Inventory management of the Technical Warehouse

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Preface

Dear reader, in front of you lays the research report of my Master thesis. My name is Freek van Eijndhoven, and I have done the final stage of my study Industrial Engineering & Management at Unilever Sourcing Unit Oss. In the last half year my world was the world of soups, sauces, and sausages, products I had seen a lot in my seven years as student.

Before the subject of this thesis was known, I have already asked Leo van der Wegen as my first supervisor from the University of Twente. My experiences with Leo were that he is patient with students, can clearly explain subjects, and is organized in his work. These aspects made me chose him as my first supervisor, and I am very thankful for the support of Leo in the last years and especially the last half year.

My second advisor was chosen based on the subject of the research and is the expert on spare parts in Twente. The suggestions and comments of Matthieu van der Heijden were very useful and I am thankful for his criticism on my report.

The enthusiasm and opportunities given by Theo Dopheide, Technical & Implementation Manager, drew me to Unilever SU Oss and he became my third supervisor in Oss. The discussions with Theo were always positive and focussed on the strategic ideas for the technical warehouse and were very helpful.

Next, the ‘no nonsense’ discussions with Grad van Schijndel were very beneficial to my research. Grad pulls no punches and says what is on his mind, and I really liked that approach. Together with him, I discussed the current situation at the technical warehouse and the possibilities for the future. I hope Grad will get the opportunity to implement our recommendations and that he will improve the technical warehouse.

The last of my supervisors at Unilever SU Oss is Joost van Rossum, who was my first supervisor. With Joost I had some good discussions about the structure of my report and about options to keep it short and concise. As my roommate, we have shared a variety of things, from frustrations about insurances to cups of coffee, and I am really thankful for everything he did for me.

Next to my five supervisors, this research could not have been successfully without the help of the technical warehouse administrators, the head of the technical department, so Maarten, Tonnie, and David, thanks a lot! Also, I want to thank the technical warehouse administrators of Unilever SU Rotterdam, Heineken Den Bosch, and Johma Losser, where I saw some great ideas for the technical warehouse of SU Oss.

Lastly, thanks to the help of Gerben van der Velde, Marjon Pol, and Sean Straatman, who critically read this report, this report got the form that lays before you.

The fixtures in this report are not real, because of confidentiality. The results are however equal to the results when using the real fixtures.

Freek van Eijndhoven, 21 September 2012

Management Summary

Unilever Sourcing Unit (SU) Oss, a 'Make' site with factories for sausages, soup and sauces has a technical warehouse (TW) where they store their spare parts. These spare parts are used to replace broken parts from the machines at the production lines. This TW is outdated at this moment, and the number of differences between stock and storages (DSS), where the number of spares in the warehouse does not correspond with the number of spares in the ERP system (SAP), is too high. Due to this, spares are not available when needed, so broken machine parts cannot be replaced and downtime at the production lines occurs.

Next to DSS, there are a lot of obsolete spares in the warehouse that are not used anymore or cannot be used anymore. Also, the traceability of spare parts is difficult and takes too much time from the 70 clients of the warehouse.

The purpose of this research is to investigate the current spare parts inventory system of SU Oss and to search for a method to optimize the warehouse, find a suitable policy to manage the warehouse and to reduce the number of DSS. To find possible solutions for the technical warehouse, the ideal situation is compared with the current situation.

The current situation is that the warehouse has one core problem, the lack of a clear organization and structure of the warehouse. This is the main cause of DSS, which cause downtime and frustration. To leave this downward spiral, the organization and structure have to be improved, and literature research on the organization and structure of technical warehouses is done to find methods to improve the organization and structure of a technical warehouse.

The uses of other documentation methods, other control and supervision methods, the use of TPM, and KPIs are some of the most important findings of the literature review. This review is used to create several alternatives for Unilever SU Oss, and is checked at other technical warehouses for feasibility. Unilever SU Rotterdam, Johma Losser and Heineken Den Bosch are visited and here is seen that the use of barcodes, TPM, and clean and organized warehouses result in less DSS and therefore a higher fill rate.

After the visits of other warehouse, the six alternatives are formed: Current Plus, Total Sup, Consignment, RFID, Barcodes, and Kanban. These alternatives are used for the analysis to find the ideal situation.

In the analysis for finding the optimal solution for SU Oss the two criteria of the main stakeholders, the operations department and the technical & innovation department are used. These criteria are the total value of all spares and the fill rate of the TW and these criteria are combined with the core problems and suggestions from literature and the following criteria are realized: total cost and the chance of DSS.

In the analysis, the six alternatives are analyzed. Using the input and output of the alternatives given by literature, costs, and stakeholder opinion, an ideal situation is given.

The results are shown in the following table:

	Current Plus	Total sup	Consignment	Barcodes	RFID	Kanban
Input (x 1.000 Euro's)	120	404	220	140	220	132.5
Output	0,094	0,204	0,058	0,199	0,299	0,146

The alternative that is recommended in this research is the use of barcodes and scanners for the documentation of spare parts. This alternative is a lot cheaper than the RFID alternative, which gives the best results, and gives the best output on chance of DSS of the rest.

Next to the use of scanners, the entire warehouse should be cleaned and organized. Selecting the not needed parts and throwing them away and sorting the spares that are left, combined with barcodes will result in an organized and structured warehouse with a low number of DSS.

Concluding, investing in barcodes for the warehouse, and cleaning and organizing the warehouse, will reduce the number of DSS that will occur. The cleaning and clearing action will result in a decline in total spare part value from 3.6 million to 3.1 million euro's and costs of downtime is prevented.

Samenvatting (Nederlands)

Unilever Sourcing Unit Oss, een fabriek waar soep, saus en worsten worden gemaakt heeft een technisch magazijn waar reserve onderdelen van machines van de productielijnen worden opgeslagen. Het magazijn is in de afgelopen decennia te weinig met zijn tijd meegegaan en daarnaast is het aantal misgrijpen is te hoog, wat zorgt voor vertragingen in de productie. Deze misgrijpen, hier DSS genoemd, zijn de verschillen tussen het aantal reserve onderdelen dat er volgens het ERP systeem (SAP) hoort te liggen en het aantal wat fysiek in het magazijn ligt. Hierdoor kunnen er geen reserve onderdelen gevonden worden voor kapotte onderdelen van machines, waardoor er stilstand van een productielijn kan ontstaan.

