:
Buy back cost per item: The buy-back price for each spare is stored and is found from SAP.
Unit handling cost at the warehouse (c_w): 8,59 €/item
Unit holding cost at the serviceables inventory (c_h):(weekly interest rate*value of the item): 0,039*replenishment price each item
Unit cleaning cost (c_c+ c_p): 37,18 €/item
Unit packaging cost (c_p): 18,59 €/item
Unit scrapping cost (c_s); 34,39 €/item

The total Cost for week (t) for a given part is calculated as follows:
TC(t): Sum of buy-back costs for all items+ return handling cost (R(t)*c_w)+ weekly inventory holding cost (I(t)* c_h)+ scrapping cost ($q_s(t)$* c_s) + cleaning cost (($q_c(t)$* (c_c+ c_p)) and packaging cost(($q_p(t)$* c_p)

The weekly costs and total cost are shown in Appendix 5. As seen from Figure 4, the total weekly cost showed a stochastic structure due to the stochastic arrival of returns as in Figure 5. There are also weeks where the return rate is too high compared to other weeks. For instance, in December and in the beginning of January, the total cost increased because the return rate increased tremendously because of stock adjustments at the end of the year (Figure 5). In addition to this, it can be concluded that the cost of returns fluctuates over weeks.

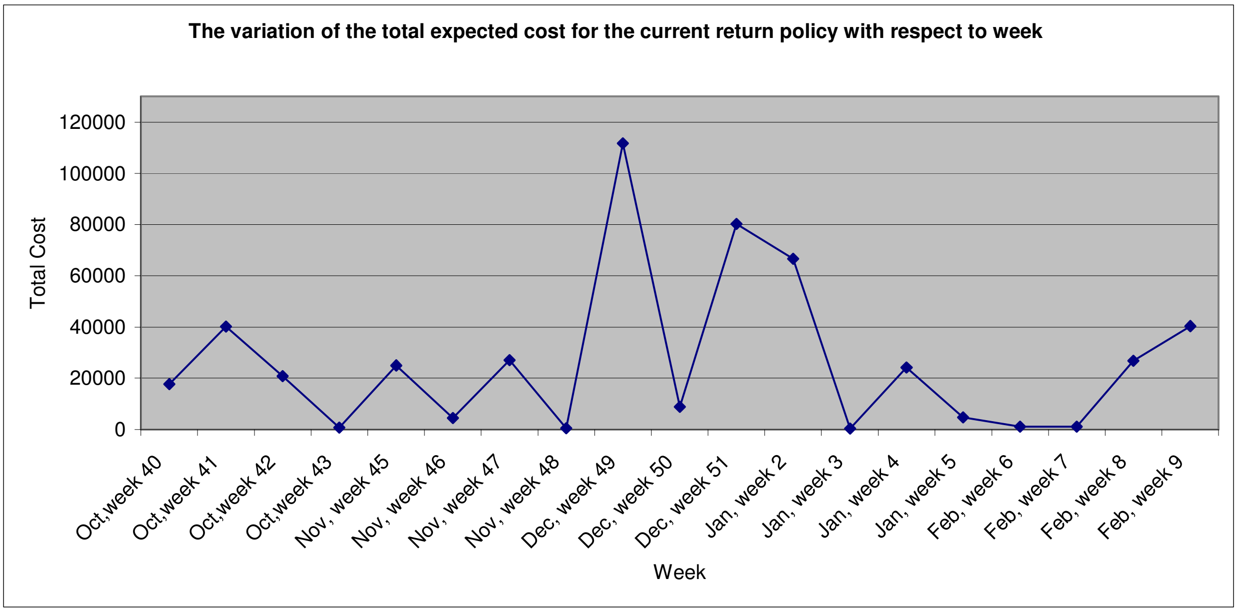

Figure 4. Weekly Total Cost Related to Returns by Using the Data from the months 10/2008-02/2009 from SAP

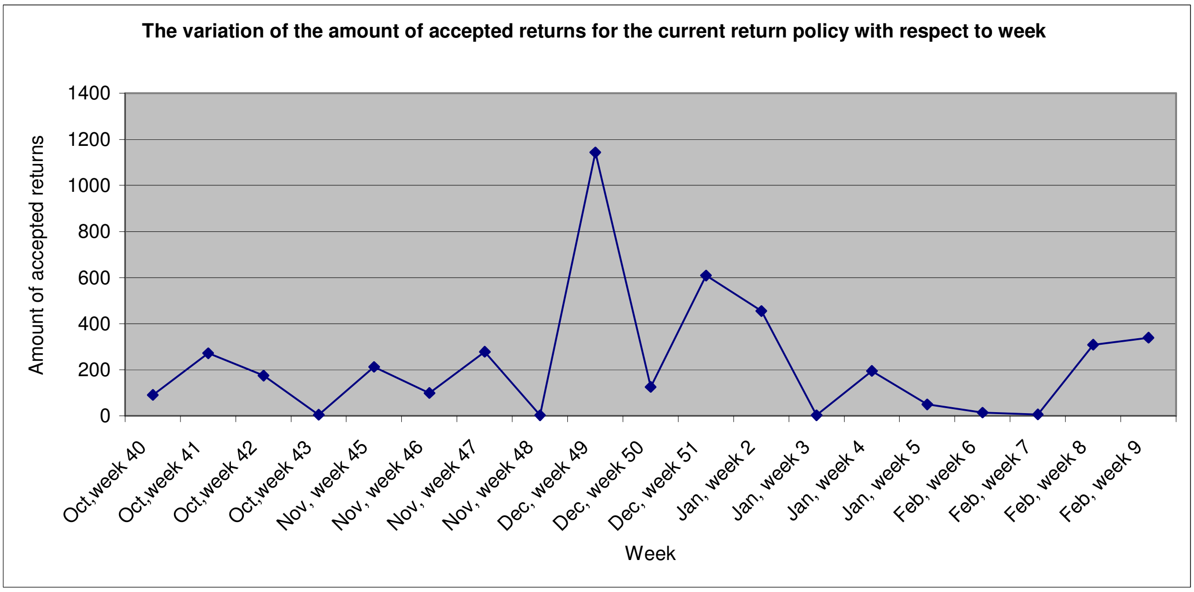

Figure 5. Weekly Amount of Accepted Returns by Using the Data from the months 10/2008-02/2009 from SAP

In order to get insight about whether GDS is losing money on the returns, another cost analysis is done. This analysis consists of computing the cost of doing replenishments instead of accepting the returns in the given period. The computation is done on all of the 1118 different spare parts that are accepted to be returned between the October 2008 and February 2009. The data is retrieved from SAP. The cost for replenishment per item is calculated by multiplying the amount of accepted items with the unit purchase price from the vendor. Then, all the costs for each item are added. This replenishment cost is then compared with the total cost of the returns including the buy-back cost, cleaning cost, handling cost, scrapping and repackaging cost.

Surprisingly, it is found out that if GDS would have purchased these items from vendors, then, the cost would have been much lower (Table 2). The cost of replenishments would have been about 29% lower than the cost of returns. Regarding these results, it can be suggested to accept no returns because replenishment offers cheap and high quality spare parts. However, the slow-moving policy forces GDS to accept returns. Therefore, it is necessary to have a return acceptance policy such that the cost for return acceptance should be reduced to make accepting returns reasonable. This target can be achieved by first gaining insight about the cost components of the return acceptance process. This analysis can show the cost components that increase the cost of return acceptance. This analysis will show in which cost components to deal with, to reduce the cost of the return acceptance.

Cost (Euro)	Total
Return cost without inventory holding cost	430272
The cost where replenishments were done instead of accepting returns	304968

Table 2. The cost of returns without inventory holding cost and cost that occurs if replenishments would have been done instead.

1.4.2 Analysis of the Cost Components of Return Acceptance Policy

The total cost from 10/2008 till the end of 02/2009 is analyzed in terms of 6 cost components: The buy-back cost, handling cost, scrapping cost, repacking cost, cleaning cost and average inventory holding cost. The percentages of each cost component over these weeks with respect to the total cost are compared. Then, it is seen that the current return policy cost is mostly affected by buy-back costs of the returns (73%), the inventory holding costs (14 %) and the handling cost (8%) (Table 3)

This result suggests that the improved system should focus on the buy-back, handling and inventory processes due to higher costs. The reduction in the amount of cleaned and scrapped parts will not be dealt in this thesis projects.

Cost/ Euro	Total (Euro)	Percentage wrt Total Cost
Handling Cost	38259.86	7.62
Scrapping Cost	1492.59	0.30
Repacking Cost	14202.76	2.83
Cleaning Cost	7956.52	1.58
Buy-Back Cost	368360.28	73.32
Average Weekly Holding Cost	72112.13	14.35
Total Cost	**502384.1428**	**100.00**

Table 3. The related percentages of various cost components on the total cost

In order to get more insight about whether GDS can recover the cost of returns by selling them and whether the returns become slow movers at GDS or obsolete stock, another analysis is done on the sales of the accepted returns which will be explained in section 1.4.3.

1.4.3 Analysis of the Sales of Accepted Returns

If accepting a return is more expensive than doing a replenishment, then its consumption after being returned becomes crucial. If the returned item is not sold for multiple periods, then its inventory cost is much higher than the inventory cost of a replenished part. This is because the value of a returned part is higher than a replenished part. Furthermore, as the accepted return can be older and used, the time that it stays in stock becomes crucial. In order to evaluate this, the ratio of spare parts (in terms of value and amount) that are not sold after being accepted within 6 months is analyzed. This is also crucial because if a spare part is not sold within 6 months, it can be counted as a slow-mover as stated by GDS. It becomes not economical then, to buy expensive returns that will eventually become slow-movers or obsolete stock. In this analysis:

- The returns accepted between the months **09/2008 and 12/2008** are retrieved from SAP.
- The returns that are sold between the months **09/2008 and 06/2009** are also retrieved together with their selling values.
- This analysis is done by comparing the amount of returns accepted in months **09/2008 and 12/2008** and the amount of spare parts that are sold between the months **09/2008 and 06/2009.** If the amount of sales is higher than the accepted returns, this means that all of the returns are sold. If not, the difference is still on stock.

If the unsold return ratio in 6 months is high, this indicates that GDS is buying the returns which are expensive than the replenishments and these expensive returns become slow-movers. The results can be seen in Table 4.

	Amount	**Value**
Returns sold until July 2009 from September 2008	3664	553295
Returns not sold until july 2009 from September 2008	287	56837.5
Percentage of not sold	7.83%	10.27%

Table 4. The percentage of returns that are not sold both in amount and value of returns.

From Table 4, it can be said that about 10% of the value for returns is lost due to accepting returns that has not enough demand. This means that 10% of the sales value has been in the stock of GDS more than 6 months. This kind of returns also increases the inventory holding cost. Also, by buying older and lower quality spare parts with a higher price is not reasonable if it stays in the stock and if there is a cheaper and high quality alternative. Furthermore, it can be concluded that 7.8% of the accepted returns has become a slow-mover.

Furthermore, a profit analysis is done to see whether GDS recovers the cost of returns by selling the returns. In order to do this the cost of returns in section 1.4.1 is compared with the value of sales from the sales of the returns from 10/2008 to 02/2009. (The cost of the returns for 09/2009 is not included because the scrapping, cleaning data collection has started in 10/2009) According to Table 5, GDS is losing money on accepting returns. The percent loss is about 5% for the defined period. This shows that GDS has not recovered the costs of the returns from 10/2008 to 02/2009 by their sales from 10/2008 until 06/2009.

	Value
Cost of returns acceptance	502384.1428
Sales of returns	479362.19
Percentage of loss	4.80%

Table 5. The loss of gains due to high cost of returns.

2 Problem Definition and Research Assignment

In this section, the results of the cost analysis and process observations will be used to state the possible problems of the return acceptance system. Next, research questions will be formulated in order to find solutions to these problems.

2.1 Problem Definition

The results of these cost analysis show that the current return acceptance policy can have higher costs than replenishment costs. This makes accepting returns not economically feasible when there is a cheaper replenishment option with higher quality. More important, it can be seen that GDS cannot recover the cost of returns by selling them. This is because GDS either cannot sell the materials within 6 months or the returns have higher costs than the selling price to the sales office. Thus, it is important to identify the causes leading to these results. So, the potential causes of high cost of accepting returns (including buy-back, inventory, replenishment, cleaning, packaging, scrapping costs) can be hypothesized as in Figure 5:

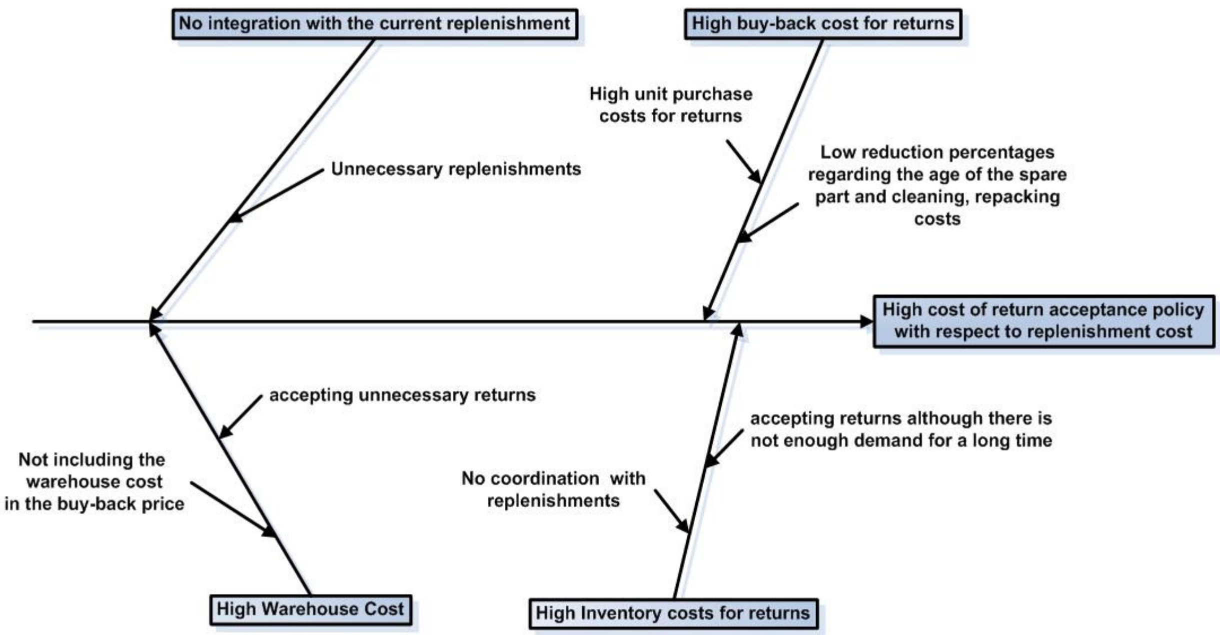

Figure 6. The cause-and-effect diagram for the reasons of high cost of return acceptance policy. The causes are determined from the costs analysis and own observations from the process at GDS.

Figure 6 shows that one of the main causes of high cost for the return acceptance policy is the high buy-back costs. The buy-buck cost equals to the number of returned parts*unit selling price of the part to the sales office*(1-reduction percentage considering the age, the cleaning and packaging cost).

According to this equation, the buy-back cost can depend on three factors:
1. First of all, the unit selling price of a part to the sales offices can be higher than the replenishment purchase price by up to 20% (maximum profit margin). Therefore, if the reduction percentage is less than 20%, it is obvious that accepting returns is more expensive than replenishing. The reduction percentages are decided to be used on the selling price by the slow-moving policy and this affects the contracting issues considering all of the sales offices. As a result of this, GDS does not prefer to change this parameter. Thus, this study will not focus on the reducing the unit-purchase price of the returns.
2. Secondly, the reduction percentages can be low so that GDS cannot compensate the costs of returns. Furthermore, it is seen that the cleaning and repacking percentages do not recover the real cost. However, this is out-of-scope of the study because the percentages are determined by the Grundfos management and can hardly be changed in the following months.
3. The last factor is the amount of returns that are accepted. This variable can be reduced by applying an effective return acceptance system.

Furthermore, the current replenishment policy does not include the accepted returns. This is because the accepted returns are not seen in SAP until they arrive at the warehouse. Although a return will be on stock, unnecessary replenishments can be done. Thus, the lack of an integrated system both increases the inventory holding cost and replenishment cost.

The handling cost is the third highest cost according to Table 2. The main cause of the high handling costs is the warehouse cost occurring during checking each return at Ceva Logistics. This cost is not paid by the customer so it directly affects GDS if the number of returns increases. This causes the increase in the cost of the current return acceptance policy which makes the return more expensive than the replenishments.

To sum up, the high buy-back costs and handling costs can make a return more expensive than replenishment. If a return is accepted although there is not enough demand the average inventory holding cost increases. Furthermore, the accepted returns can become slow-movers in 6 months when there is not enough demand as section 1.4.3 shows. It can be also the case that the demand can decrease and diminish such that the accepted return can not be sold and become obsolete.