Daarnaast is het aantal reserve onderdelen wat opgeslagen ligt enorm toegenomen in de afgelopen jaren en liggen er reserve onderdelen die niet meer gebruikt (kunnen) worden. Deze niet gebruikte onderdelen zowel oude, versleten en onnodige spare parts.

Het doel van dit onderzoek is om het technisch magazijn te onderzoeken en een advies te geven over een methode om het magazijn te optimaliseren, voor goede regels om het magazijn te beheren en om het aantal misgrijpen te verminderen. Hiervoor wordt de huidige situatie onderzocht en vergeleken met de gewenste situatie.

In de huidige situatie beschrijving bleek dat het hoofdprobleem van het magazijn niet zozeer het aantal spares is of de lage service graad, maar het ontbreken van een correcte organisatie en structuur. Dit is de grootste oorzaak van misgrijpen en die veroorzaken stilstand en frustraties. Door deze frustraties kunnen er dan weer nieuwe misgrijpen ontstaan.Om deze neerwaartse spiraal te verlaten moeten de organisatie en structuur van het magazijn verbeterd worden en dit is gedaan aan de hand van literatuuronderzoek. In dit onderzoek zijn de mogelijkheden voor het verbeteren van de organiatie en structuur en de verbetering van discipline door onder andere nieuwe elektronische afboeksystemen onderzocht.

Naast het literatuuronderzoek zijn de technische magazijnen van Unilever SU Rotterdam, Heineken Den Bosch en Johma Losser bezocht. Hier is gekeken naar de methodes die zij gebruiken om het aantal misgrijpen tegen te gaan en naar de manieren om discipline te handhaven. TPM, Barcodes en KPIs zijn enkele van de meest voorkomende oplossingen bij de drie magazijnen.

Het literatuuronderzoek en de bezoeken aan andere magazijnen resulteerden in zes mogelijk alternatieven: de huidige situatie, totale supervisie, consignatie, barcodes, RFID, en Kanban. Deze alterantieven zijn meegenomen in de analyse.

In de analyse voor het bepalen van de gewenste situatie voor SU Oss zijn de twee criteria die door de belangrijkste stakeholders, de afdelingen operaties en techniek & implementatie, waren opgesteld gecombineerd met de resultaten uit het literatuuronderzoek en het hoofdprobleem. De service graad, het aantal spares en organisatie en structuur resulteerden in totale kosten en kans op misgrijpen.

In the analyse worden de zes alternatieven getoetst voor het bepalen van de ideale situatie. Hiervoor worden de input en output scores van de alternatieven bepaald, gebruik makend van literatuur, kosten en de meningen van de stakeholders.

In onderstaande table staan de scores van de zes alternatieven:

	Current Plus	**Total sup**	**Consignment**	**Barcodes**	**RFID**	**Kanban**
Input (x 1.000 Euro's)	120	404	220	140	220	132.5
Output	0,094	0,204	0,058	0,199	0,299	0,146

Het alternatief wat aanbevolen wordt in dit onderzoek is het gebruiken van barcodes en scanners voor het afboeken van de spares. Dit alternatief is een stuk goedkoper dan RFID, die wel de hoogste output heeft. Daarnaast heeft barcodes de hoogste output score van de betaalbare opties.

Naast het gebruik van barcodes en scanners zal het magazijn ook schoongemaakt en geordend moeten worden. Het selecteren van de spares die niet meer gebruikt (kunnen) worden en het sorteren van de spares op de juiste locaties gecombineerd met barcodes zal een georganiseerd en gestructureerd magazijn opleveren met een veel lagere kans op misgrijpen.

Concluderend, investeren in barcodes en methodes om de organisatie van- en de structuur in het magazijn te verhogen leveren een daling in de waarde van het totale aantal spares op van 500.000 euro en daarnaast zal het aantal misgrijpen drastisch afnemen, waardoor het magazijn een nog grotere toegevoegde waarde voor Unilever SU Oss zal worden.

List of acronyms

AHP = Analytic Hierarchy Process

AM = Autonomous Maintenance

AT = Available Time

CDSS = Critical Differences between Stock and System

CFO = Canned Food factory Oss

CM = Corrective Maintenance

DCF =Discounted Cash Flow

DPV = Discounted Present Value

DRP = Distribution Requirements Planning

DSS = Differences between Stock and System

EOQ = Economic Order Quantity

ERP = Enterprise Resource Planning

ET = Effective Time

FF = Frankfurter line

FIFO = First In, First Out

FTE = Full Time Employement

JIT = Just in time

KP1 = Keurpak 1 (vacuum packed and pasteurized smoked sausages production line 1)

KP2 = Keurpak 2 (vacuum packed and pasteurized smoked sausages production line 2)

KPI = Key Performance Indicator

MAUT = Multi-Attribute Utility Theory

M&B = Mixing and Blending

MC = Market Cluster

MCAP = Multi Criteria Analysis Procedures

MCDA = Multi Criteria Decision Analysis

MCO = Multi Country Organisation

METRIC = Multi-Echelon Technique for Recoverable Item Control

MRP = Material Requirement Planning

MT = Management Team

ND = Spare parts that are ordered manually by experience instead of automatically

OE = Operational Efficiency

OT = Operational Time

OU = Operational Utilisation

PAMCO = Plant and Machine Control

PE = Production Efficiency

PM = Preventive Maintenance

PT = Production Time

QLE = Quality, Labour and Environment

RFID = Radio Frequency Identification

RMI = Raw material income

SKU = Stock Keeping Unit

SMART = Simple Multi-Attribute Rating Technique

SPP = Spare Part Procedure

SPS = Smoked pork sausages

S/S = Soup and sauce

SSF = Soup and sauce factory

SU = Sourcing Unit

T&I = Technical & Implementation

TD = Technical Department

TPM = Total Productive Maintenance

TW = Technical Warehouse

USCC = Unilever Supply Chain Company

Z6 = Spare parts that are re-ordered by the MRP run, so automatically instead of manually.

Table of Contents

1. Introduction

In this chapter an introduction to the research is given, starting with the motivation of the research (§1.1), followed by an introduction to Unilever N.V. (§1.2) and to Sourcing Unit Oss, where the research has been conducted (§1.3). After the introductions the problem definition (§1.4), the goal of this research (§1.5) and the research questions (§1.6) are given. The chapter ends with the scope (§1.7) and the conclusion (§1.8), where the next steps of this research are shown.