2.2 The Research Questions for the Project and the Project Description

The problem analysis above shows that in the current process, it is economically infeasible to accept returns because its cost is higher than replenishments. Thus, accepting returns is not reasonable when the alternative source is doing replenishments with lower cost and higher quality. However, there is a trade-off of accepting returns to adjust the stocks of the sales offices which is a necessity for GDS. Thus, it is obvious that the solution cannot be accepting no returns. Also, one of the objectives of GDS is to have an economically feasible return acceptance system while following the slow-moving policy. Therefore, the solution should target to reduce the cost of the return acceptance policy while satisfying the return requests of the sales offices under the slow moving policy.
As stated at the problem description, the reduction percentages, unit purchase prices for returns can hardly be changed in the short term because of the slow-moving policy and the

rights of the sales offices. Furthermore, the returns cannot be controlled by having a centralized decision making system with a vendor managed inventory because the sales offices work in a decentralized way and essential infrastructure is missing currently. Also, it is not possible to achieve this due to the limited time available for the Master project. Therefore, the thesis project only considers the processes done at GDS (number 2 at Figure 2).

Then there are two ways remaining to reduce the cost of returns to make the acceptance of returns economically reasonable: optimizing the amount of returns to accept and integrating replenishments with returns. Accepting optimal amount of returns can decrease unnecessary acceptance of returns. This can also decrease unnecessary buy-back and handling cost as well as the inventory costs. The inventory costs can be reduced by preventing to accept returns that will become a slow-mover or obsolete in case of decreasing rate of demand. In addition to this, the coordination of replenishment decisions can prevent the decision of unnecessary replenishments when already a return is accepted (Figure 7).

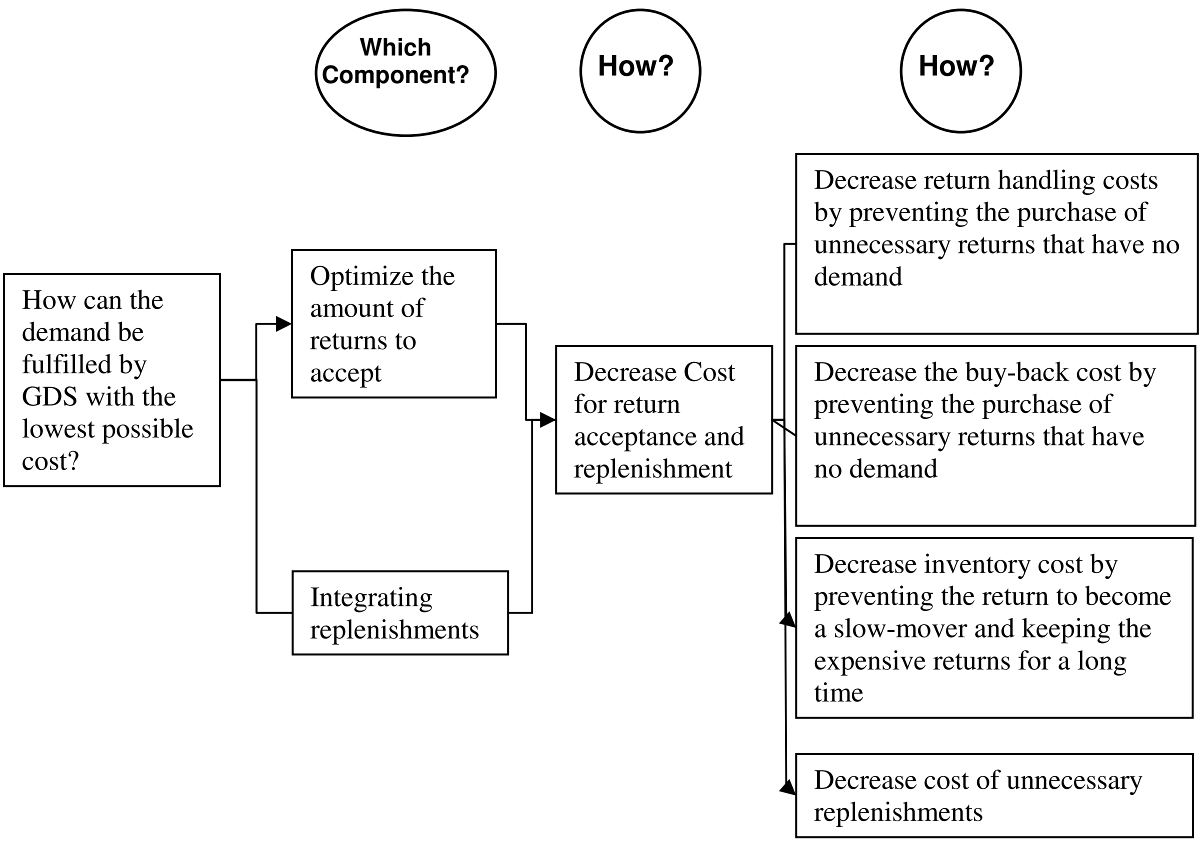

Figure 7. The solution tree for the problem of the high cost of return acceptance process which is obtained by the relevant cost analysis and own observations

Furthermore, GDS also aims to have insight about when and until when the returns should be accepted in a given planning horizon so that GDS recovers its cost. Thus, the proposed solution should also take into account this target.

Considering these issues, the relevant research questions to be answered in this research study are as follows:

- **How should a return acceptance policy be designed such that acceptance of returns become an economically feasible source alternative to replenishments?**

A new return acceptance policy should be designed to accept optimal amount of returns to reduce the total cost for the return acceptance policy. Moreover, the proposed system should decide on the optimal replenishments regarding the coordinated inventory system.

- **How long should GDS accept the returns in order to recover the costs?**

The planning period when the cost of returns becomes economically feasible should be determined for a finite planning horizon. So that if the slow-moving policy takes place between this period, GDS can know that they can recover the return costs. Furthermore, GDS will have an insight about the time after which stopping accepting returns will recover its costs.

This period can be computed by determining the optimal starting time to accept returns and the last time to accept returns. The optimal starting time to accept returns can be found such that before this time accepting returns will no longer be profitable. The optimal last time to accept returns should be determined such that before this time accepting returns will lead to minimum cost. GDS should stop accepting returns whenever the company starts to lose money. For instance, when the demand of a spare part decreases and diminishes, GDS should know when to start to reject the returns. This is an important issue because if GDS accepts these returns, then they can become obsolete when the demand diminishes after the decision.

These questions can be answered by a new return acceptance policy. The proposed system for the thesis project is defined as:

Decision Support System for an Integrated Returns Acceptance and Inventory Replenishment Policy

This decision support system should help the planner with deciding on the amount of returns to accept and the amount of replenishments of spare parts taking into account the accepted returns. With this model, returns will be accepted based on the stochastic demand and the inventory levels. The replenishment policy is called integrated because the replenishment decisions will be done in coordination with the returns. Another important characteristic of this decision support system is that it will indicate when to start and end accepting returns with minimum cost within a finite planning horizon.

The related literature and the integrated decision support system and will be described in the following sections section to find answers to the research questions above.

3 Literature Review

According to the problem description at section 2.1, an appropriate inventory control model should be developed. The solution procedures on the inventory control models for return and replenishment policy can be found in the literature. The inventory control models with return flows can be divided into deterministic and stochastic models. According to the proposed methodology in section 2, the literature on stochastic models for inventory control with return flows will be analyzed. This type of models can be further investigated in continuous and periodic review approaches.

The control of a single stock point is first analyzed by Whisler (1967) where the optimality of a two parameter inventory policy for remanufacturing, disposal and replenishment is shown with stochastic demand. Considering the two-echelon case, Simpson et al. (1978) establish the optimality of a three-parameter policy consisting of a remanufacture-up-to, an order-up-to, and a dispose-down-to level assuming zero procurement lead times. Inderfurth (1997) then, focuses on an optimal policy structure in case of equal lead times. The remanufacturing, disposal and replenishment decisions are made by using disposal and replenishment parameters. The optimal structure of the policy is obtained by stochastic dynamic programming. The author also analyzes the impact of different lead times on the optimality of the policy structures. In this case, due to growing dimension of the state space, the optimal policy structure is more complex.

In the paper of Van der Laan and Salamon (1997) continuous and stationary policies with push and pull strategies are investigated. In this model disposal options and setup costs are present. The computation of the optimal control parameter for both strategies are derived, however, the time considerations for the computations are not given. Fleischmann and Kuik (1998) show the optimality of a stationary (s, S) policy for a single stocking point in case recovery has the shortest lead time and fixed costs.

Indefurth et al. (2001) develop a simple four-parameter control rule (s_m, Q_m,Q_r,s_d) for the inventory model with remanufacturing in case of different lead times. In this control rule remanufacturing, manufacturing and disposal decisions are made by using one reorder level. Via this control rule, it is shown that by determining the inventory position in a suitable way, the performance of the policy can be improved. However, the authors use the same inventory position for remanufacturing and manufacturing. In this setting an analytical solution of the optimal inventory position cannot be given.

In the paper of Kiesmüller and Van de Laan (2001) a periodic review inventory model is developed with product returns that are dependent on demand stream. The model consists of a finite planning horizon and is controlled by a periodic order-up-to-level policy. The model is different form the previous researches by the consideration of returns that are dependent on demand. In the paper, the computation of the optimal order-up-to level is shown for the case of dependent returns. Also, it is shown how the optimal policy and the minimum average total cost depend on the recovery probability. By their study, the minimal recovery probability or the minimal length of planning horizon for which reuse is profitable can be determined. Mahadevan et al. (2003) analyze a periodic review inventory policy for manufacturing where the push strategy for returns is used. The authors suggest an order-up-to level policy under stationary demand and return streams. They develop several heuristics by using the traditional inventory model of Silver et al. (1998).

The effect of different lead times under periodic review policy is analyzed by Kiesmüller (2003). In this research a new approach is provided for the control of a stochastic hybrid manufacturing and remanufacturing system. The order-up-to level and remanufacture-to-level (S,M) policy is used based on two inventory positions. The results suggest that the decisions considering remanufacturing and replenishment should vary according to the length of the lead times. Kiesmüller and Scherer (2003) provide a fast dynamic programming method for the computation of nearly optimal policy parameter values for a periodic review policy. In this paper, formulas for the exact computation of the optimal period control policy are given. The system is one product recovery system with stochastic and dynamic demands and returns with identical lead times. The formulations are done both by considering no stock keeping unit for returns and an inventory location for returns. Then, as the computation of the exact formulations is time consuming, approximations are done based on a dynamic model and a deterministic model.

Kiesmüller et al. (2003) provide formulae for determining policy parameter values in a periodic review inventory control model for a joint environment of production and remanufacturing. The general idea of a newsvendor model is used for determining how many items to produce and remanufacture in a periodic review inventory control system. The performance of different parameter settings under the proposed (S,M) policy is analyzed by a cost function that involves the expected inventory holding cost for remanufactured item stock and the serviceable item stock together with the backorder cost. As the determination of optimal values for (S, M) values is time-consuming, approximations are made. These approximations include the determination of underage and overage costs under the alternative lead times for the remanufacturing and the production.

Teunter et al. (2004) explore heuristic approaches for the case of non-identical lead times. The spare parts acquisition in post product life cycle is analyzed by Inderfurth et al. (2008). The authors consider an (S,M) policy while determining the optimal combination of final lot decisions, remanufacturing and replenishment. The authors first show that the stochastic dynamic programming fails to give exact solutions due to the computational burden. Thus, they suggest a heuristic that uses news-vendor related calculations under dynamic demand and returns stream.

The description of the current system shows that the problem considered in this thesis can be considered as an extension of the papers of Kiesmüller and Scherer (2003) and Mahadevan et al. (2003) with the focus of periodic review model and non-stationary demand. The parameters of the study have some distinct properties. First of all, the costs related with returns and replenishments are not fixed and vary with respect to the customers and time. Moreover, the reuse of returns is more expensive than replenishments. There is also only one inventory position for returns at GDS. According to these, (R,S) policy is selected to be used in the proposed decision support system with one stock position.(s,S) type of inventory policy is not reasonable in this project because the costs are not fixed. .Furthermore, as stated by Silver et al. (1998), (R,S) policy is easy and practical for companies because it uses two parameters and allows a lower workload on the employee. Moreover, GDS already used an (R,S) policy so it becomes easy to implement the proposed system without changing the regular process.

4 The Proposed System and the Model Description for an Integrated Return Acceptance and Replenishment Policy

4.1 The Proposed System Description:

The cost of the current recovery system of the GDS is mostly affected by buy-back costs of the returns (contributing 73% of the total cost), handling cost (7.6%), and the inventory holding costs (14 %). In addition to this, it is also realized that 10% of the value of the spare parts that are returned have still not been sold for at least six months which makes these returns slow-movers as stated by the GDS policy. Hence, it is crucial that the new return acceptance system should reduce the inventory cost, buy-back cost and replenishment cost by accepting the returns efficiently considering the inventory level and the demand rate. In this way, the proposed system can eliminate the acceptance of returns that will become obsolete. Thus, by rejecting unnecessary returns, buy-back, inventory holding and handling costs can be reduced. The replenishments should also be done regarding the accepted returns and the demand rate which can reduce the cost for unnecessary replenishments. The performance of the return acceptance and replenishment policy can be evaluated by an integrated inventory control model.

The integrated inventory control model considers a recovery system as illustrated in figure 1. The stochastic non-stationary demand (D(t)) for a specific spare part is satisfied from a single stocking point which is denoted as serviceables inventory (x_s). In this system, the single stocking point is replenished by two different sources. First of all, there are return requests (R(t)) that occur per period because the sales offices want to decrease their inventory levels by sending back the slow movers and obsolete spare parts. (It is crucial to know that the returns are not due to quality and warranty issues.) These return requests from the sales offices can be either accepted or rejected before they are transported back to GDS. Thus, the rejected returns are assumed to have no cost on the system because they are not transported to the company. From this, it can be stated that there are no disposal costs for rejecting returns. The quality of the returns is not known at the time of the acceptance decision. So, if return requests are accepted ($\hat{R}(t)$), then the corresponding returns can be cleaned and repackaged (Figure 8). The returned parts can also be reused without any transformations or scrapped directly according to their physical condition. In the current system, it is observed that the returns are directly pushed to the single stocking point. This property is present also in the proposed system. The returns that arrive at the company are transformed to be put into the serviceables inventory. In other words, accepted returns are reused without being stocked at an intermediary stocking area. In the inventory control model, in addition to the returned spare parts, there can be replenishments (P(t)) if there are not enough returns available to satisfy the demand.

The demand and return rates are observed to be non-stationary for the spare parts in GDS. In order to analyze this, 5 spare parts are selected (3 with low demand and 2 with high demand rates). As stated by GDS, these spare parts can represent a general overview about the demand and return rated. The monthly demand and return rates are depicted with respect to time. As seen from Figure 9, demand rates and return rates fluctuate within months. This is because of the seasonality of the need for the spare parts for repair services. Due to non-stationary demand, the order-up-to levels are different for each review period (S(t)).

In case of decreasing rate of demand, some spare parts can be disposed at the end of each period (q_e(t)) (Teunter, 1999). This is because the inventory on hand at the end of the period can be higher than the order-up-to level of the next period. The difference is sent back to one of the manufacturing companies at the end of each period.

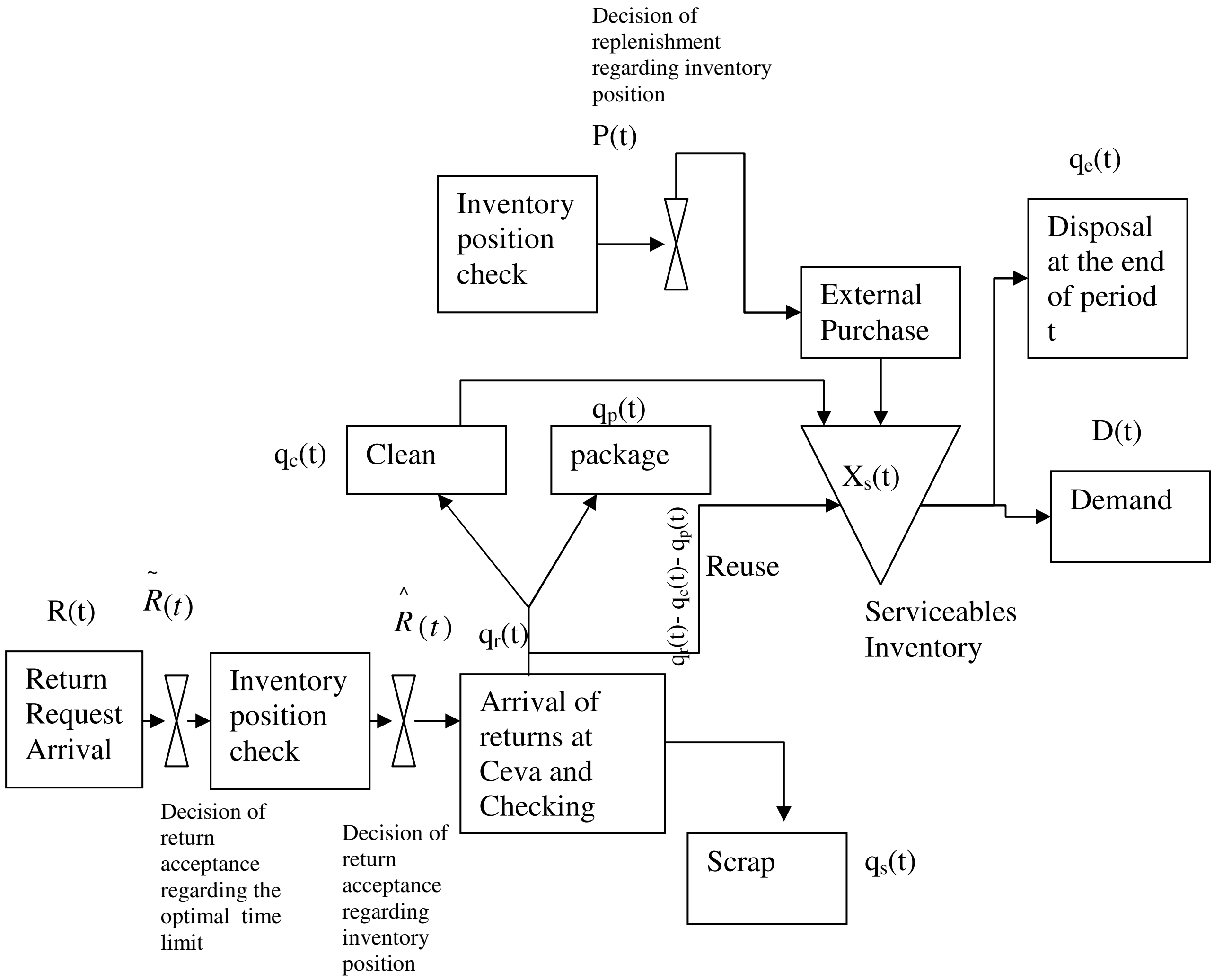

Figure 8. The flow diagram for return acceptance policy for spare parts

The integrated return acceptance and replenishment policy works as a decision support system which is modeled to be a finite horizon periodic order up to policy (R, S). In this policy, the return acceptance and replenishments will be done according to the inventory position and the order-up-to levels. The policy works as follows: at each review period, the inventory position will be reviewed. Here, inventory position is defined as the on-hand inventory at the beginning of the period minus the backorders. (The spare parts that are on order are not included in this definition due to zero lead time assumption which will be explained in section 4.3.1.) If the base-stock is higher than the inventory position, then the return request up to this difference will be accepted. If the base stock level is still not reached after the return acceptance, then the remaining difference will be replenished. Otherwise, no replenishments will be done.

The problem that arises in such a recovery system is to determine how many returns to accept and how many items to replenish and how many items to dispose. A new aspect that is not explained in this system is to decide when to start and end to accept returns in order to recover the costs of returns. Thus, these problems should be solved by using an efficient inventory control model.

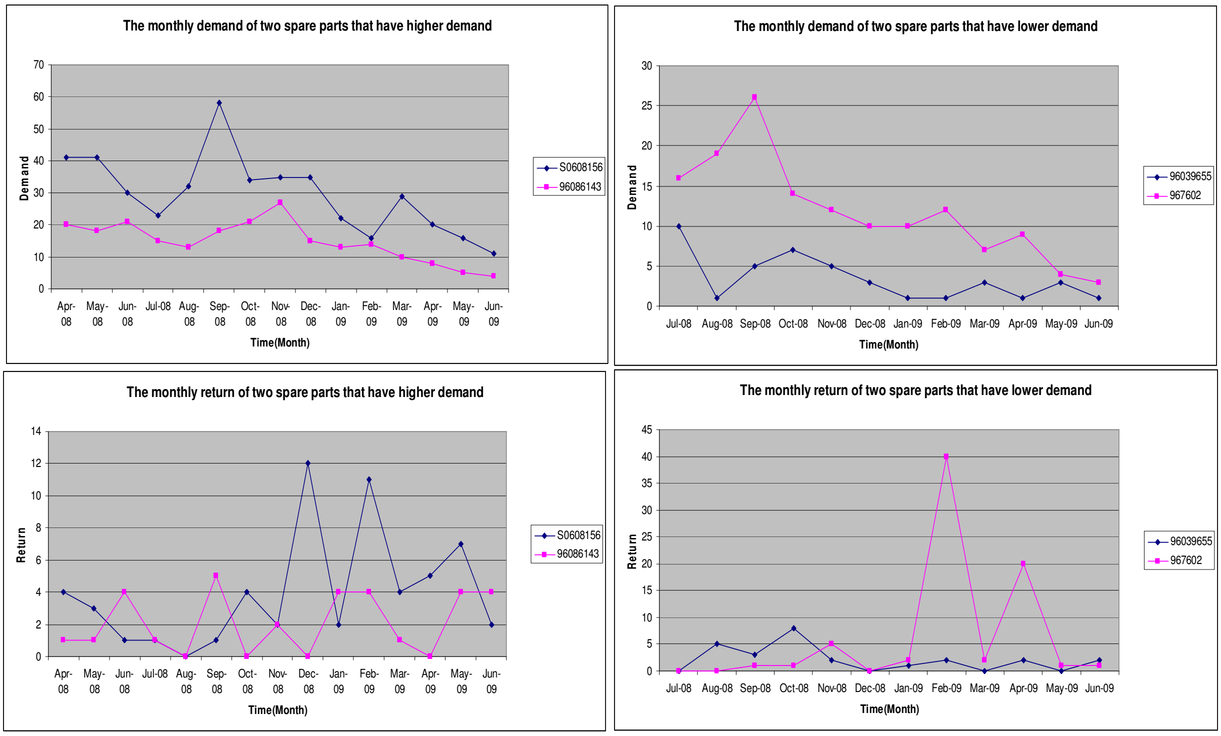

Figure 9. The monthly demand and return data for spare parts that have high and low demand rates. The data is retrieved from SAP for the months between June 2007 and June 2009

4.2 Research Design for the Proposed System

The research questions stated at section 2 will be answered by developing an optimization model relevant to the recovery system described in section 4.1. Before going into the model, a research design for the proposed system is built to define the scope of the research.

System Boundaries and Scope

The scope of the design of the integrated return acceptance and replenishment policy will be to determine the optimal amount of returns to accept, amount to replenish and to determine the optimal time period that makes GDS to recover the costs of returns. The research will not cover the determination of optimal buy-back prices and reduction percentages. This is because these variables can hardly be changed by the Grundfos management in short term. Furthermore, the proposed system will not include the optimization of the ordering polices of the sales offices. This option is considered to be not possible with the current decentralized structure of decision making by the suggestion of GDS.

Objective

- The main objective is to minimize the total cost of return acceptance and replenishment decisions over a finite planning horizon for a certain spare part. Within this objective, the optimal order-up-to-levels will be determined considering the customer service level for each period. Furthermore, it is aimed to determine the optimal amount of returns to accept, the optimal amount to replenish, the optimal amount to dispose at the end of each period according to the optimal order-up-to levels. It is also aimed to find the time period to accept returns to recover the cost of returns. This period is determined by finding the starting time and ending time to accept returns that return acceptance and replenishment cost is minimized.

Decision variables

According to the objective above, the decision variables in the model are:

- Order-up-to levels for each period
- Starting time (B) and the last time to accept returns (A) to recover the cost of returns for a finite horizon. When this interval value is known, the returns that arrive before time B and after time A should not be accepted. Note that, A can easily be adapted to the return regulations of GDS (Appendix 1) where the electrical parts and motors are not accepted after a certain time period.

According to these decision variables, the optimal value of the variables below will be found:

- The amount of returns to accept at each period
- The amount to replenish at each period
- The amount to dispose at the end of each period

Input Parameters

The input parameters are the demand rates and return rates for each period, the target customer service level, the holding cost rate, the buy-back cost at each period, the cost of cleaning, handling the returns, scrapping and repackaging and the cost of replenishment.

System Constraints

The only system constraint is to satisfy the target service level. There are no capacity constraints related to returns and replenishments. For GDS, the target customer service level is described as the non-stock-out probability. This is the probability that the demand in a certain period is smaller than the order-up-to level for that period. This service level is chosen to be 0.98 by GDS.

4.3 The Detailed Description of the System

In order to model the system with respect to the described design, the system should be described in detailed. The description of the system will include the assumptions, the sequence of decisions, and the initial and ending conditions.

4.3.1 The Model Assumptions:

The following assumptions are used to develop the model for the proposed policy. These assumptions are related with the real situation at GDS:

- The unmet demand is backordered and there is no shortage cost as stated by GDS.
- In order to simplify the system, a review period is fixed to one month.
- The lead times for replenishment and transformation of returns are assumed to be zero to simplify the system. This assumption is relevant with the real process. This is because at the real process all the replenishments and returns are available serviceables stock before 1 month.

- The customer service level is measured through the non-stock-out probability. The non-stock-out probability is measured by the probability that the order-up-to-level is higher than or equal to the demand occurring during the period. The target customer service level is 98% for GDS.
- The amount of inventory which is higher than the order-up-to level of the next period is assumed to be returned back to one of the Grundfos manufacturing company at the end of each period except the last period.
- Demand is assumed to have non-stationary Poisson process with mean $\lambda_D(t)$ at each period. It is observed that the arrivals of demand orders are not so frequent within a month and sample size within a month less than 10. Thus, like in most of the literature and Silver et. Al(1999), Poisson process is a better estimate for distributions for spare parts.
- Return requests are assumed to follow a non-stationary Poisson process with mean $\lambda_R(t)$.
- The remaining stock on hand at the end of the planning horizon is scrapped. This assumption is made because at the end of the planning horizon, there will be no demand for the spare part. Thus, it is reasonable to scrap the remaining parts.

The following assumption is made to make the model simpler. This assumption is made also relevant to the reality.

- In the proposed system for simplicity of computation, it is assumed that the age of the returns is equal to the current period. This is done for determining the reduction percentages in the buy-back price in a simpler way. The main logic behind this that through the end of planning horizon as the demand will decrease the buy-back prices also decreases. (The computation for determining the time that the returned spare part stays at the customer is complex so it is kept out of scope.)

4.3.2 Sequence of Decisions that Occur during the Proposed Integrated Return Acceptance and Inventory replenishment Policy

The periodic review process together with the proposed return acceptance policy and replenishment policy occurs with the following sequence of events:

1. At the beginning of the period, all the return requests are to be received before any replenishment decisions(R(t)).
2. Then, the period of the return is analyzed. Regarding this analysis, the return request is either accepted if the time of the request is between the period of starting time and last time to accept returns ([B,A]). Otherwise, the return request is rejected. The accepted returns are denoted as $R^{\sim}(t)$.
3. As a third step, the inventory position is reviewed at the beginning of the period.
4. According to the inventory position at the beginning of the period, a second acceptance decision is made with respect to the base-stock level and the inventory position. The amount of returns to be accepted after this decision is denoted as $R^{\wedge}(t)$.
5. Depending on the state of the part, the received returns are either repacked ($q_p(t)$) and cleaned ($q_c(t)$). This is assumed to be done instantly because of zero lead time assumption.
6. Due to simplification, the cost of cleaned and repacked returns and the amount of buy-back cost according to the time period are computed at the beginning of the period.
7. After determining $R^{\wedge}(t)$), the inventory position is updated regarding the accepted returns.
8. Next, a replenishment decision is made also at the beginning of the period (P(t)) with respect to the inventory position.

9. The replenishment cost is incurred at the beginning of the period.
10. During the period demand takes place (D(t)).
11. The inventory on hand at the end of the period is computed. This value is denoted as(I(t)),
12. The inventory holding cost is charged.
13. As a last step, except for the last period of the planning horizon, if the inventory on hand is higher than the maximum of the next periods' order-up-to level than the difference is returned to one of the manufacturing companies of Grundfos.

If the dynamics of the proposed system is further analyzed, it becomes necessary to describe how the (R,S) policy, the return acceptance and replenishment policy works at a period.

In the developed system the return requests should be planned such that they arrive to GDS at the beginning of the period before any replenishment decisions. The amount of returns to be accepted (R~(t)) is firstly decided by analyzing the given starting time and last time to accept returns (B and A) with the time period of the decision. If the time of the return request is between the time interval of starting time(B) and the last time to accept returns (A), then the total return request is accepted (R~(t)). Otherwise, return request is rejected. According to this decision R~(t) equals to either 0 or R(t).

According to the inventory position, the amount of returns to be accepted is updated. The amount of returns to be accepted at the beginning of period (R^(t)), is now the minimum of either the difference between the order up to level at the current period (S(t)) minus the inventory position or the R~(t). If inventory position is higher than order-up-to level than no return is accepted.

After determining R^(t), if the inventory position is still not equal to the order up to level (S(t)), then a replenishment order is given at the beginning of the period (P(t)). If not, then no replenishment is made.

The amount of disposed items (q_e(t))), is equal to the difference between the inventory on hand at the end of the period minus the maximum of the next two period's order-up to levels, if inventory on hand is higher than the next periods order up to level. Due to the non-stationary demand, it is possible that the inventory at end of the previous period is higher than the order-up-to level. Because the replenishments and the accepted returns are computed from the order-up-to levels, it is possible that there are excess products that remain in the inventory. This problem can be solved by using a usual process from GDS which is to dispose these by returning this amount to one of the manufacturing facilities at Denmark. The amount to dispose can be calculated by the difference between the inventory on hand at the end of the period minus the maximum of the order-up-to levels of the two consecutive periods. Here, the maximum of the two consecutive periods are used because if S(t+1) is greater than S(t), then it means that the disposed amount will be needed in the next period although they are sent away. Thus, to prevent this situation maximum expression is used.

4.3.3 Initial and Ending conditions

In the inventory control model, it is assumed that the period starts from month 1. Furthermore, the first return request is received at the beginning of the first period.

At the end of the planning horizon (T), the ending stock on hand is scrapped.

4.4 Mathematical Model Formulation

In order to compare the performance of the proposed system with the current process and to have insight about how frequently the rejection of returns will be done, five scenarios will be modeled.

First scenario will be about modeling the proposed system with both return acceptance policy described in section 4.3.2 and the integration of replenishments and returns. Second scenario will be about to observe how many times a rejection is done for returns and how effective the return acceptance policy is. Third scenario will model the proposed return policy when there is no integration between the returns and the replenishments. Thus, by comparing scenario 1 and 3, the effect of integration on the performance of the system can be realized. Fourth scenario will model the current situation where all the returns are accepted and there is no integration between the returns and the replenishments. The fourth scenario will be the base model. The final scenario will be used to estimate the total cost when there is no return accepted and only replenishments are done. This scenario will also perform as a base model. The description of the scenarios can b found in Table 6.

In each of the scenarios, a cost minimization model for a finite planning horizon is built to find the optimal order-up-to levels for each period and the optimal time period to accept returns according to the description of the proposed system. After finding these, the optimal amount of returns to accept, the optimal number of replenishments and the optimal amount of disposals for each period can be computed as described in section 4.3.2.

		Integration	
		Yes	**No**
Acceptance Policy	**Yes**	Model I	Model III
	No	Model II	Model IV

Table 6. The design of the scenarios according to Integration with replenishment and proposed acceptance policy

The decision variables, variables and parameters in the optimization model are as follows:

Decision Variables

A : Time to stop accepting returns so that all the return requests after this time are rejected to be returned

B : Time to start accepting returns so that all the return requests before this time are rejected to be returned

S (t): The order-up-to level for serviceable inventory at time t, t=1, ..T

Parameters

c_h : holding cost rate for servicables at the serviceables stock

c_{pr} : purchase cost from the vendor per unit

c_s: scrapping cost per unit

c_p: repacking cost per unit

c_c: cleaning cost per unit

c_w: handling cost per item at the warehouse

I_0 : initial inventory at the serviceables stock

s: average sales value per item to a sales company and it is computed with respect to a percentage of purchase cost from the vendor(Each sales company has a different sales price, so to have a generic decision average sales price is computed) The buyback price for a return is equal to s*percentage of reduction due to age

α : target non-stockout probability

t_r : transportation price from GDS to the manufacturing company for excess stock

Variables:

$D(t)$: demand occuring during period t

I(t) : the serviceables inventory at the end of the period t

P(t): amount of replenishments to be done at the beginning of period t

p_c: probability that the accepted returned item is cleaned

p_p: probability that the accepted returned item is repacked

$R(t)$: amount returns requested at the beginning of period t

$\tilde{R}(t)$: amount of return requests to be accepted after the decision regarding the age of the return at the beginning of period t where the age of the spare part is assumed to be the same as the period.

$\hat{R}(t)$: amount of return requests to be accepted after the inventory position review at the beginning of period t

$q_p(t)$: number of returns that are released to be repacked at the beginning of period t

$q_c(t)$: number of returns that are released to be cleaned at the beginning of period t

$q_r(t)$: total number of returns that are decided to be cleaned, repacked or reused directly

analytically it can be expressed as: $q_r(t) = \hat{R}(t) - q_s(t)$

$q_e(t)$: amount of excess stock to be returned back to the manufacturing company due to the non-stationary demand

$p(t)$: 1-the percentage reduction in the return price with respect to t and whether the return is cleaned or repacked.

$bb(t)$: buy-backprice of an item with age t which is computed by $bb(t) = s*p(t)$

$y(t)$: is a binary variable indicating that the return request is scrapped:

$$y(t): \begin{cases} 1 \text{ with probability } p_s \\ 0 \text{ with probability}=1\text{-}p_s \end{cases}$$

4.4.1 Objective Function and the Optimization Model for the Proposed System: Scenario 1

The objective function of the model is to compute the total expected cost for return acceptance, replenishment and disposal over the finite planning horizon with the ending period T.

$$\min_{(B,A,S(1),S(2),..S(T))} E[C_T] = E[\sum_{t=1}^{T} (\hat{R}(t)*bb_t + \hat{R}(t)*c_w + q_c(t)*(c_c + c_p) + q_p(t)*c_p + P(t)*c_{pr} + I(t)*c_h) + \sum_{t=1}^{T-1} q_e(t)*t_r + I(T)*c_s]$$

(1.1)

Subject to

$$\Pr(D(t) \leq S(t)) \geq \alpha \quad (1.2)$$

Where:

- Buy back cost of returns that is computed at the beginning of period t.
  $\hat{R}(t)*bb_t$
- Handling cost of all of the accepted returns at the warehouse in period t
  $\hat{R}(t)*c_w$
- Cleaning cost of the returns that are accepted at the beginning of period t. These returns are also repacked so the repacking cost is also incurred in the expected cost.
  $q_c(t)*(c_c + c_p)$
- Packaging cost of the returns that are accepted at the beginning of period t.
  $q_p(t)*c_p$
- Purchasing cost per period where the purchasing decision is made at the beginning of the period t.
  $P(t)*c_{pr}$
- Inventory holding cost at the serviceables inventory per period.
  $I(t)*c_h$
- The remaining inventory at the end of the planning horizon is scrapped. So the total cost of this scrapping process is:
  $I(T)*c_s$
- The cost for returning excess items from GDS to a manufacturing company
  $q_e(t)*t_r$

For the proposed model it is necessary to have the expressions for the variables of the amount of returns to accept and the amount of returns to reject, the amount of replenishments and the amount of disposals.