1.1. Motivation

Unilever Sourcing Unit Oss, a factory where they make soup, sauces and sausages has a problem with their spare parts inventory. A spare part is "a replaceable component, sub assembly, and assembly identical to and interchangeable with the item it is intended to replace" (Business Dictionary, 2012). For Sourcing Unit (SU) Oss, spare parts are the parts that can replace the parts of machines at the production lines that are broken and the parts that are replaced during revision.

Over the last decades the number of spare parts in stock has risen to over 10 thousands different parts or stock keeping units (SKUs), which are stored in the technical warehouse (TW). In the technical warehouse, the spare parts of the machines of different production lines are stored.

According to the problem owners of this research, which are the Technical & Implementation Manager and the maintenance manager, the level of service of this technical warehouse is too low and the number of spare parts is too high. Advice on improving these two criteria is given at the end of this research, which starts with an introduction to Unilever N.V. and Sourcing Unit Oss.

1.2 Introduction to Unilever N.V.

Unilever N.V. is a Dutch-British multinational with activities on the markets of personal care, refreshment, food, and homecare products. These products are globally and sold under one of the circa 400 Unilever brands, but also on behalf of other companies.

The company is officially established in 1930, after a merger of the British soap producer "Lever Brothers" and the Dutch margarine producer "Margarine Union", which both use oil. As competitors for oil suppliers, merging gave them buying power, which resulted in "Unilever". In 2011 the results of this multinational were:

- Turnover of € 46.5 billion, which is 5% higher than in 2010
- Operating Profit of € 6.4 billion, which is 1% higher than in 2010
- Net profit of € 4.6 billion which is 1% higher than in 2010
- Advertising and promotions spent of € 6.2 billion (Unilever, 2012)

The activities of Unilever are geographically divided into eight market clusters (MC), which are divided into several Multi Country Organizations (MCO). The activities of Unilever Netherlands, and therefore also the activities of SU Oss, are part of the MCO "Unilever Benelux NL", which is a part of MC Europe.

The MCO “Unilever Benelux” consists of five Sourcing Units, four in the Netherlands and one in Belgium. The Dutch SUs are the margarine factory in Rotterdam, the ice-cream factory in Hellendoorn, the toothpaste factory in Amersfoort and the factory for meat products, soups and sauces in Oss.

Next to the geographical clusters and the division into categories, Unilever has a third allocation of the activities: a division structure. This structure is shown in Figure 1.

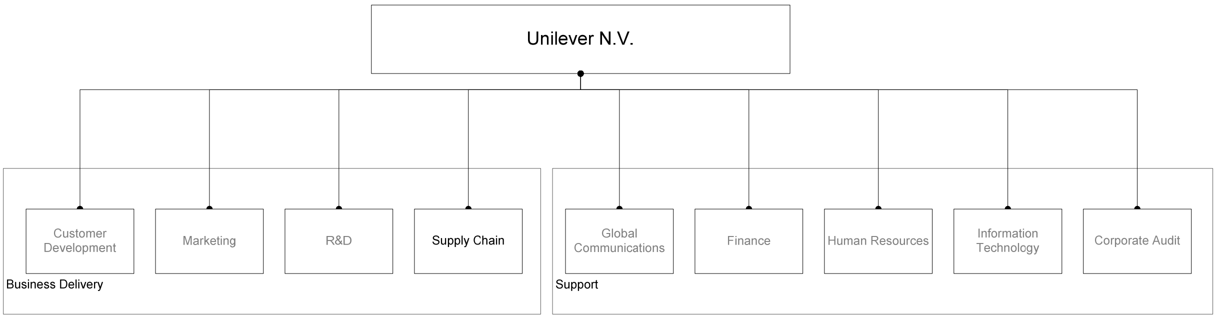


Figure 1: Dimensions of Unilever N.V. (source: Unilever)

The earlier described SUs are part of the Business Delivery division “Supply Chain”. This division has four main functions: Source, Make, Deliver and the overarching function Plan. The European supply chain activities of Unilever are coordinated by the highest organ in the supply chain called the Unilever Supply Chain Company (USCC). The USCC is a subsidiary of Unilever and is responsible for the (financial) performance of the European supply chain division.

It is essential for all the SU that the agreed capacity and cost price are realized. A higher production cannot be sold elsewhere and therefore cannot be used by the USCC. A lower production leads to a higher cost price per unit and difficulties for the deliveries to customers of the USCC.

Concluding, Unilever SU Oss is a ‘make’ factory from the supply chain division in the category savoury of food in the MCO Benelux, which is part of MC Europe. The MCO is the customer of SU Oss, while the USCC is the ‘boss’ of SU Oss. An introduction to Sourcing Unit Oss is given in the next section.

1.3. Introduction to Sourcing Unit Oss

If you would ask people outside of Oss where they know Oss from, they would respond with SP (the socialist political party which is originated in Oss), the knife fighters (In Dutch: messentrekkers), Organon, and the sausages of UNOX. The meat industry was and is one of the most important industries for Oss, as it provides thousands of jobs. This all started with two rival companies: Hartog and Zwanenberg.

Hartog Hartog was originally a merchant in cattle. In 1876 he started a butchery in Oss. He extended his activities with editing the fat for margarine and soap factories (fat is the main raw material of soap). In 1880, Zwanenberg exports pigs and cattle to England and later started a butchery next to the track in Oss.

UNOX

After several mergers, the competitors become part of the same company in 1970; a company go under the name Unilever Meat Group Netherlands. In 1957, canned soup entered the market for the first time. In 1991, the sauce factory is opened in Oss, and in 1997, the first Unox-hat appeared at the "Elfstedentocht". (Unilever Sourcing Unit Oss, 2012)

SU Oss in 2012

In 2012, the production volume of SU Oss has grown to 92.000 tons and the total plant area is 106.148 m^2. The number of employees declined over the years and at the moment there are 417 employees on payroll (Unilever Sourcing Unit Oss, 2012). On this site, there are three factories, one for soups, sauces and sausages. The soups and sauces factory (SSF) is combined and the sausages factory is called Canned Food factory Oss (CFO). Sauces and soups are made in their own production line and the CFO is divided into three production lines, one frankfurter line (FF) and two smoked pork sausages lines which are called 'Keurpak' lines (KP 1 and 2). Production volumes of SU Oss are shown in Table 1.