The expression for the amount of returns to accept can be shown by using the acceptance policy explained at section 4.3.2. If it is recalled from the return acceptance policy, the amount of returns that are accepted in period t is decided in two steps: First decision is to accept the returns in the request if the age of the parts is between the time period of [B, A] where B is the optimal start time and A is the optimal ending time for accepting returns. Otherwise, all the returns requested are rejected:

$$\tilde{R}(t): \begin{cases} R(t) \text{ if } B \leq t \leq A \\ 0 \quad \text{otherwise} \end{cases} \tag{1.3}$$

The second analysis for the acceptance of returns is done according to the inventory position and order-up-to level:

$$\hat{R}(t) = \min\left\{ [S(t) - (S(t-1) - D(t-1))]^{+};\ \tilde{R}(t) \right\} \tag{1.4}$$

where $[.]^{+}$ is a function denoting the value of the argument inside if it is positive and assumes a value of zero otherwise.

Next, the expression for the amount of replenishments that are decided at the beginning of period t, should be computed considering the amount of accepted returns:

$$P(t) = [S(t) \quad - S(t-1) + D(t-1) - \hat{R}(t)]^{+} \tag{1.5}$$

The inventory on hand at the end of the period is then:

$$I(t) = [S(t) - D(t)]^{+} \tag{1.6}$$

Finally, it is also crucial to express the amount of excess parts to be returned from GDS:

$$q_e(t-1) = [I(t-1) - \max(S(t), S(t+1))]^{+} \tag{1.7}$$

It is also crucial here to mention the computation of the input parameter buy-back cost. The buy-back cost is calculated by the average selling price of the part to a customer (s) *the percent reduction with respect to the age of the return (p(t))*the number returns to be accepted ($\hat{R}(t)$). The average selling price is computed by: sum of selling price from all sales offices that have returned this part/ number of sales offices.

4.4.2 Objective Function and the Optimization Model for Scenario 2

One of the aspects for the proposed system at scenario 1 is that GDS can reject many return requests if the demand rate is low for the returned part. However, the frequency of rejection for returns is crucial because the main objective of GDS is to help the sales offices to reduce their inventories. Thus, if the new system frequently rejects the returns, then the sales offices will not be able to reduce their inventories by returning them. Rather they would be forced to scrap them. In order to maintain this role of GDS, a new scenario is developed in addition to the new system described in section 4.3.2.

The main objective of developing scenario 2 is to observe how frequently the rejection of returns will be done. Another objective is to investigate the contribution of integrating the replenishment with returns. If the performance of scenario 2 is nearly the same with scenario 1, then it can mean that the most of the contribution is because of the integration. In order to analyze these, all the properties of Scenario 1 are kept the same except the return acceptance policy. With this policy, all the return requests will be accepted without regarding the time period and the inventory levels.

All the assumptions and sequence of events are the same as the proposed system. The replenishments are again done while considering the returns (same as equation 1.5). All the other formulations are the same as the scenario 1 (1.6 and 1.7). The objective function and the constraint (1.1 and 1.2) are kept the same for scenario 2.

4.4.3 The Model for the Scenario 3

According to scenario 3, the return requests will be accepted with respect to the proposed model in scenario 1. Thus the equation 1.4 still holds for this scenario.

- The only difference is that the replenishments will be done without considering the accepted returns. The amount of replenishments per period is the maximum of the difference between the order-up to level and the inventory on hand or zero.

$$P(t) = (S(t) \quad - I(t-1))^{+} \tag{1.8}$$

- The inventory level at the end of the period is the order-up-to level minus demand at the period plus the returns accepted during the period minus the amount of scrapped parts during the period:

$$I(t) = (S(t) - D(t) + \hat{R}(t) - y(t) * \hat{R}(t))^{+} \tag{1.9}$$

4.4.4 The Model for the Current System: Scenario 4

In order to be able to compare the total expected cost for the new system and the current system, the current return acceptance system is modeled under the same sequence of events. Here, the real cost of the current system is not used because of the assumptions we have made.

The assumptions and sequences of decisions for the proposed model at section 4.3 are valid for the current system, too. The difference between the current system and the proposed system is that in the current system all the returns are accepted only looking at the age of the part without analyzing the inventory position.

The cost minimization model has the same as the objective function 1.1 and the constraint 1.2.

However, the replenishment value, accepted amount of returns and inventory at the end of the period change when compared with the proposed system. The differences in the computation of expected amount of returns, expected value for replenishments and inventory at the end of period are as below:

- In the current system, at each period all of the returns requests are accepted without considering the inventory levels. The only criteria considered are the part's group and the age of the product. If the part is a pump head or a motor and the age is greater than 2 years, then the return is refused. For the rest of the parts if the age is greater than 3 years, then the return is refused. These age limits can be modeled with the last time to accept variable (A). This is because of the assumption that the age of the part is equal to the time period. If a part is a pump head, then A should be equated to 24. If the age of the spare part to be returned is more than 24, then the return request should be rejected.

Thus, the expected amount of returns in each period is the expected number of return requests per period ($\tilde{R}(t) = \hat{R}(t)$) where $\tilde{R}(t) = \begin{cases} R(t) \text{ if } t \leq A \\ 0 \quad \text{else} \end{cases}$ (1.10)

Different from the proposed system, the replenishments are done without considering the returns. If the inventory position at the beginning of the period is less than the order-up-to level, than the difference between the order-up-to level and the inventory position is replenished from the vendors. Otherwise, no replenishments are done. The equations 1.8 and 1.9 hold for also the current system.

The amount of parts that should be returned back to one of Grundfos manufacturing companies is the same as the equation 1.7.

4.4.5 The Model for the Replenishment only System: Scenario 5

This model is built to compare the cost of the proposed system with the situation where only replenishments are done. Thus, in this case, $\tilde{R}(t) = \hat{R}(t) = 0$.

The amount of replenishments is the same as equation 1.8
where

$$I(t) = (S(t) - D(t))^{+} \qquad (1.11)$$

5 Results

5.1 Solution Procedure for the Optimization Models

The models described in section 4 have three type of decision variables to be optimized: Starting time (B) and last time (A) to accept returns and the order-up-to levels for each period (S(t)). Furthermore, the optimization should be done for multiple periods defined in the finite horizon. Thus, the exact solution is difficult and complex to find. In order to solve this optimization model, a hierarchical heuristic is proposed.

The hierarchical heuristic algorithm is as follows:

Step 1: Determine the order-up-to level for each period in the finite planning horizon according to the constraint $\Pr(D(t) \leq S(t)) \geq \alpha$

Step 2: Compute the expected total cost for all values of A (from 0 to the end of the planning horizon T) with a fix value of B starting from period 1.

Step 3: Search for the A value that gives the minimum expected total cost with fixed B.

Step 4: Increase the value of B in units of 1 until the end of horizon and record all the minimum expected costs for all possible [B,A] pairs.

Step 5: Search for the minimum of the expected total costs among different values of A and B. Denote the period to accept returns to have minimum cost ([B*,A*])

By the results of Step 3, Step 4 and Step 5, GDS can know that it is not optimal to accept returns before B* and after A*. Furthermore, it becomes economically feasible to stop accepting returns after A*.

In order to find these optimal values, the expected cost function is needed to be computed. The formulations for the expected cost function will be given in the next section.

5.1.1 The Expected Cost function

The expected total cost of the whole finite planning horizon is as below:

$$E[C_T] = \sum_{t=1}^{T} E[\hat{R}(t)] * bb_t + E[\hat{R}(t)] * c_w + E[q_c(t)] * (c_c + c_p) + E[q_p(t)] * c_p + E[P(t)] * c_{pr} + E[I(t)] * c_h + + E[q_e(t)] * t_r + E[I(T)] * c_s$$

(1.12)

In order to compute the total expected cost function, the expected value of accepted returns, expected value of replenishments, expected inventory and expected amount of excess parts to be disposed for each period should be known.

- First, the expected value of amount of returns to accept for scenario 1 and 3 is computed. In order to find the expected value of $\hat{R}(t)$, let:

$$[S(t) - (S(t-1) - D_{(t-1)})]^{+} = \text{X1}(t) \quad \tilde{\text{R}}(t) = X2(t) \qquad (1.13)$$

Then, E[$\hat{R}(t)$]=E[min{X1(t) and X2(t)}]

As a result of computations in Appendix 6, E[$\hat{R}(t)$] is as follows:

$$\hat{E[R(t)]}=\lambda_{rd}(t)=\begin{cases}\lambda_r & \text{if } \min\{E[X1(t),E[X2(t)]\}=E[X2(t)] \text{ and } B\le t\le A\\ S(t)-S(t-1)+\lambda_D(t-1) & \text{if } \min\{E[X1(t)],E[X2(t)]\}=E[X1(t)] \text{ and } S(t)-S(t-1)\ge 0 \text{ and } B\le t\le A\\ \sum_{k=S(t-1)-S(t)}^{\infty}(S(t)-S(t-1)+k)P(j=k) & \text{if } \min\{E[X1(t)],E[X2(t)]\}=E[X1(t)] \text{ and } S(t)\text{-}S(t\text{-}1)<0 \text{ and } B\le t\le A\\ 0 & \text{otherwise}\end{cases}$$

where $j=D(t-1)$

(1.14)

For Scenario 4, expected value of $\hat{R}(t)$ is:

$$\tilde{E}[R(t)]=E[\hat{R}(t)]\begin{cases}E[R(t)] \text{ if } t\le A\\ 0 \quad \text{else}\end{cases} \tag{1.15}$$

- Then, the expected amount of replenishments can be decided by considering the amount of accepted returns $\hat{R}(t)$ at the beginning of period t for scenario 1 and 2. Therefore, the expected amount of replenishments per period becomes:

So acording with the above derivations , the expected value for scenario 1 and 2 becomes:

$$E[P(t)]=\begin{cases}(S(t)-S(t-1)+\lambda_D(t-1)-\lambda_{rd}(t) & S(t)-S(t-1)\ge 0\\ \sum_{k=S(t-1)-S(t)}^{\infty}(S(t)-S(t-1)+k)P(j=k) & S(t)-S(t-1)<0\end{cases} \tag{1.16}$$

$j=D_{(t-1)}-\hat{R}(t)$ distributed as Poisson with mean $\lambda_D(t-1)-\lambda_{rd}(t)$

- For Scenario 3 and 4, therefore, the expected amount of replenishments per period becomes:

$$E[P(t)]=\begin{cases}\sum_{k=0}^{S(t)}(S(t)-k)P(j=k) \text{ if } t\le A \text{ where } j=S(t-1)-D(t-1)+\hat{R}(t-1)\\ \sum_{k=0}^{S(t)}(S(t)-k)\,P(i=k) \text{ else where } i=S(t-1)-D(t-1)\end{cases}$$

(1.17)

- The expectation of inventory on hand at the end of the period for scenario 1 and 2 is:

$$E\left[I(t)\right]=\left\{\sum_{k=0}^{S(t)}(S(t)-k)P(D(t)=k)\right\} \tag{1.18}$$

The expectation of inventory on hand at the end of the period for scenario 3 and 4 is:

$$E[I(t)] = E[(S(t) - D(t) + \hat{R}(t))^{+}]$$

$$E[I(t)] = \sum_{k=0}^{S(t)} (S(t) - k)P(j = k) \text{ where j=} D(t) - \hat{R}(t) \tag{1.19}$$

- For all of the scenarios expected amount of cleaned and repacked spare parts are as follows:

$$E[q_c(t)] = \begin{cases} E[\hat{R}(t)] * p_c & \text{if } \hat{R}(t) > 0 \\ 0 & \text{otherwise} \end{cases} \tag{1.20}$$

$$E[q_p(t)] = \begin{cases} E[\hat{R}(t)] * p_p & \text{if } \hat{R}(t) > 0 \\ 0 & \text{otherwise} \end{cases} \tag{1.21}$$

- As a last computation, I(t-1)- max(S(t),S(t+1)) is assumed to be returned back to the manufacturer of Grundfos with a transportation cost. The S(t) and S(t+1) are assumed to be known before hand so they become deterministic. So fro all of the scenarios, the expected value of the amount of returned items becomes:

$$E[q_e(t-1)] = E[(I(t-1) - \max(S(t), S(t+1))^{+}] \text{ which is:}$$

$$E[q_e(t-1)] = \left\{ \sum_{k=S(t)}^{\infty} (k - \max(S(t), S(t+1))P(i = k) \right\} \text{ where } i = S(t\text{-}1) \text{ - } D(t-1)$$

(1.22)

5.2 Numerical Analysis

The numerical analysis is done to apply the proposed return acceptance and replenishment process for the real-life data. Another aim is to compare the total expected cost for different scenarios as explained in section 4. In this analysis, we will compare the performance of the proposed model and the scenarios 2 and 3 with respect to the two base cases: the scenario 4 which represents the current system and the scenario 5 which represents the pure replenishment without any return acceptance. If the total expected cost of the proposed scenarios (Scenario 1,2 and 3) is lower than the current system's cost, then this indicates that there is an improvement with respect to the current system. Furthermore, if any of the scenarios 1,2 and 3 have lower total expected cost than scenario 5, then this means that the scenario is economically feasible with respect to doing replenishments. The reasoning is that if one of these scenarios is better than doing only replenishments (scenario 5), then the scenario is reasonable for accepting returns which are expensive than replenishments.

In order to analyze these, a sample size of 20 spare parts is selected as a pilot study of the real system. The selection is done according to the availability of demand and return data. As GDS has recently started to accept returns, there are not too much data for returns. Thus, we have selected the spare parts that have the highest amount of return and demand data. Another criterion of the selection is the variety of the spare parts. The sample of the spare parts shows variety to represent a more general view of the materials in GDS (with the agreement of GDS). First of all, each spare part is of a different type of material and has a replenishment value in the range of 90-870 Euros (Table 7). This value range is selected because as the spare parts' value becomes higher, the impact of the type of return acceptance policy is more on the total expected cost. Moreover, the sample size consists of both slow movers and fast movers. Therefore, this study will give an insight about the effect of the proposed system and other scenarios on the spare parts that have different consumption rates. The number of spare parts that satisfies these criteria is 20 so the sample size is decided to be 20 spare parts.

Part	Material Code	Description	Consumption Type	Replenishment Value
1	85900529	Single Packaging	Slow Mover	863.62
2	96039352	Kit, Stub Shaft D28/IEC100-112	Fast Mover	102.53
3	96059968	Kit, Term. box MGE80 MkII suit CHIE4 / 8	Fast Mover	229.92
4	96086142	Term.box, MGE90-100, 3kW,D	Fast Mover	302.19
5	96086143	Kit, Terminal box MGE112-132 5.5kW D	Fast Mover	486.12
6	96459602	Terminal box Magna Model D	Fast Mover	154.33
7	96499919	Kit, Pump head E, F MAGNA 65-120	Slow Mover	234.86
8	96513647	Kit, C.Box E,F MAGNA 32/40-120,50/65-60	Fast Mover	154.33
9	96740842	HILGE-3A1-CTE-28-kaK O1	Slow Mover	767.62
10	96567343	Secondary shaft seal YJ3458065 sparepart	Fast Mover	98.95
11	96760248	Sensor DPI 0-2.5 bar 5m cable	Fast Mover	144.65
12	S0608156	Kit, Rep. CLM/CLP-CDM/CDP	Fast Mover	110.65
13	S0810108	Kit, CLM100/125-CDM125/150	Fast Mover	107.75
14	S0810109	Kit, R. CLM150/200-CDM200/210	Fast Mover	159.7
15	96003297	Pump unit 1x230V for APL/D81,82	Slow Mover	598.77
16	96039655	Kit, Shaft D32 Mech. Seal NK 1.4401	Slow Mover	203.13
17	96509610	Kit, FKM Modul for standard pump	Fast Mover	133.65
18	96459608	kit, Pump head MAGNA UPE(D)32-120 MOD.D	Slow Mover	125.37
19	96603587	Level sensor RMQ A/ SPARE	Slow Mover	131.63
20	96003151	Kit, Shaft seal w/o impeller D22 AUUE	Slow Mover	90.53

Table 7. The description of the spare parts that are used for the numerical analysis

Before going on with how the numerical study is done, it is necessary to explain the data collected for the numerical analysis, which will be explained in the following section.

5.2.1 Data Collection

The demand and return values and the cost parameters for each spare part are retrieved from SAP. These parameters are collected based on each period in the planning horizon. One review period is assumed to be one month which is relevant in the real situation because replenishments are done on a monthly basis. The planning horizon for each of the spare part is different because return acceptance has started at different periods for different products.

The demand and return request data are analyzed within each month. In this analysis, it is considered that the request for one spare part is one order. Furthermore, it is observed that the arrivals of demand orders and return requests are not so frequent within a month and less than 10. According to Silver et al.(1998), for such a small sample, it can be assumed that the demand and return processes follow a Poisson process. Furthermore, as investigated at section 4.1, the demand and return rates are non stationary. For each month, the expected values for the demand and return data are computed.

In order to solve the proposed model, the data in Table 8, has retrieved from the manager of GDS and Ceva logistics. The table contains the common cost parameters for all the spare parts that are used.

Name	Value
I(0)	0
Monthly Traget Service Level	98%
Name	**Value per unit (Euros)**
cw	34.39
cs	34.39
cp	34.39
cc	34.39
cw	34.39
ch	1.39
ctr	120

Table 8. The cost data retrieved from GDS and Ceva Logistics

5.2.2 The Results of the Numerical Analysis

The numerical study is done by computing the total expected cost for each of the spare part separately by using the data in section 5.2.1. This is done for each of the 5 scenarios which can be seen at table 6. Then, the total expected cost for all 20 parts are compared for these scenarios. All the computations are done using an Excel Spreadsheet. According to the method above, the result of the total expected costs for 20 spare parts with respect to 5 scenarios are shown in Table 9.

		Scenario 1			Scenario 2	Scenario 3	Scenario 4 (Base Model)	Scenario 5
Part	**Planning Horizon**	**B***	**A***	**Total Cost (Euro)**	**Total Cost(Euro)**	**Total Cost (Euro)**	**Total Cost (Euro)**	**Total Cost (Euro)**
1	13	7	11	48371	54079	53575	58397	48652
2	25	13	25	25385	27254	27200	28065	25522
3	18	8	18	69244	70822	69990	72132	69756
4	20	13	20	137658	136839	139735	138279	137887
5	17	5	17	123807	129628	129493	133941	126445
6	19	13	18	52478	55355	53983	56052	52584
7	15	9	15	20957	25341	22294	24817	21040
8	18	7	18	308390	312331	310580	313632	309435
9	10	1	4	9850	15020	9871	15869	9871
10	17	9	17	55938	58020	56627	58518	56133
11	12	7	12	45062	46702	57608	60099	45071
12	15	8	15	50200	51618	50725	52162	50274
13	15	7	15	83620	85845	84760	86813	83763
14	20	9	20	86208	85322	87481	86351	86693
15	19	8	17	50596	56579	53500	56228	51147
16	12	2	9	10496	14310	10888	14578	10528
17	15	7	15	124750	126694	125132	127261	125018
18	19	9	17	13548	15441	14942	16023	13677
19	17	13	17	7062	9314	8160	9929	7069
20	15	9	15	10058	13116	13874	18180	10294
Total				**1333679**	**1389632**	**1380417**	**1427326**	**1340858**

Table 9. The total expected cost for the finite horizon integrated return acceptance and replenishment system with respect to different last time to accept returns and different scenarios. The data is provided from SAP for the selected spare part

The results show that by preventing the acceptance of unnecessary expensive returns and unnecessary replenishments Scenario 1 has the least total expected cost (Figure 10, Table 9). Furthermore, it is observed that Scenario 1 has 6.56% lower cost than the current model and has 0.54% lower cost than doing only replenishments (Table 10). Thus, it can be stated that the proposed system at scenario 1, makes the acceptance of expensive returns economically feasible for the selected sample. Another important result from this scenario is the optimal starting and ending period. It is seen, that for most of the cases, the optimal starting period is greater than the 6th month. This can be an indicator that, the reduction percentage (in the buyback price) for the spare parts between 0-6 month is too high (95%) to minimize the cost of GDS. Furthermore, it is seen that the optimal period to stop accepting returns is the last period in the planning horizon. This is because as we go along the end of the planning horizon, due to high reduction prices, the returns become cheaper enough to become economically feasible. However, as seen from the optimal starting and ending acceptance periods, this scenario rejects almost 40% of the returns. This may not be so much desired for the sales offices. Thus, the performances of the alternative scenarios become crucial.

Therefore, scenario 2 is, then analyzed in more detail to see the total expected cost when all the returns are accepted with integrated replenishments. From Table 9 and 10, it can be said that this system has higher costs than the proposed model. However, it still improves the current system by reducing the cost by 2.64%. However, it is seen that accepting all the returns does not make the return acceptance economically feasible because it has 3.64% higher cost than the pure replenishment alternative.

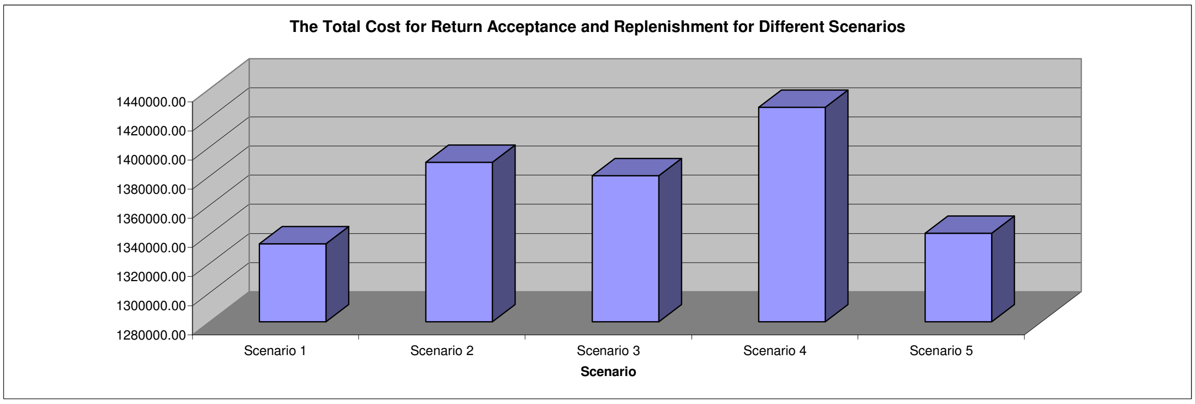

Figure 10. The comparison of total expected costs for different scenarios

Scenario 3 is analyzed to see the impact of return acceptance with respect to optimal starting and stopping time parameters, base stock levels and inventory positions. This scenario also improves the current model. However, it is seen that although most of the returns are rejected, the cost is still high with respect to scenario 5. This is because the lack of integration of replenishments is effective on the total cost. Without the integration, unnecessary replenishments are done without considering the accepted returns which are expensive than replenishments. Although for the selected spare parts scenario 3 is performs better than scenario 1, a system without integration is not reasonable (Figure 10). This is because GDS has an enough infrastructure to have integration. Replenishing without considering returns then become not reasonable if there is an opportunity to implement the integration easily.

	Scenario 4	Scenario 5
Scenario 1	6.56%	0.54%
Scenario 2	2.64%	-3.64%
Scenario 3	3.29%	-3.64%

Table 10. The percentages of total expected costs of Scenarios 1,2 and 3 with respect to the current model and the case where only the replenishments are done.

The total costs are now splitted into buy-back, handling, average inventory holding, cleaning and packaging costs as seen in Table 11.

	Total Expected Buy-back Cost(Euro)	Total Expected Handling Cost (Euro)	Total Expected Cleaning Cost (Euro)	Total Expected Repacking Cost (Euro)	Total Expected Inventory Cost (Euro)
Scenario 1	78274	4132	236	319	3834
Scenario 2	137697	6700	483	653	3837
Scenario 3	78568	4329	283	382	3837
Scenario 4	137697	6700	483	653	3837

Table 11. The total expected buy-back, handling, average inventory holding, cleaning and packaging costs for each of the scenario.

According to Table 12, it is seen that Scenario 1 and Scenario 3 reduces all the costs related to accepting returns. Scenario 1 has a better performance than Scenario 3 with respect to inventory because as there is an integration with the replenishments, so there is less inventory in the system (Table 12). Scenario 2 has the same amount of returns as the current model because all of the returns are accepted. Thus, there is no improvement in the system regarding the cost of returns. Furthermore, the numerical results show that there is no cost for GDS to return the spare parts to the manufacturing companies for all of the scenarios. This can suggest that the policy to decide on how much to return back to the manufacturer is efficient for the related spare parts.

(%) with respect to the Current Model	Scenario 1	Scenario 2	Scenario 3
Total Expected Buy-back Cost	43.16%	0.00%	42.94%
Total Expected Handling Cost	38.33%	0.00%	35.38%
Total Expected Cleaning Cost	51.09%	0.00%	41.54%
Total Expected Repacking Cost	51.09%	0.00%	41.54%
Total Expected Inventory Cost	0.08%	0.00%	-0.02%

Table 12. The percentage improvements in the total expected costs related to returns and inventory with respect to the current system

When Scenario 1 and 3 are compared, it is seen that integration has a crucial effect in reducing the cost. This is because the performance of Scenario 1 with integration is better than Scenario 3 without integration. The comparison between Scenario 1 and 2 suggests that also return acceptance policy leads a better performance. Accepting all the returns as Scenario 2 suggests does not make the system a better option than Scenario 1. Thus, the combined effect of integration and return acceptance policy makes the return acceptance process economically feasible.

As discussed, considering all of these costs Scenario 1 has the best performance. It performs better with respect to both the current system and the option of doing only replenishments. However, as a drawback, it rejects 40% of the returns. Most of the rejection occurs because the proposed system in this scenario suggests starting accepting returns after 6-12 months. This is because of the low reduction percentages. These low reduction percentages make the buy-back price higher and make accepting returns expensive. So the system rejects buying the returns between the periods when returns are expensive. To decrease this rejection percentage, GDS should increase the reduction percentages in the buy-back prices. If this scenario is not preferred, the second choice should be to accept all the returns with the integration with replenishments as in the case of Scenario 2. This scenario also performs better when compared to the current system. Yet, its performance according to the pure replenishment option is not as good as the Scenario 1.

6 Sensitivity Analysis

In section 5, it is seen that the proposed integrated return acceptance and replenishment model performs better than the current system and the other scenarios when the selected spare parts are analyzed. However, it is crucial to have a more general perspective of the return process for a wide variety of spare parts with different demand and return rates. This is because the performance of the proposed system can show variety depending on the kind of the returned spare part and the probability of cleaning and repacking. (The scrapping probability is not included in the analysis because it is zero or very small for most of the parts. GDS also motivates the sales offices to return parts with higher quality to decrease the scrapping probability.)Thus, in order to have better understanding of the proposed policy, a sensitivity analysis is done by analyzing the effect of the values of the variables on demand and return rates, cleaning and repacking probabilities as described in the sections below.

Throughout the analysis, the finite planning horizon is set to 25 months in order reflect the reality.

The experimental design consists of different values of 5 variables: slow movers and fast movers; increasing or decreasing demand rate, demand and return rates where demand rate is higher than return rate, demand rate is equal to the return rate and return rate is higher than the demand rate; the cleaning and the repacking rate. 16 different cases are analyzed for each of the scenarios with the combination of these variables (Table13).

Case #	**Description**
Case 1	Increasing Demand-Fast mover-Demand>Return
Case 2	Increasing Demand-Fast mover-Demand=Return
Case 3	Increasing Demand-Fast mover-Demand<Return
Case 4	Decreasing Demand-Fast mover-Demand>Return
Case 5	Decreasing Demand-Fast mover-Demand=Return
Case 6	Decreasing Demand-Fast mover-Demand<Return
Case 7	Increasing Demand-Slow mover-Demand>Return
Case 8	Increasing Demand-Slow mover-Demand=Return
Case 9	Increasing Demand-Slow mover-Demand<Return
Case 10	Decreasing Demand-Slow mover-Demand>Return
Case 11	Decreasing Demand-Slow mover-Demand=Return
Case 12	Decreasing Demand-Slow mover-Demand<Return
Case 13	Decreasing Demand-Slow mover-Demand>Stationary Return
Case 14	Decreasing Demand-Slow mover-Stationary Demand>Stationary Return
Case 15	Cleaning Rate
Case 16	Repacking Rate

Table 13. Experimental design for the sensitivity analysis

In order to model various demand and return rates, the demand and return mean is modeled as a linear model like: $a+\mu t$ where "a" is a constant, μ is the mean rate for the demand/return and t is the time period. In this way by setting μ negative, positive or zero the effect of decreasing, increasing and stationary demand/return rate can be investigated.
For each of the 16 cases: μ and a values are as follows in Table 14 :

	Demand		Return	
	a	µ	a	µ
Case 1	10	3	2	1
Case 2	10	3	10	3
Case 3	10	3	15	3
Case 4	50	-1	2	0.05
Case 5	50	-1	50	-1
Case 6	50	-1	50	1
Case 7	2	1	1	0.5
Case 8	2	1	2	1
Case 9	2	1	2	2
Case 10	15	-0.05	2	0.05
Case 11	15	-0.05	15	-0.05
Case 12	15	-0.05	15	1
Case 13	15	-0.05	2	0
Case 14	5	0	2	0
Case 15	15	-0.05	2	0.05
Case 16	15	-0.05	2	0.05

Table 14. The demand and return expression for different scenarios for each period

When all of the 16 cases are applied to 5 of the scenarios, it is seen that for the entire cases scenario 1 performs the best (Table 15 and Figure 11). Scenario 2 has the second highest performance with respect to both the current system and the Scenario 5. The third scenario in total has the highest cost among the three although it is still better than the current system and Scenario 5. A more detailed analysis is done to investigate the effects of each variable used in the sensitivity analysis.

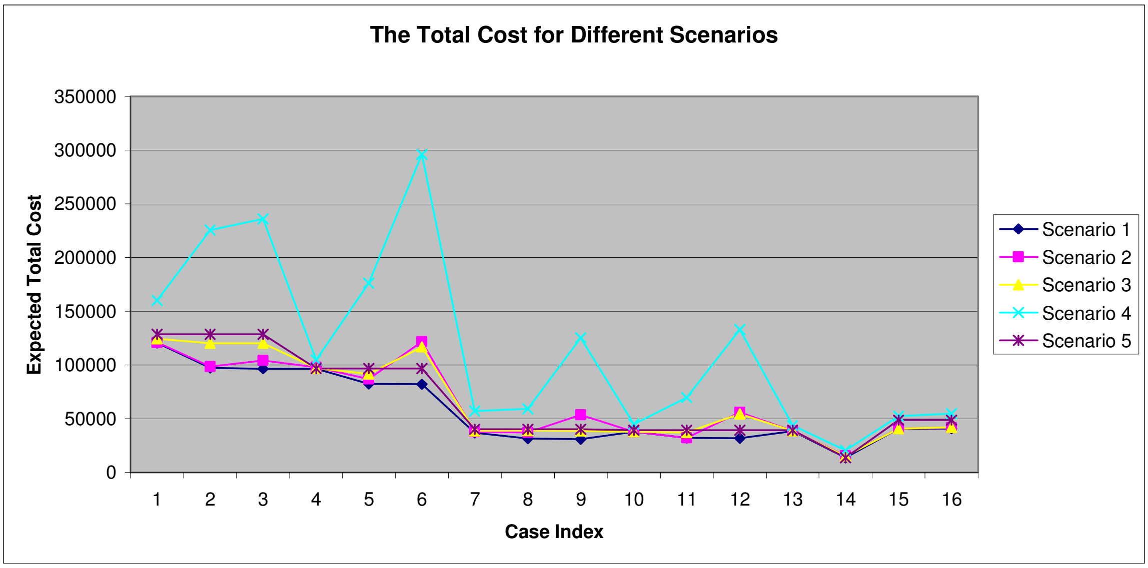

Figure 11.The total expected cost for all of the 5 scenarios under 16 different cases

	Scenario 1			Scenario 2	Scenario 3			Scenario 4	Scenario 5
	B*	A*	Total Expected Cost	Total Expected Cost	B*	A*	Total Expected Cost	Total Expected Cost	Total Expected Cost
Case 1	13	25	120702	121115	13	25	124367	160048	128702
Case 2	7	25	97252	98377	7	25	120090	225563	128702
Case 3	7	25	96548	104183	7	25	120078	235995	128702
Case 4	13	25	96630	97971	13	25	97059	104851	96796
Case 5	7	25	82463	86765	7	25	91704	176178	96796
Case 6	7	25	82035	121556	7	25	116883	296057	96796
Case 7	13	25	36825	37729	13	25	38740	57195	40240
Case 8	13	25	31570	37267	13	25	38947	59330	40240
Case 9	13	25	31029	53452	13	25	38827	125353	40240
Case 10	7	25	37893	38040	7	25	37963	44920	39223
Case 11	7	25	32174	32330	7	25	37129	69687	39223
Case 12	7	25	31882	56187	7	25	54314	133043	39223
Case 13	7	25	38329	38501	7	25	38772	43694	39258
Case 14	25	25	13620	15310	25	25	15282	20504	13710
Case 15	1	25	40604	40769	1	25	40745	52365	48663
Case 16	1	25	40653	41772	1	25	41873	54920	48655
Total			**910207**	**1021324**			**1052773**	**1859702**	**1065168**

Table 15. The total expected cost for all of the 5 scenarios under 16 different cases

6.1 The effect of Demand Rate for Spare Parts

The performance of scenario 1 is robust to the effect of demand rate. According to Table 16, Scenario 1 performs 24.58% better than Scenario 4 when the demand is increasing. It is also 7.84% better when the demand is decreasing. This also shows that Scenario 1 has higher improvement when the demand is increasing. This is because as demand increases, more returns are needed. However, as the returns are more expensive, the elimination of the acceptance of returns has higher impact on the increasing demand. The system motivates to have cheaper replenishments when the returns are rejected.