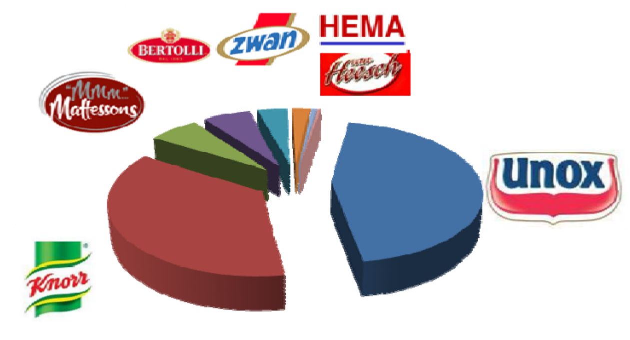
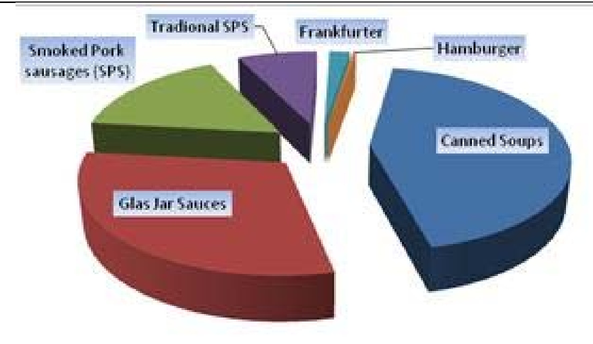
Volumes by brand	Volumes by production line
	

Table 1: Total volume of Unilever SU Oss by brand and production line (source: Unilever Sourcing Unit Oss (2012))

1.4. Problem definition

Because of the different production lines with different spare parts they have and had in the past, there are a lot of different spare parts in the technical warehouse of SU Oss. New innovations and technologies also causes a lot of different spare parts because of new machines, and this results in the technical warehouse there is today. At this moment, the number of spare parts of the different production lines has grown to over ten thousand different spare parts with an estimated value of over 3 million Euros.

Having a large number of spare parts is not a big problem on its own, as long as the service level of the warehouse is close to 100%. According to the technical warehouse administrators this is not the case, which is investigated in the next chapter. This means that some of the spares are not available when they are needed. Breakdowns of machines are already bad for production and waiting for spare parts when they are not available at the technical warehouse increases the impact of that problem.

Next to waiting for spares that are not available, there is a high number of differences in the number of items in the warehouse and the number of items that must be in the warehouse according to the IT system. This situation is called 'differences in system and stock (DSS)' in this research. DSS do not always lead to downtime immediately, because some differences can be caught before they become problematic. When DSS leads to downtime, it is called critical DSS or CDSS. According to all stakeholders, the main causes of DSS are incorrect document handling and lack of discipline.

Concluding, the problems faced for the technical warehouse are the high number of DSS, the low service level and a high number of spares.

1.5. Research goal

Based on the problem definition in Section 1.4, the goal of this research is defined.

The goal of the research is to give advice on the technical warehouse at Unilever Sourcing Unit Oss, so the amount of spares can be reduced and the service level can increase.

1.6. Research question(s)

To realize the goal of this research, several research questions are developed. The main research question of this research is:

What is the best possible spare parts system for the technical warehouse that can be implemented at Unilever Sourcing Unit Oss?

Here, a spare parts system includes all the policies that influence the performance of the technical warehouse, its order policies and its infrastructure. The spare parts system does not include the maintenance that is done, which results in a demand for spares.

Sub questions:

1. How are the spare parts in the technical warehouse currently managed?

Before any literature research can be started and recommendations can be given it is necessary to describe the current spare parts handling of the technical warehouse. This question is answered in Chapter 2, the current system or 'AS IS' situation.

2. Which alternatives are available in literature for managing spare parts in production companies?

Instead of changing the current system, it is interesting to describe some feasible spare parts inventory systems when you could start from scratch. A literature research will be conducted for the best spare parts inventory systems and this question is answered in Chapter 3.

3. Which alternatives are used by other production companies in the Netherlands and at other Unilever sites with comparable complexity?

After describing the spare parts inventory system, the comparison between the current system and other systems can be done by investigating how other production companies in the Netherlands / Europe control their spare parts inventories. This question is also answered in Chapter 3.

4. What is the best possible spare part system for the technical warehouse of Unilever SU Oss?

After the second and third sub question, some solutions are found. These solutions are made into alternatives for Unilever SU Oss and need to be compared. For the comparison, a method (MCDA) is used, criteria are needed, and the feasibility will be checked. After this analysis, a best solution or 'TO BE' situation is found. The criteria are given in Section 4.1, the MCDA method in Section 4.2, the analysis in Section 4.3, and the best alternative is given in Section 4.4.

5. How can the recommended system be implemented at SU Oss?

In Chapter 5, the implementation plan starting with the concluded solution is given. After the implementation plan, the conclusion is given in Section 6.1, followed by the recommendations in Section 6.2 and the discussion in Section 6.3.

1.7. Scope

As this research is performed in six months, it cannot include every aspect and solve all the problems. To make this a feasible research with not only general recommendations, the scope of this research is defined. This scope gives the inclusion and exclusion of subjects to make this research feasible within the given time. After the lists of included and excluded subjects, the explanation for these subjects is given.

Included in this research (based on current situation and feasibility)

- Consumable machine parts
- Maintenance is breakdown based
- Single-site model / Centralized warehouse
- The possibilities of consignation
- Use of electronic devices (Barcodes, RFID, etcetera)

Excluded in this research

- Repairable machine parts
- Preventive Maintenance
- Decentralized /Multi Echelon Warehouses
- Other ERP systems

Machine parts can be divided into two different types, consumables and repairables. The difference is that consumable machine parts are tossed away when they are broken and repairables can be repaired. According to the warehouse administrators, the mechanics, and the head of the Technical Department (TD), the number of repairable machine parts is very low (less than 5%). Because of this low number of repairables, all the spare parts at SU Oss are seen as consumables.

Using consumables instead of repairables is also because of the current type of maintenance at SU Oss. At this moment, the maintenance is breakdown based. The goal of SU Oss in the coming years is to change this to preventive maintenance, which is described in Chapter 2, but at the moment it remains breakdown based.