As an important result, it is seen that Scenario 2 performs better than Scenario 3 in case of increasing rate of demand (Table 16). This is because of the fact that Scenario 2 prevents unnecessary replenishments by the integration. Scenario 3, however, replenishes at an increasing rate although returns are accepted.

Scenario 3 is better when the demand rate decreases because at the end of planning horizon, unnecessary returns are rejected which reduces the cost. In scenario 2, all of the returns are accepted even there is no demand for spare parts.

Scenario 4	Scenario 1	Scenario 2	Scenario 3	Scenario 5	Scenario 1	Scenario 2	Scenario 3
Case 1	24.58%	24.33%	22.29%	**Case 1**	6.22%	5.89%	3.37%
Case 2	56.88%	56.39%	46.76%	**Case 2**	24.44%	23.56%	6.69%
Case 3	59.09%	55.85%	49.12%	**Case 3**	24.98%	19.05%	6.70%
Case 4	7.84%	6.56%	7.43%	**Case 4**	0.17%	-1.21%	-0.27%
Case 5	53.19%	50.75%	47.95%	**Case 5**	14.81%	10.36%	5.26%
Case 6	72.29%	58.94%	60.52%	**Case 6**	15.25%	-25.58%	-20.75%
Case 7	35.62%	34.04%	32.27%	**Case 7**	8.49%	6.24%	3.73%
Case 8	46.79%	37.19%	34.36%	**Case 8**	21.55%	7.39%	3.21%
Case 9	75.25%	57.36%	69.03%	**Case 9**	22.89%	-32.83%	3.51%
Case 10	15.64%	15.32%	15.49%	**Case 10**	3.39%	3.02%	3.21%
Case 11	53.83%	53.61%	46.72%	**Case 11**	17.97%	17.57%	5.34%
Case 12	76.04%	57.77%	59.18%	**Case 12**	18.72%	-43.25%	-38.48%
Case 13	22.46%	22.15%	22.19%	**Case 13**	16.56%	16.22%	16.27%
Case 14	46.79%	37.19%	34.36%	**Case 14**	16.45%	14.15%	13.94%
Total	51.06%	45.08%	43.39%	**Total**	14.55%	4.12%	1.16%

Table 16. The percentage improvements in total cost for Scenario 1,2 and 3 with respect to current model and doing only replenishments. The percentages are calculated as: (Total expected cost of the base case- Total expected cost of the target scenario)/(Total expected cost of the base case)

6.2 The effect of Consumption Rate for Spare Parts

Scenario 1,2 and 3 are robust to the consumption rate of the spare parts. In other words, whether the spare part is a slow mover or a fast mover, three scenarios performs better than the current model. However, it is seen that three of the scenarios performs better when the spare part is a slow mover. This is because as the demand rate decreases, the amount of returns to accept and replenishments to do become crucial. As unnecessary replenishments and return acceptance are done too much cost is incurred on inventory and purchase costs.

Scenario 2 performs better than Scenario 3 in both of the cases when the demand is increasing. This is because of the integration of replenishments in Scenario 2. So in both fast and slow mover no unnecessary replenishments are done.

6.3 The effect of the Return Rate for Spare Parts on the Performance of the Integrated Return Acceptance Model

The return rate is one of the crucial variables that affect the performance of the proposed return acceptance policy. Scenario 1, Scenario 2 and 3 performs better when the return rate is higher than the demand rate. This is because considering the whole planning horizon, accepting higher return rate becomes cheaper than the replenishments. This is because through the end of planning horizon, the buy-back percentages are reduced.

When the return rate is higher than the demand rate (Cases 6, 9 and 12), it is seen that scenario 1 is the only that that is economically feasible compared to only replenishment option. Scenarios 2 and 3 have high negative percentages when compared to Scenario 5. For instance, for case 6, Scenario 2 has 25% higher cost and Scenario 3 has 21% higher cost than Scenario 5. This is also true for cases 9 and 12. This suggests that accepting all the returns and not integrating replenishments makes the return acceptance policy more expensive when the return rate is higher than demand. In this case, it becomes necessary to reject the returns that have no demand. Also, at higher return rate, GDS should do the replenishments according to accepted returns to decrease unnecessary inventory. Therefore, Scenario 1 performs better when the demand rate is lower than the return rate.

As an important fact, as return rate is higher or equal to the demand rate, two of the scenarios performs nearly the same. As the return rate is lower, Scenario 1 accepts all the returns within the optimal period. This becomes near to the Scenario 2. Scenario 3, however has lower performance than these three due to the lack of integration.

6.4 The effect of Stationary of Demand and Return Rates

When the return rate is stationary, all of the three scenarios perform nearly the same. As the return rate does not fluctuate, accepting all the returns leads to lower costs. However, when the demand and return rates are both stationary, Scenario 1 performs better by only accepting returns after period 25. This is because of the fact that Scenario 1 starts to accept all the returns after two years. The percentage reductions at GDS have higher effects on the total cost under stationary demand and return rate where the reductions are too high to have economical feasible acceptance policy.

6.5 The Effect of Cleaning and Repacking Probability

Three of the scenarios have the minimum cost under lowest probability of cleaning and repacking rate for all of the scenarios (Figure 12). This is because as cleaning and repacking probabilities increase, there is more cost incurred. Furthermore, not all of the cleaning and repacking costs are taken form the sales offices. When three of the scenarios are compared, Scenario 1 performs better under higher rate of cleaning and repacking.

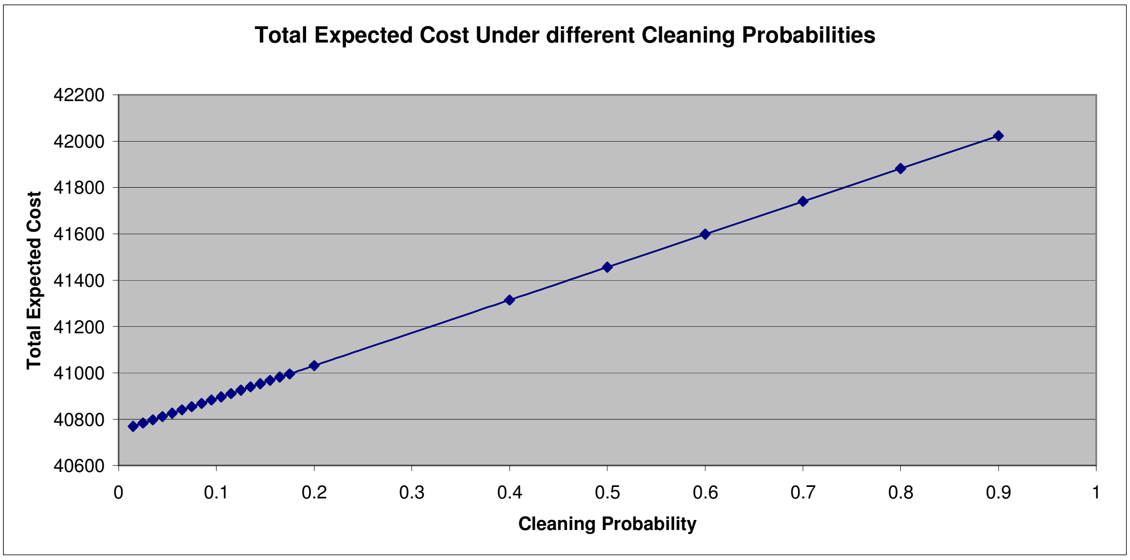

Figure 12. The total expected cost for Scenario 2 under different cleaning probabilities.

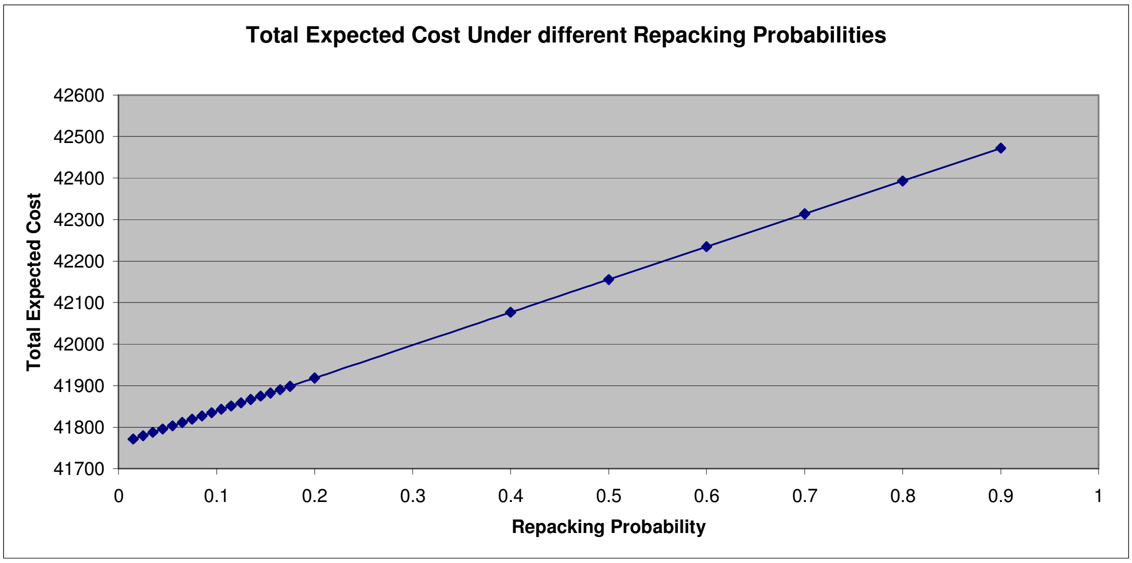

Figure 13. The total expected cost for Scenario 2 under different repacking probabilities.

6.6 Discussion

According to the results of the sensitivity analysis, it is seen that the performance of Scenario 1 is the best for all of the cases of fast moving, slow moving spare parts with either increasing or decreasing demand when compared to the current system at GDS and the other scenarios. The proposed system also performs better when the return rate is higher.

GDS can use the system under Scenario 1 because the expected total cost is lower than both the current system and the system where there are only replenishments. This is true for all of the different cases used in the sensitivity analysis. However, Scenario 1 rejects about 40% of the return requests. Thus, alternative possibilities can be considered if this is not preferred.

As an alternative to Scenario 1, Scenario 2 can be used by GDS because accepting all the returns performs well under increasing rate of demand. Yet, this choice is not economically feasible for decreasing rate of demand because unnecessary returns can be accepted although there is no demand. Furthermore, Table 16 suggests that Scenario 2 does not perform well compared to Scenario 5 when the return rate is higher than the demand. Thus, a combined usage between Scenario 2 and Scenario 1 can be motivated. Scenario 2 can be used until the demand rate starts to decrease and until the demand rate is higher than the return rate. After the demand starts to decline Scenario 1 can be used.

7 Implementation Plan

In the previous sections, a new return acceptance system has been designed and described for the spare parts at GDS. This new system is called as “an Integrated Return Acceptance and Inventory Replenishment Policy” which has been designed to decide on the return acceptance with respect to the inventory levels and the replenishments according to the accepted returns. In this section, the implementation of the proposed system will be elaborated.

Before going on the detail of the implementation, it is necessary to state that the decisions to be used at the proposed system (as in Scenario 1) depend on how the assumptions, made to build the model, are related to the reality (as in Section 4.3.1). All of the assumptions are made related to reality. Thus, all the decisions that the proposed policy suggests can be implemented. Although this is the case, the review time to make the decisions should be kept longer than the lead time of returns and replenishment in order to have the zero lead time assumption valid. (It is already known that GDS uses 1 month as a review time which is less than the lead time of return and demand arrival.)

The implementation plan consists of three sections: the proposed system description with respect to company structure and the relevant system requirements, the implementation of the return acceptance and replenishment policy and the implementation of the optimization model.

7.1 The Integrated return Acceptance and Replenishment System under GDS Structure and the System Requirements

To recap, the integrated return acceptance and replenishment system is designed to eliminate the acceptance of expensive returns that will eventually become slow movers or obsolete spare parts. Furthermore, it is aimed to reduce unnecessary replenishments while taking into account the accepted returns at that period. These objectives are achieved by the design of a periodic review order-up-to level inventory control policy. This control policy can be implemented to GDS by using the company's current system constraints.

The integrated return acceptance and replenishment system is a decision support system for GDS to decide on how much returns to accept, how much replenishments to have and when to stop accepting returns for each period. An Excel Spreadsheet has been made for the implementation of the decision support system. So, when the company enters the necessary input parameters, the output variables will the given by the decision support system via the Excel spreadsheet. Then, in order to GDS to use this decision support system, certain data is required. So, first of all, the proposed process should be described in terms of input parameters that GDS will use to apply the method and the output variables and the performance measures that GDS will get as a result to use on the decision of the return acceptance and replenishments.

The input parameters that GDS will use is the demand data for each period for the specific spare part, the return request for each period, the cost parameters concerning handling, inventory holding, scrapping, cleaning and repacking of returns, the customer service level and stock on hand at the end of each period. Then, the proposed decision system via the spreadsheet will transform these parameters into variables as the order-up-to levels, how much return to accept per period, how much replenishments to do and until when to accept returns. Furthermore, the average cost per period and the profit can be used as performance measures by GDS.

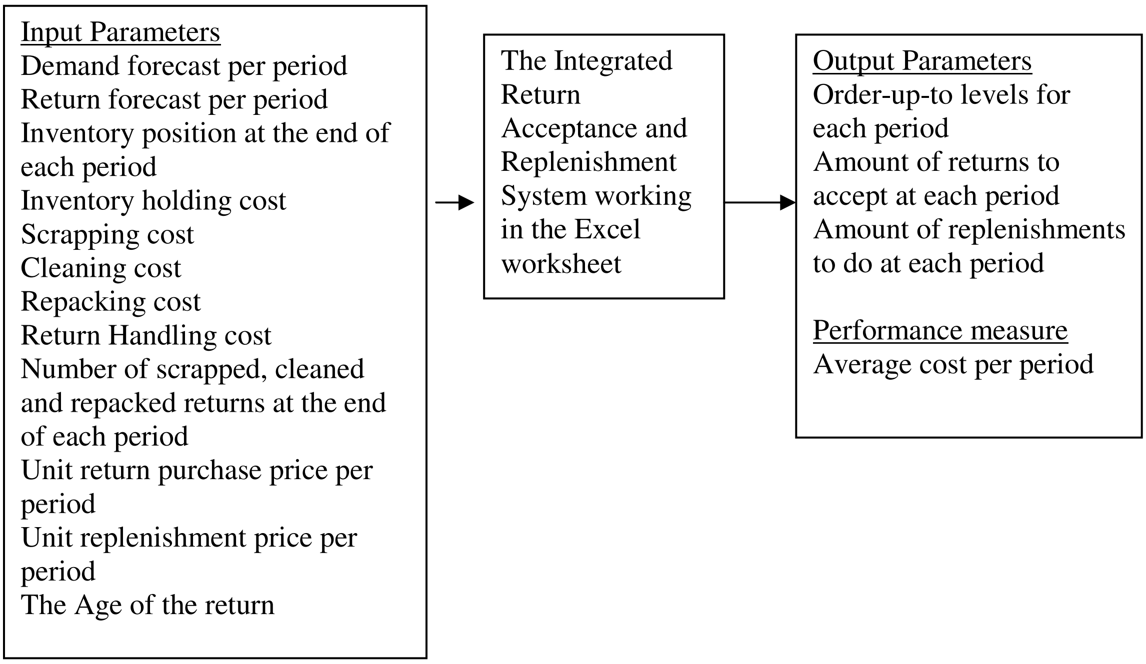

Figure 14. The data structure for the integrated return acceptance and inventory replenishment system

7.1.1 Input Data Retrieval and System Requirements

In order to work with the proposed decision supports system, the input parameters given above should be obtained by using GDS information system tools. The cost parameters should be retrieved from CEVA logistics and Grundfos' return policy. The inventory position at the end of each period is already available at SAP. One should enter the spare part code and can see the inventory on hand at any time period. The number of scrapped, cleaned, and repacked returns after each return is received is retrieved from CEVA Logistics through e-mail.

The input parameters needed for the optimization model is to determine the starting time and last time to accept returns includes: the forecasts of the demand and return rates over a planning horizon. In order to be integrated with the GDS's current information system, the following forecasting method is suggested to be used in the implementation: ARIMA model. This method can be used by GDS to forecast next periods demand and return rate according to the given guideline provided at the Appendix 7. Furthermore, for long horizon forecasts, regression analysis can be applied. These two methods can easily be implemented in Excel. (The forecasting techniques are explained at Appendix 7)

The system requirement for the decision tool has no cost for GDS where all the computations and decisions can be easily done by using an Excel Spreadsheet.

7.2 The Implementation of the Return Acceptance and Replenishment Policy

By the information from the previous section, it is assumed that all the input parameters together with the forecasted demand at the decision period are available. Next, the length of one period is set to 1 month as at GDS the order-up-to levels, the replenishments and the forecasts are done at the beginning of each month by using past data from SAP. Te return requests are planned to be received at the beginning of every month before any replenishments is done.

The proposed policy is implemented in an Excel Spreadsheet where GDS can easily change between different scenarios as discussed in section 6. How much to accept and the order-up-to levels are calculated by the spreadsheet.

The implementation of integration is as follows: In the beginning of each month, GDS should put the accepted returns into SAP under blocked stock before they are received physically. So, the accepted returns will be seen in the system. The replenishments will be done accordingly. In order to improve the integration, GDS should motivate the sales offices to send the returns before the length of the review period. Thus, returns can become physically available before the possible replenishments.