The location where the consumable spares are stored is a central technical warehouse, with the production lines of the sourcing unit within a five minute walk. Because of the relatively compact sourcing unit, the use of decentralized or multi echelon warehouses is not relevant, as it is not beneficial. The terms centralized, decentralized, multi echelon and single-site models are also explained in Chapter 2.

The current ERP system of SU Oss is SAP, and the documentation of the spares is done by SAP. This system works well according to the stakeholders, and should not be replaced. The possibilities to upgrade the use of SAP are investigated, as it can be beneficial and complementary.

Last point that is investigated is the possibility of consignation, or outsourcing the warehouse. After describing the current system of SU Oss in Chapter 2, this is the first section of Chapter 3, as the use of consignation could lead to a relocation of the current problems to the supplier.

1.8. Conclusion

As described in this chapter, this research will focus on the technical warehouse of Unilever SU Oss. This warehouse has over 10.000 different spares and a high number of differences between SAP and the actual stock, and those two points need to be investigated.

In this investigation, the AS IS or current situation is described in Chapter 2, in which the problems with the TW are 'established'. After the formulations of these problems, a couple of research points are defined, which are used in Chapter 3. Possibilities for technical warehouses and comparable companies are used to make several alternatives for SU Oss. These alternatives are made to establish the TO BE or ideal situation for the TW.

For this establishment a MCDA method will be used. The explanation of MCDA can be found in Section 4.2 and in the rest of that chapter, the analysis is done. At the end, after a successful analysis, the ideal situation is given and several recommendations are made.

Before this can happen, the current situation has to be described, which is done in the next chapter.

2. Current situation

In this chapter, the first research question is answered.

"How are the spare parts in the technical warehouse currently managed?"

The current situation at the technical warehouse of Unilever SU Oss is determined in four steps, starting with the current system in Section 2.1, followed by the current control and management (§2.2), the current performance (§2.3) and the current problems and bottlenecks (§2.4). After the current situation is sketched, a summary is given (§2.5).

2.1. Current system

Before the bottlenecks and problems within SU Oss can be found, the current system is described. This description consists of all actions that involve spare parts management in the TW and starts with an explanation of what a technical warehouse is, and what the characteristics of the TW in SU Oss are.

2.1.1. Characteristics of a TW: SU Oss

The technical warehouse is the location for stocking spare parts, as mentioned by the classical repairable problem of Sherbrooke (1968). The classical repairable problem is the military logistics problem of stocking repairable parts for aircrafts at bases which are capable of repairing some, but not all broken parts, and a central depot which serves all of the bases (Sherbooke, 1968). The main difference between the system of Sherbrooke and the situation of SU Oss is that repairing and stocking are separated at SU Oss. Repairing is done by the technical department (TD) and stocking is done at the TW.

Mechanics and production personnel can take spares from the warehouse when the corresponding machine parts do not function as requested. The TW of SU Oss is an open warehouse, where around 70 people (excl. third parties) can enter and is controlled by two warehouse administrators. The 70 people can all search for spares in SAP, the ERP system used at SU Oss, find the spare part and handle the documents. In the rest of this report, the 70 people are referred to as 'clients' of the TW.

Most of the spares are stored on one location, the TW, but there are some spares at the production lines, which makes the TW a centralized and a decentralized warehouse. At decentralized warehouses, or warehouses which use Multi-Echelon Techniques for Recoverable Item Control (METRIC) there are decentralized bases that are supplied by a depot, but as mentioned in Section 1.7, the warehouse is seen a centralized warehouse, as the bases at SU Oss are just spare parts at the production lines and the walking distances between the warehouse and the SSF and CFO are 15 minutes maximum, so supplying bases from a depot is unnecessary. Concluding, the TW of SU Oss can be seen as a centralized (or single-site) model, with 70 clients who can get spare parts when they are needed.

2.1.2. Machine breakdown and the role of the TW

The TW process is shown in Figure 2 and here explained step-by-step. This system shows the actors and actions which are involved in a breakdown of a machine and the role of the TW in this process.

The system starts when a machine breaks down (1). At that moment, the TD is called to check which part is broken (2). When the broken part is identified, the mechanic or the first operator of the machine checks in SAP if the spare part is on stock (3). If the item is on stock, the TD looks for the needed item on the location in the TW as indicated by SAP (4). In the best case scenario, the item is also physically in stock and the TD can put this new part in the machine (9), after documentation in SAP (8) and the machine works again (11). If the machine does not work after the installation of a new part (12), the TD is contacted again to find another broken part, which needs replacement.

When the spare part is not available according to SAP, the spare part must be checked for reparability (6). When this is not possible, the spare must be ordered by the technical planner of the production line of the broken machine (7). After repair of the spare or the delivery of a new one, the process continues at step 8.

There are still two processes left, the stage after documentation, and differences between stock and system (DSS). When SAP shows that there are still some parts on stock and the TD cannot find them in the TW, there is a critical DSS (CDSS). The TW administrator changes the inventory in SAP (5) and then the system resumes at step 6.

The last process that is described is the documentation (8) and the step after it (13). It is crucial for the correctness of the warehouse that all spares that leave the warehouse are documented, so DSS will not occur after a MRP run. MRP is a production planning and inventory control system used to manage manufacturing processes and tries to ensure that spares are available when needed.

When documentation is done properly, the Material Requirements Planning (MRP) system that runs overnight finds the inventory levels of all the spares that are below their reorder point. When this happens, the spare is documented on the order list, which is checked by the warehouse administrator and ordered, so the level of spares is correct again. Ordering the spare parts is described in Section 2.2.4.

2.1.3. Maintenance

Next to the normal break down process, the TW handles spare parts demand from maintenance. In literature, there are two well-known types of equipment maintenance; breakdown repair or corrective maintenance (CM) and preventive maintenance (PM). Breakdown repair is the practice of caring for equipment when it breaks and preventive maintenance is the practice of tending to equipment so it will not break down and operates according to requirements. It entails understanding and maintaining all the physical elements of manufacturing – machine components, equipment, and systems – so they consistently perform at their required levels. (Nicholas, 1998)

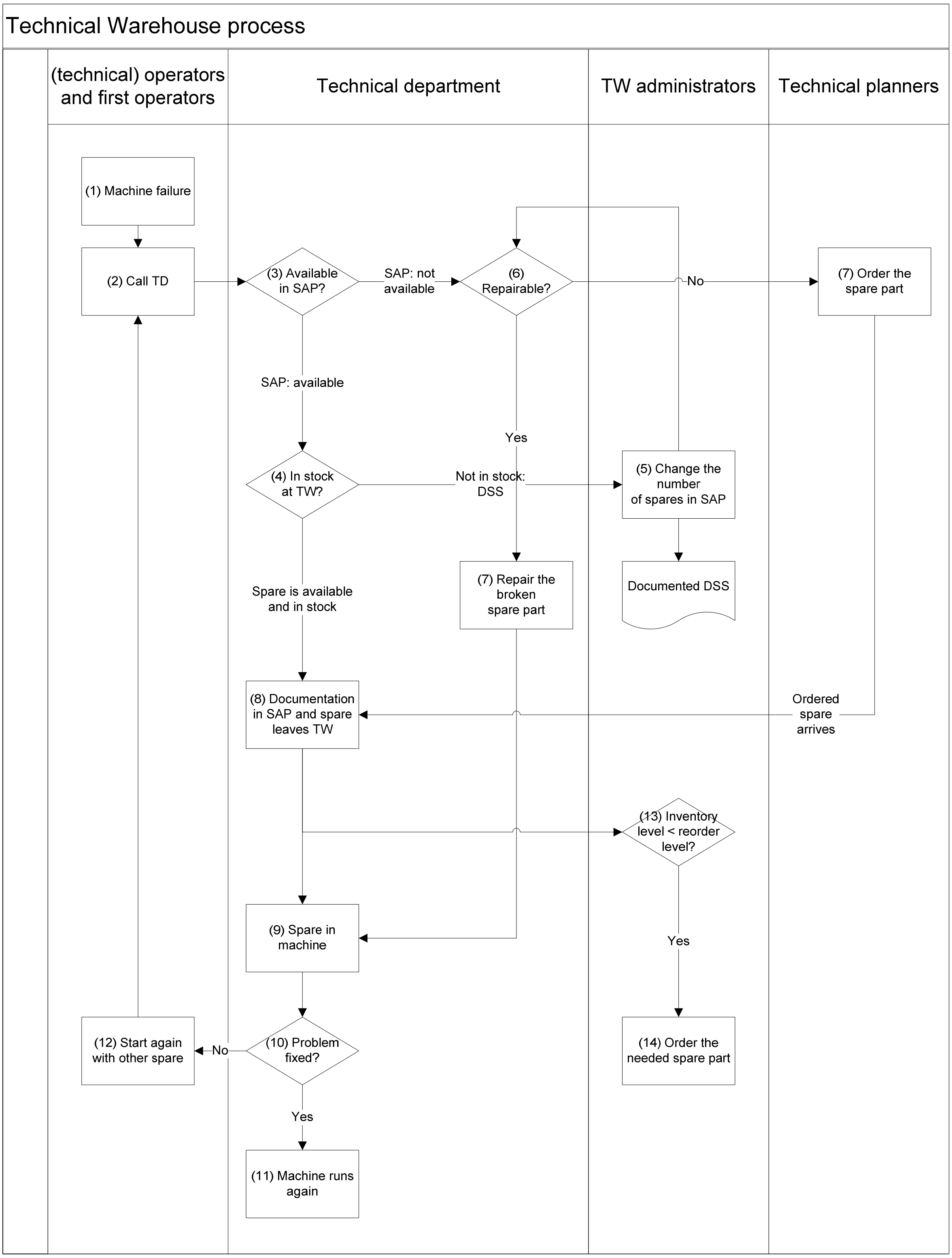


Figure 2: Current system for the technical warehouse of SU Oss, using a failure as starting point (source: Unilever Sourcing Unit Oss)

Doing maintenance following breakdown repair results in a lot of downtime, because if it is broken, it has to be fixed before the production line can continue. One method to make sure that downtime is minimized is preventive maintenance. In SU Oss they introduced autonomous maintenance (AM) at the factories as the first step to total preventive maintenance.

At the moment, once a week a shift (8 hours) of autonomous maintenance (AM) is done, which consists of cleaning, lubrication and inspection of the production lines. During this shift, there is no production. By inspecting the production lines, breakdowns can be prevented and it becomes clearer when a new spare is needed.

2.2. Current control/management

As is the case in any type of system, there needs to be a reliable control policy for the operation of a spare parts system. The choice of the control system depends on the complexity of the operating scenario, the number of items that need to be controlled, the number of locations where inventory may be housed, and the availability of timely information to support the inventory control policy (Frazelle, 2002).

The control over the TW is divided here into two types of control: personnel / stakeholders, and ordering methods. The stakeholders are responsible for the functioning of the TW and the ordering methods. First, the organizational charts are described so the locations of the TW and TD in the organization are clear.

2.2.1. Organization

In Figure 3 the composition of the management team (MT) of Unilever SU Oss is given. In this management team, led by the works director, there are six different departments, from which one is responsible for the production (Operations Manager). The managers of the six departments are together with the works director the MT of SU Oss.

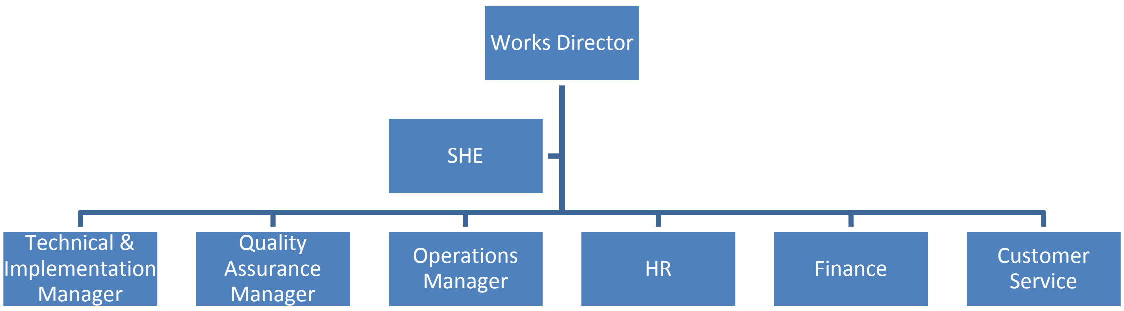


Figure 3: Organizational chart of SU Oss (source: Unilever Oss)

In Figure 4, the organizational chart of the operations part of SU Oss are given, which are managed by team leaders. SSF and CFO both have three team leaders. One of the team leaders of SSF is responsible for fabrication of the soup/sauce and two for filling, heating and packaging. At the CFO, there are two team leaders responsible for smoked pork sausages (SPS) and packaging, and one for mixing & blending (M&B), raw material income (RMI) and FIONA (traditional sausage). Next to these six team leaders with their own department, there is one site broad team leader, the head of the technical department (TD).