7.3 The Implementation of the Optimization Model Concerning the Decision of the Starting and Ending Time to Accept Returns

The starting and ending time to accept returns is determined by considering the total expected costs over a certain planning horizon. In order to be relevant with the real process of GDS, the optimization model will be done in a rolling schedule basis. A rolling schedule is formed by solving the finite horizon problem and only implementing the first period's decisions about starting and stopping. One period later, the optimization problem is updated as better forecasts will become available. This procedure will be repeated until the demand of the spare part diminishes.

The optimization model should be run for a period of 12 months. This is because from the numerical results and the sensitivity analysis it is seen that the optimal starting periods can range between 6-12 months. So, GDS can be able to see the optimal starting period in each optimization planning horizon. This can make the calculations easier for GDS. The rolling horizon will lead to more efficient forecasts in this long period.

Before going on with the model, GDS should forecast the 12 months demand and return rate at monthly level by using regression as explained in Appendix 7. (The forecasts should be tested by an experienced person and data sharing should be used with the sales offices to increase accurate forecasts.) The probability of scrapping, cleaning and packaging should be computed by using the past data over a year. (Simply by dividing the total number of scrapped; cleaned; repacked returns by the total amount of returns of the relevant part) Then, by using an Excel sheet, the optimal starting and ending time can be found. In this implementation, it is important to search for optimal stopping time to accept returns (A*) until the end of planning horizon T. until the time of optimal starting period comes in an optimization problem, the B* value should be updated. If the B* value does not change until period B* comes, the return acceptance should start at B*. For instance, we assume that B* is 13^{th} month in the planning periods [2^{th} month,14^{th} month]. Then, at the next optimization model, the B* should be again found. If it is different then 13^{th} month, B* should be updated (may be to 15^{th} month) until the last updated period becomes the current period. At each optimization problem session, the following steps should be done:

Notation: *T*: The last time that demand occurs for the spare part, *i:* current period

Step 1: If i ≤ T, forecast the demand and return rates over periods [i,i+12-1], go to Step 2; otherwise go to step 6.
Step 2: Solve the optimization model and find optimal B* and A* using the Excel Spreadsheet. Update A* value. If B* value is not the current period over the periods [i,i+12-1], go to Step 4; otherwise go to Step 3.
Step 3: Fix the B* value for the rest of the problem until time T and start accepting returns. Then, go to step 5.
Step 4: Update A* and B* values.
Step 5: Go to the next period and let the current period be i=i+1. (Update the demand and return data according to the previous period's data that have become available). Then go to Step 1.
Step 6: Stop B* and A* are the last updated values.

7.4 The implementation of the proposed system in the organization of the company

In addition to the process implementation, the implementation of the proposed system to the organization of GDS should be done.

First of all, by the beginning of each month the purchasing planner should do the forecasting. This activity involves forecasting the demand data (which is next 12 months) which is needed for the optimization model. The forecasts can be done automatically by an excel sheet. The replenishments will be done also by this employee using SAP. This activity takes at most 2 minutes for one spare part by using SAP.

The acceptance of returns requests, the forecast of returns, the probabilities of cleaning and repackaging and optimization model are all done by logistics planners during the period. All these actions are done based on an Excel spreadsheet by using the data from SAP and the computations of the purchase planner. The return forecasts and the optimization model will be done every month. This can take about 2 minutes per spare part that has the return requests. This time can be longer for the time period that is learned, however due to learning curve this time can be reached. If there is integration is done with SAP and the Excel spreadsheet, then this can be less than 2 minutes. The return acceptance process can take 2 minutes for each spare part.

If there are at most 6692 spare parts that can be requested to be returned for a year, then weekly 12 hours is needed for the logistic planner to implement the new return acceptance policy. For the purchasing planner weekly 4 hours will be sufficient. Then, the return acceptance policy will form the 10% of the weekly workload for the purchasing planner and 30% of the weekly workload of the logistic planner.

8 Conclusions and Future Research

8.1 Conclusion

In this study, it was targeted to develop a cost efficient decision support system for an integrated return acceptance and replenishment policy for GDS. For the current return acceptance policy, it has been shown that the cost of return acceptance is higher than doing replenishments. Moreover, it is observed that there are more returns accepted than needed regarding the stochastic non-stationary demand rates. Some of the returned items are accepted although they become obsolete with the decreasing rate of demand. Furthermore, one of the disadvantageous aspects of the current system is that the replenishments are done without considering the accepted returns. All of these aspects, increases the current cost of return acceptance and replenishment. Moreover, return acceptance becomes not economically reasonable as an alternative to cheaper replenishments. In order to solve these problems, the following research questions are formulated: How should a return acceptance policy be designed such that acceptance of returns becomes an economically feasible source alternative to replenishments and how long should GDS accept the returns in order to recover the costs? In order to reach these objectives a decision support system for the integrated return acceptance and replenishment policy is designed.

The integrated return acceptance and replenishment policy reaches the objective of being economically feasible by accepting efficient amount of returns and doing replenishments considering the accepted returns. According to the results of the numerical and the sensitivity analysis, it is seen that the proposed system has lower expected cost than the current return acceptance system and doing replenishments only. The objective of finding the optimal period to accept returns is reached by an optimization model.

The performance of the proposed decision support system together with other scenarios is evaluated both by a numerical study with a sample size of 20 different spare parts. One of the scenarios is based on accepting all the returns with integration with replenishments. The third scenario consists of accepting returns according to the proposed policy without an integration. In this analysis, there are two base models, which are the model of the current system and the model with no returns but only replenishments. From the results of the numerical analysis, it can be concluded that:

- The integrated return acceptance policy performs better than the current acceptance system and doing only replenishments.
- The integrated return acceptance policy reduces the buy-back, handling, cleaning and repacking costs by accepting returns in an optimal period.
- The proposed policy rejects 40% of the returns.
- High buy-back price for returns play an important role in deciding on when to accept returns. Until 7^{th} period no returns are found to be optimal to accepted. Therefore, GDS should reduce the buy-back costs to make the return acceptance policy economically feasible.
- As an alternative policy all returns are accepted with integration of replenishments. This policy also performs better than the current system. However, this alternative under the investigated spare parts is not economically feasible when the demand rate is decreasing and the return rate is higher than the demand rate.
- The performance of accepting returns under the proposed policy without an integration is also investigated. This alternative is not economically reasonable because there is no integration with the replenishments. As GDS have enough infrastructure for the integration, this scenario can hardly be an alternative.

Also a sensitivity analysis is done to analyze the behavior of the system with respect to varying demand rates, return rates, buy-back price, and probability that a return is cleaned or packaged. The sensitivity analysis is also done for the 5 scenarios. The results of the analysis are as below:

- The proposed system's performance is robust regarding the fast moving or slows moving spare parts with decreasing or increasing rate of demands, return rates and unit purchase prices. The system always gives the end of planning horizon as the optimal time to stop accepting returns. However, the optimal starting time is either 7th or 13th period. This can indicate the low reduction percentages in the buy-back prices .Moreover, the proposed system always better than the current system at GDS and the other 3 scenarios.

- The alternative method of accepting all of the returns with integration performs better for the spare parts with an increasing rate of demand. The proposed method performs better under decreasing rate of demand.

- As the cleaning, repackaging probabilities increase, the total cost also increases. Thus, the gate keeping over the quality of returns should be kept high to decrease the spare parts that need to be cleaned and repacked.

GDS can implement the decision support system for the integrated return acceptance and replenishment system by using the Excel spreadsheet. GDS can also further develop this system by making an integration with SAP and Excel spreadsheet to decrease the workload. Furthermore, GDS should motivate the sales offices to transport the returns before the length of the review period.

From the academic perspective, the conclusion for academic is as follows: this study contributes an extension to the literature related to the inventory control with returns. In this study a return acceptance policy is developed to obtain minimum return cost under non-stationary return and demand rates. Thus, in this aspect the thesis project can be considered as an extension of Kiesmüller and Scherer (2003) and Mahadevan et al, (2003). In these papers, also optimal inventory control models are studied for returns acquaintance under non-stationary demand.

8.2 Recommendations

Regarding these results further recommendations are made for GDS:

- If GDS hesitates to reject returns from the sales offices, then GDS should accept all the returns with integration with replenishments.
- GDS should increase the reduction percentages in buy-back prices.
- GDS should use the order-up-to levels that are used for replenishments also for accepting the returns.
- GDS should consider the accepted returns while replenishing. This can be complex because SAP has no integration with returns. However, this can be solved by putting returns into SAP under blocked stock as soon as they are accepted. Thus, the stock levels will be updated accordingly.
- GDS should integrate SAP with the Excel Spreadsheet to decrease the workload of the employees.
- GDS should trace the return rates and the scrapped, cleaned and packaged amounts at the end of each month. Thus, the forecasting for these variables can be done and the quality of returns can be monitored.
- The company should take all the cleaning and repackaging costs of returns from the sales offices in order to cover the cost of returns.
- GDS should motivate the sales offices to return the accepted spare parts as soon as possible to prevent any late arrivals of the returns.

8.3 Future Research

8.3.1 Future Research for GDS

One of the main targets of Grundfos is the centralization of the inventory decisions. However, currently there is so few or no centralization due to the fact that sales offices control their inventories in a decentralized way. Therefore, the study considers GDS in a decentralized way by preventing GDS to have high costs on accepting returns. Thus, as a future research, the return acceptance can be managed by considering the inventories of sales offices too.

Before this study, GDS was unaware of whether it was losing money on accepting returns or not. With this study, it is seen that due to low reduction percentages in buy-back prices GDS is losing. However, in this study this loss is reduced by accepting returns more efficiently in an inventory level without focusing on the optimal pricing strategy. Thus as a future research the optimal pricing strategy can be studied.

8.3.2 Future Research for Academics

In this study, a kind of myopic optimization is used in order to decide on the order-up-to levels and the last time to accept returns. This is done due to the complexity of optimization under non-stationary demand within the time restrictions. By this approach, there can be cases where returns are rejected unnecessarily although they will be needed in the upcoming periods. Thus, as a further study, the order-up to levels can be calculated by considering the demand and return rates considering the complete planning horizon.

The optimization model assumes zero lead time for a monthly period. However, in reality the effect of lead times on the availability of the spare part can be high. Thus, a study can be done by considering the lead times for returns and demand.

Moreover, in GDS a return requests involves different spare parts. In this study only the return of an individual spare part is considered. As a future research, return acceptance should be studied under a joint-replenishment.

The case that the return rates and the demand rates are correlated can be studied so that returns can be forecasted from the demand rates.

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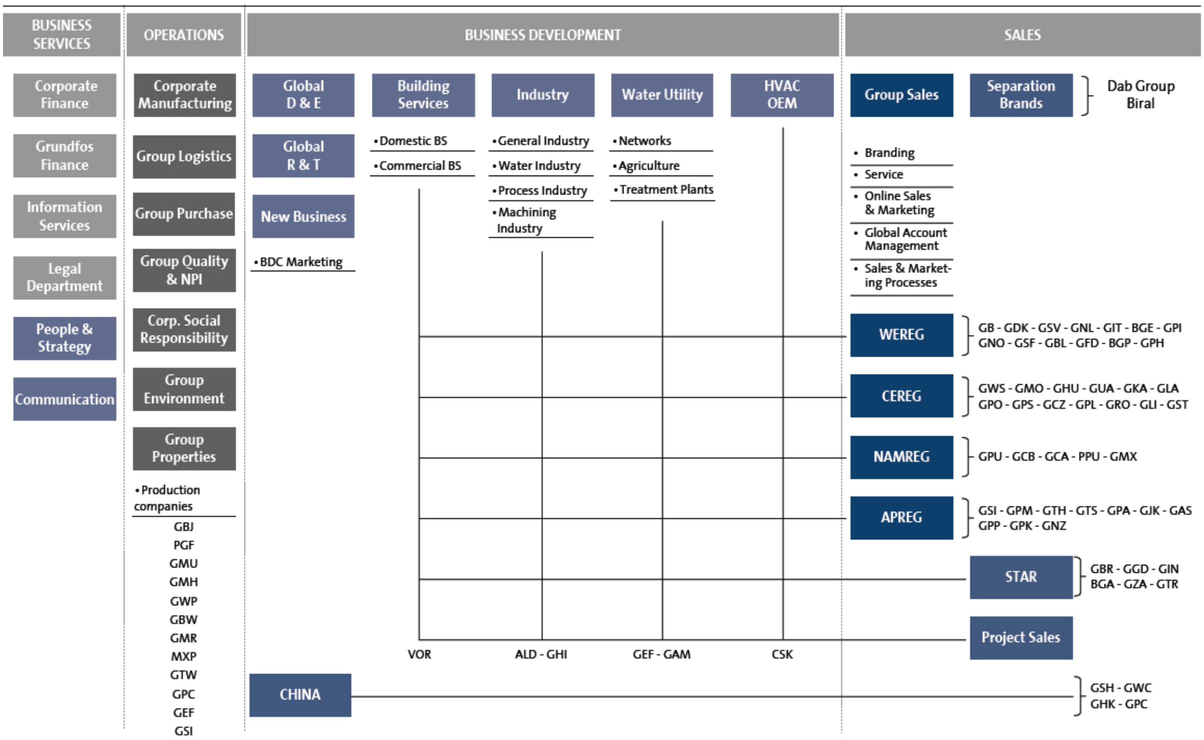
10 Appendices:

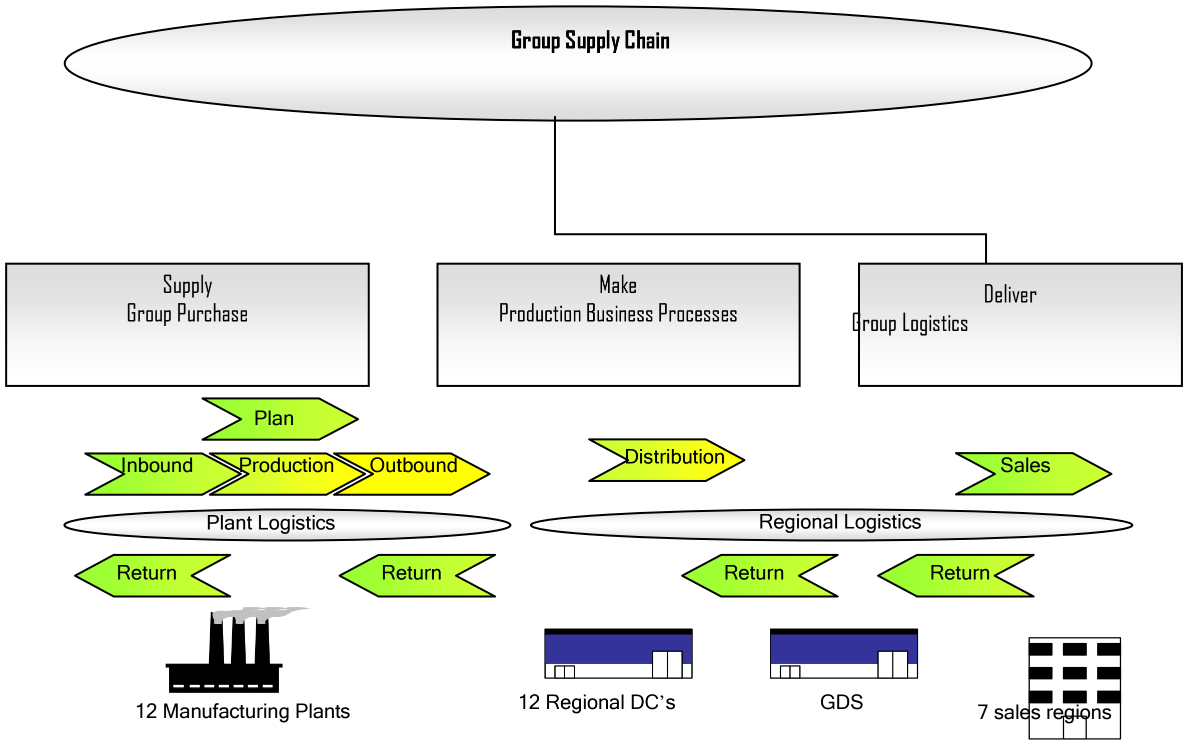
Appendix 1: The buy-back price percentages for returns of spare parts which is retrieved from the slow-moving policy of Grundfos 2009

<table>
<tr><th colspan="3">Settlement of returned Spare Parts</th></tr>
<tr><td colspan="3">• The reduction of price based on the age of the products</td></tr>
<tr><td>Returned article</td><td>Necessary actions</td><td>Reduction of selling price</td></tr>
<tr><td>Spare Parts</td><td>less than 6 months</td><td>5%</td></tr>
<tr><td>Spare Parts</td><td>between 6-12 months</td><td>20%</td></tr>
<tr><td>Spare Parts</td><td>between 12-24 months</td><td>45 %</td></tr>
<tr><td>Spare Parts</td><td>Older than 24 month but less than 3 years</td><td>60 %</td></tr>
<tr><td>Spare Parts</td><td>Older than 3 years</td><td>90%</td></tr>
<tr><td colspan="3">• motors and pump heads older than 2 years are considered obsolete and must be scrapped locally
• spare parts containing electrical parts older than 3 years are considered obsolete and must be scrapped locally</td></tr>
<tr><td colspan="3">• Additional reduction of price based on the condition of the spare parts</td></tr>
<tr><td>Spare Parts</td><td>Repacking</td><td>20 %</td></tr>
<tr><td>Spare Parts</td><td>Repacking and cleaning</td><td>35 %</td></tr>
<tr><td colspan="3">• spare parts damaged or used as well as blister packed KITS where the packaging has been opened are considered obsolete and must be scrapped locally
• The total value of the spare parts return per order must exceed 100,00 EUR. However, as the analysis of joint replenishment is very complex, in this thesis singe spare part is assumed to have value higher than 100 Euros.</td></tr>
</table>