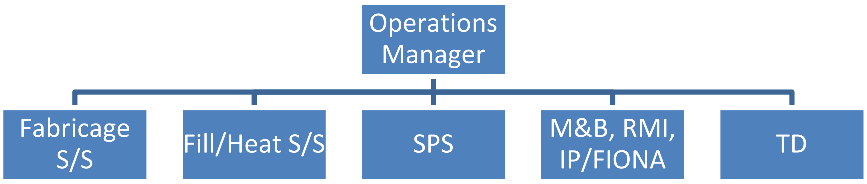


Figure 4: Organizational chart of Operations SU Oss (source: Unilever Oss)

The TW is part of the technical and implementation (T&I) manager's functions and not directly controlled by operations. As a 'Make' factory, production is leading for SU Oss, so the needs of the operations part of the factory are important for the TW. The difference between low costs (technical and implementation manager) and high service level (all operations parts) is the field of tension where the TW has to work with.

2.2.2. Personnel / Stakeholders

The 70 clients of the TW are divided into several stakeholders, which are described in a stakeholder analysis. In this analysis, it becomes clear who influences the warehouse and who the main stakeholders are. The two most influential actors in Figure 3 are the Technical & Implementation (T&I) Manager and the Operations Manager. The T&I manager is responsible for the TW and the Operations manager is responsible for the production lines, and is the boss of most of the stakeholders.

The Operations department consists of five production lines, which are influenced by the TW because of the availability of the needed spare parts. The **first operators** of the production lines, the **technical planners**, the **technical operators (Toppers)** and the **technical department personnel** are the persons who have access to the warehouse and are among others responsible for the correctness of SAP.

Toppers are responsible for the specific part of the production line they are stationed at. Some of the regular operators have received a technical training to become Toppers. They have more responsibilities and a little ownership of their specific part of the production line. Ideally, the part of the line is inspected continuously by the Topper and results in preventive maintenance and less breakdowns.

The technical department (TD) is the department that is responsible for the mechanics and repairing machines and its spare parts. As mentioned in Section 1.7, this research focuses on the consumable spares instead of repairable spares. Technical department personnel are the mechanics that are called when a machine breaks down. Their task is to fix production lines, so the production can continue, and to repair spare parts. Before repairing a spare part, it must be investigated if is technically possible and economically profitable.

The Technical & Implementation (T&I) department is responsible for the TW. The **maintenance manager** and the **warehouse administrators** are responsible for the daily management of the TW. The warehouse administrators are responsible for the control of the warehouse, and the warehouse is managed by the maintenance manager.

The Technical & Implementation Manager, who is the problem owner in this research, is as member of the MT already represented, but as problem owner gets his own part in the stakeholder analysis.

Other stakeholders that are interviewed in this research are the department heads, the finance department, and management team (MT), as they are important for SU Oss.

2.2.3. Stakeholder Analysis

Before the interviews and their results are shown, the stakeholders are analysed. Initial consideration of stakeholders is often done using a technique based on some kind of stakeholder grid or map of which many versions exist. In this research, the "Power versus Interest grid" of Mendelow (1981) is used, as both the power as the level of interest of the stakeholders shows which stakeholders are the most important to involve in this project and which stakeholders can influence the success of the conclusions and recommendations. The results of this method are shown in Table 2, and the elaborated analysis is shown in Appendix 1.

Next to Table 2, the stakeholders are shown in Figure 5. In this figure, the powers between the stakeholders are shown, so it is clear who is responsible and financially accountable.

High		Management Team (MT)			Operations Manager	T&I Manager
			Team leaders of the production lines			Maintenance manager
Power						
				Work preparer	Technical department personnel	TW administrators
Low		First operator				
		Topper				
		Low	**Level of Interest**			High

Table 2: Power versus Interest grid of the stakeholder analysis (source: Mendelow (1991))

The relations between the stakeholders are presented in a map in Figure 5. This map displays three different types of relations: hierarchical relations, representation relations, and control relations. In addition, the map displays different kind of actors, i.e. internal and external actors for the TW.

The internal actors are the actors that are daily or weekly visitors of the TW and influence the correctness of the warehouse. With correctness, the level of spares, the correct ordering methods, and part of the cleanliness is meant.

The external actors are the actors that do not influence the correctness of the warehouse. These actors are not directly responsible for the cleanliness, as they are just clients or are higher hierarchical levels.