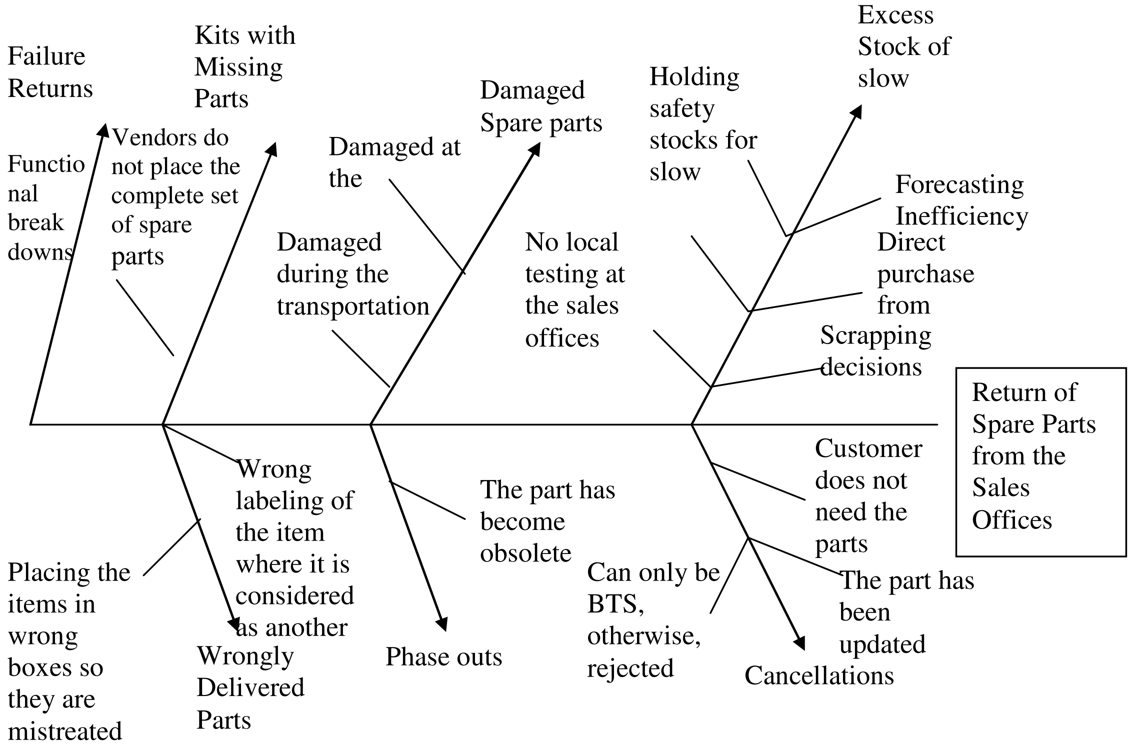
Appendix 2: The organization matrix of Grundfos Group which is retrieved from the intranet of Grundfos Portal in June 2009.



Appendix 3: The Closed Loop Supply Chain for Grundfos Group which is retrieved from the intranet of Grundfos Portal in 2009.



Appendix 4. Cause and Effect Diagram for the returns from sales offices to the GDS which is designed with respect to the observations done by following returns of different spare parts and experiences of the supervisor



Appendix 5. Weekly Cost calculation of Return Acceptance Process where the data has been retrieved from SAP

	Week																		
Cost/ Euro	40/O8	41/08	42/08	43/08	45/08	46/08	47/08	48/08	49/O8	50/08	51/08	2/O9	3/O9	4/O9	5/O9	6/O9	7/O9	8/O9	9/O9	Total
Handling Cost	781.69	2336.48	2070.19	42.95	1417.35	1829.67	2388.02	25.77	3908.45	1082.34	5239.90	9818.37	25.77	1675.05	429.50	120.26	51.54	2654.31	2362.25	38259.86
Scrapping Cost	0.00	180.92	0.00	0.00	90.46	45.23	90.46	45.23	0.00	0.00	407.07	452.30	0.00	0.00	45.23	0.00	45.23	0.00	90.46	1492.59
Repacking Cost	2937.22	1821.82	92.95	18.59	483.34	0.00	1152.58	0.00	3383.38	148.72	2788.50	334.62	0.00	223.08	185.90	0.00	55.77	241.67	334.62	14202.76
Cleaning Cost	966.68	148.72	111.54	37.18	148.72	0.00	780.78	0.00	334.62	297.44	669.24	297.44	0.00	1115.40	743.60	817.96	74.36	594.88	817.96	7956.52
Buy-Back Cost	10243.69	28482.41	13729.83	680.72	17204.98	1307.77	20869.33	425.06	99777.98	5841.07	66298.71	45922.33	318.54	17612.68	2566.84	124.60	816.39	16949.07	19188.28	368360.28
Average Weekly Holding (	2845.25	7168.92	4761.22	27.71	5617.26	1342.75	1846.96	15.53	4300.59	1381.20	4853.73	9814.93	16.13	3493.62	662.94	10.04	31.33	6395.48	17526.53	72112.13
Total Cost	17774.53	40139.27	20765.73	807.15	24962.11	4525.42	27128.13	511.59	111705.02	8750.77	80257.15	66639.99	360.44	24119.83	4634.01	1072.86	1074.62	26835.41	40320.10	502384.14

Appendix 6: The Computation for the Expected Value for the Amount of Accepted Returns

In order to find the expected value of $\hat{R}(t)$, let:

$$[S(t)-(S(t-1)-D_{(t-1)}-y_{(t-1)}*\hat{R}(t-1))]^{+} = X1 \quad \tilde{R}(t)=X2$$

(1.1)

Then, E[$\hat{R}(t)$]=E[min{X1 and X2}]

In order to simplify the computation, the amount of scrapped returns is assumed to be zero under the consultation of GDS. This assumption is valid in reality because the probability to have scrapped returns is zero or very small for most of the time.

Then X1=$[S(t)-(S(t-1)-D_{(t-1)})]^{+}$

In order compute the expected value, it is necessary to find the probability mass function (pmf) of minimum of X1 and X2. So in order to find this, let M=min{X1,X2}. Then we should find the pmf ,p(M=m), by the following equations:

$$P(M>m)=P(X1>m)*P(X2>m)$$

$$p(M=m)=P(M>m-1)-P(M>m)$$

Alternatively this expression can be written as:

$$p(M=m)=(1-P(X1\leq m))*p(X2=m)+(1-P(X2\leq m))*p(X1=m)+p(X1=m)*p(X2=m)$$

Then the expected value of E[min{X1,X2}]= $\sum_{m=0}^{\infty} p(M=m)*m$

Hence, in order to calculate this expectation, the probability distribution functions X1 and X2 should be determined.

$X1=[S(t)-S(t-1)+D_{(t-1)})]^{+}$ can be splitted as:

$\Delta(t)=S(t)-S(t-1)$ and $D_{(t-1)}$

Then, the expected value X1=$\Delta(t)+D_{(t-1)}$can be computed as follows:

$$E[X1]=\begin{cases} \sum_{k=0}^{\infty} (S(t)-S(t-1)+k)P(j=k) & \text{if } \Delta(t)\geq 0 \\ \sum_{k=S(t-1)-S(t)}^{\infty} (S(t)-S(t-1)+k)P(j=k) & \text{if } \Delta(t)<0 \end{cases} \quad \text{where } j=D_{(t-1)}$$

Finally, the expected value of X2 is: $E[\tilde{R}(t)]:\begin{cases} E[R(t)] \text{ if } t\leq A \\ 0 \quad \text{otherwise} \end{cases}$

The expected value of min{X1 and X2} can be then computed as follows:

$E[X1]=\lambda 1 \,\&\, E[X2]=\lambda 2$

$$p(X1=m)=e^{-\lambda 1}\frac{\lambda 1^{m}}{m!} \,\&\, p(X2=m)=e^{-\lambda 2}\frac{\lambda 2^{m}}{m!} \qquad (1.2)$$

Explicitly the expected value of min{X1, X2} is as follows:

$$\text{E}[\min\{\text{X1,X2}\}]=\sum_{m=0}^{\infty} p(M=m)*m:$$

$$\sum_{m=0}^{\infty} e^{-\lambda 1}\frac{\lambda 1^{m}}{m!}*m+\sum_{m=0}^{\infty} e^{-\lambda 2}\frac{\lambda 2^{m}}{m!}*m-\sum_{m=0}^{\infty}\sum_{k=0}^{m} e^{-\lambda 1}\frac{\lambda 1^{k}}{k!}*\sum_{m=0}^{\infty} e^{-\lambda 2}\frac{\lambda 2^{m}}{m!}*m$$

$$-\sum_{m=0}^{\infty}\sum_{k=0}^{m} e^{-\lambda 2}\frac{\lambda 2^{k}}{k!}*\sum_{m=0}^{\infty} e^{-\lambda 1}\frac{\lambda 1^{m}}{m!}*m+\sum_{m=0}^{\infty} e^{-\lambda 1}\frac{\lambda 1^{m}}{m!}*\sum_{m=0}^{\infty} e^{-\lambda 2}\frac{\lambda 2^{m}}{m!}*m$$

Finally, $\text{E}[\hat{\text{R}}(\text{t})]$ is reduced to:

$$\text{E}[\hat{\text{R}}(\text{t})]=\lambda_{rd}(t)=\begin{cases} \lambda_r & \text{if } \min\{\text{E[X1,E[X2]}\}=\text{E[X2] and } t \le \text{A} \\ S(t)-S(t-1)+\lambda_D(t-1) & \text{if } \min\{\text{E[X1],E[X2]}\}=\text{E[X1] and } S(t)-S(t-1)\ge 0 \text{ and } t\le \text{A} \\ \sum\limits_{k=S(t-1)-S(t)}^{\infty} (S(t)-S(t-1)+k)P(j=k) & \text{if } \min\{\text{E[X1],E[X2]}\}=\text{E[X1] and } S(t)-S(t-1)<0 \text{ and } t\le \text{A} \\ 0 & \text{otherwise} \end{cases}$$

where $j=D(t-1)$

Appendix 7

ARIMA Model for Forecasting the demand and return of the next period*(Introduction to Arima, http://www.duke.edu/~rnau/411arim.htm):

ARIMA(p,q): ARIMA models are, in theory, the most general class of models for forecasting a time series which can be stationarized by transformations such as differencing and logging.

A nonseasonal ARIMA model is classified as an "ARIMA(p, q)" model, where:

- **p** is the number of autoregressive terms, and
- **q** is the number of lagged forecast errors in the prediction equation.

The notation ARMA(*p*, *q*) refers to the model with *p* autoregressive terms and *q* moving average terms. This model contains the AR(*p*) and MA(*q*) models with the following equation:

$$\hat{Y}(t) = c + e(t) + \sum_{i=1}^{p} \alpha_i Y(t-i) + \sum_{i=1}^{p} \theta_i e(t-i)$$

where :

$\hat{Y}(t)$: the forecasted value for demand/return at period t

$Y(t)$: the demand/return value at period t

c: constant for the linear equation

α_i : weight parameter for each of the demand/return value in the regression

$e(t)$: the error term in the model

θ_i : parameters for the error term

Spreadsheet implementation: ARIMA models such as those described above are easy to implement on a spreadsheet. The prediction equation is simply a linear equation that refers to past values of original time series and past values of the errors. Thus, you can set up an ARIMA forecasting spreadsheet by storing the data in column A, the forecasting formula in column B, and the errors (data minus forecasts) in column C. The forecasting formula in a typical cell in column B would simply be a linear expression referring to values in preceding rows of columns A and C, multiplied by the appropriate AR or MA coefficients stored in cells elsewhere on the spreadsheet.

Regression for Forecasting the demand and return(Regression with Microsoft Excel",2009)

The standard forecasting models can only estimate the next period. However, for optimization next 12 periods demand and return rates are needed. The needed demand and return values can be obtained through regression. The regression equation is as follows:

$$\hat{Y}(t) = c + \sum_{i=1}^{12} \alpha_i Y(t-i)$$

$where$:

$\hat{Y}(t)$: the forecasted value for demand/return at period t

$Y(t)$: the demand/return value at period t

c: constant for the linear equation

α_i : weight parameter for each of the demand/return value in the regression

The following procedure is applied:

1. First, write the historical monthly demand or return rates after the demand starts to decline as show in below. With the help of an experience, delete the radical data points.

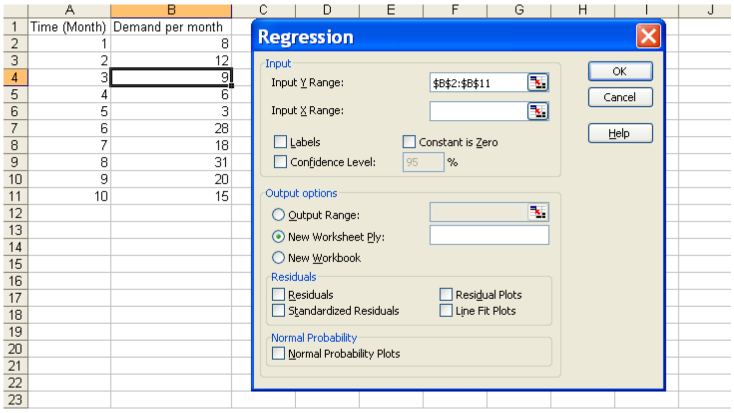
	A	B	C
1	Time (Month)	Demand per month	
2	12	31	
3	9	20	
4	13	20	
5	14	21	
6	15	11	
7			

2. To do regression in Excel, you need the Analysis Toolpak add-in to be installed in Excel. This was an option when you installed Excel, but you might not have selected it. If you didn't install it, Excel will ask you for the CD, when you try to add the toolpak.

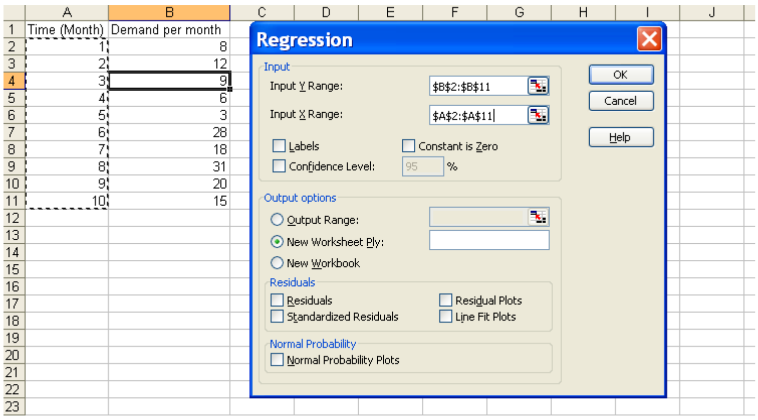
Check that the add-in is installed, and added-in, by choosing Add-ins from the tools menu. Then ensure that "Analysis ToolPak" is selected.

3. You can now use the data analysis functions in Excel, which include regression. To get to the data analysis function in Excel, you select the **Tools** menu, and then choose **Data Analysis**. This gives the following Dialog, click on **Regression** and then click OK.

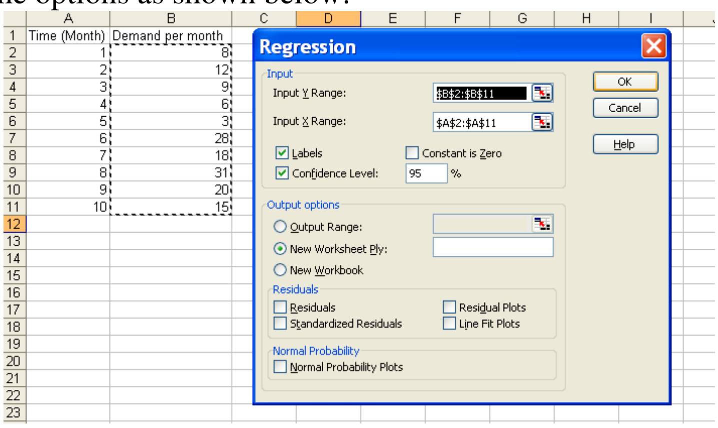
4. Then select the demand or return rates in Input Y Range as shown below:



5. Then select the time in Input X Range as shown below:



6. Now, select the options as shown below:



7. The results are as follows:

	A	B	C	D	E	F	G	H	I	J
1	SUMMARY OUTPUT									
2										
3	*Regression Statistics*									
4	Multiple R	0.979816								
5	R Square	0.96004								
6	Adjusted R Square	0.94006								
7	Standard Error	1.172018								
8	Observations	4								
9										
10	ANOVA									
11		*df*	*SS*	*MS*	*F*	*Significance F*				
12	Regression	1	66.00274725	66.00275	48.05	0.020183711				
13	Residual	2	2.747252747	1.373626						
14	Total	3	68.75							
15										
16		*Coefficients*	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*	
17	Intercept	29.6747	4.035750754	10.26539	0.009357	24.06413743	58.79301	24.06413743	58.79301	
18	12	-0.91566	0.245721756	-6.93181	0.020184	-2.760552086	-0.64604	-2.760552086	-0.64604	
19										

The significance level and p_values should be less than 1-confidence interval. If it is so, the equation is 29-0.91566t. So that following months can be computed. As the demand or return data becomes known, the forecast should be updated.

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Subject headings: Return acceptance, a periodic review order-up-to level control system, spare parts