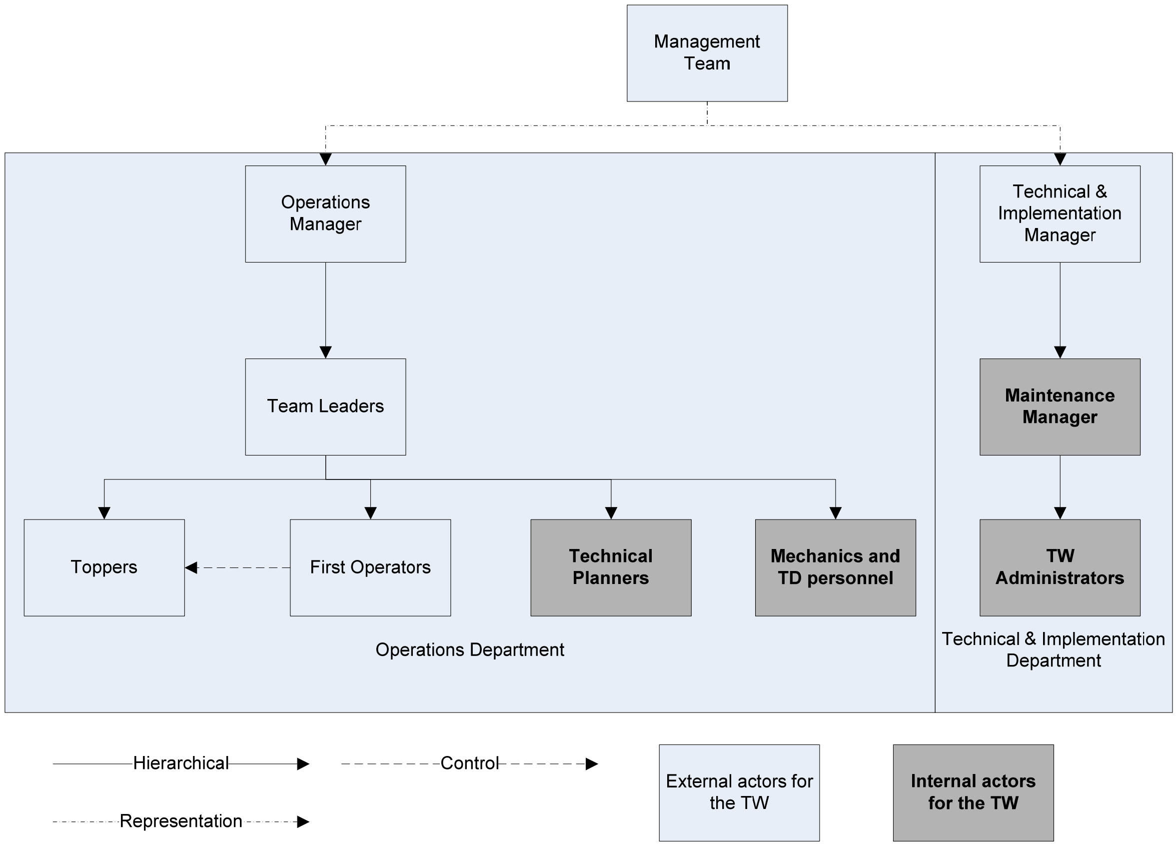


Figure 5: Network of stakeholders and their control (source: Unilever SU Oss)

2.2.4. Ordering methods

Next to the stakeholders and their influence on the technical warehouse, the current control can be described by the method of ordering spares at the technical warehouse. The procurement of spare parts in SU Oss consists of two different ways of ordering. One of the two methods is done automatically and uses a (r,q) model, while the other method is purely based on experience.

The first way in SU Oss is based on a continuous stochastic model, which Winston (2003) describes as (r,q). In a (r,q) system, r is the reorder point, which is triggered when the stock level drops below r, and at that moment, the reorder quantity q is ordered. In SAP, the r and q can be used, so the system automatically orders q, when r is reached. Because of this, no control over these types of orders is needed and it is ideal for low cost items and fast movers. These items are called “Z6”.

Fast movers are the spares that are used more than once per month and therefore easier to forecast. Next to the Z6 items, there are items called “ND”, which are all other spare parts. If a spare is a ND item, they are ordered by the experience of the warehouse administrators, technical planners and TD.

At SU Oss, the Z6 items have an r and a q. The r and q of all the cheap items are chosen based on the order time, experiences of the supplier and historical data.

2.3. Current problems/bottlenecks

After the stakeholder analysis, the stakeholders are interviewed to find the current problems of the TW. These problems are not based on fixtures yet; the performance of SU Oss on those problems is given in Section 2.4. At the end of this section, the interviews of the stakeholders and the resulting problems are shown in a problem tree. The entire list of results of the stakeholder interviews is given in Appendix 2.

2.3.1. Interviews of stakeholders

The ten stakeholder groups, as mentioned in Section 2.2, have been interviewed about their experiences with SU Oss and the technical warehouse. During these interviews the stakeholders were asked to suggest improvement possibilities for SU Oss and the warehouse. Corresponding to their position in the stakeholder map, the amount of time per interview varied. Stakeholders "Finance Department" and "MT" were interviewed once. The TW administrators, maintenance manager, T&I manager were interviewed more often and more extensively.

Instead of a fully developed package of questions, a list of interview subjects is used and several of the subjects are discussed with the stakeholders. This type of interview is called a semi-structured interview protocol. It is beneficial to have an interview guide prepared that can be asked in different ways for different participants (Lindlof & Taylor, 2002). The list of question topics can be found in Appendix 2.

The most important results of the interviews are given in this section, the rest can be found in Appendix 2. The results described next are problems that are given by 4 or more stakeholder and are grouped in the three interview subjects.

Performance of the technical warehouse:

- The number of spares is too high
- TW policies are outdated
- There is only supervision during the day and not in the afternoon and at night
- There is one central warehouse, but lots of spares on sub-locations next to the production line
- A lot of old spares are stored, which corresponding machines are already replaced
- Too many double entries in SAP

Document handling of spares and the use of SAP

- Lack of discipline results in DSS
- High number of responsible actors
- Document handling with SAP takes too much time
- No SAP available on all locations of warehouse, which results in paperwork

Financial impact

- Cost of DSS
- Not the correct purchasing policy and control, which results in high stock.

2.3.2. Problem Tree

The TW problems given by the stakeholder interviews are used for the problem tree given in this section. This tree is used to give a clear view of the problems and the causes of these problems. The starting points of the problem tree are “low service level” and “too many spares in TW”. The most important goal for the TW of the Operation Manager is a high service level and the most important goal for the Technical & Implementation Manager is to have low costs. All the points in the problem trees will be briefly introduced.

The first main problem is the service level, which is too low according to the problem owners. This is caused by the number of times that a spare is not in stock, the difficulty to find a spare part, and because improving the service level is sometimes considered to be too expensive. The number of times a spare is not in stock is mainly caused by DSS. According to all the stakeholders, it happens too often that SAP tells them that there are spares in stock, and that the inventory level is zero or at least lower than the number SAP shows. DSS are caused by not having the correct organization and structure.

The second problem is that spares are hard to find. Next to the warehouse, there are several storage locations next to the production line, and sometimes the spare is not on the correct location or not even labelled. This all decreases the traceability of the spares. This problem is caused by not having the correct organization and structure.

The third and last problems is that improving the service level is too expensive. For example, if the service level of a warehouse is 99%, it may be more expensive to improve it to 100% than improving from 50% to 51%. These figures are normally used in service level agreements when outsourcing, hence they are not applicable to the core problem at the TW.

Two of the three previous problems are caused by not having the correct organization and structure, which has six causes.

1. **Too many problems with documentation**; the problems with documentation are a lack of discipline, a lack of training, and difficult reporting procedure.
2. **TW is too widely spread**; The number of little storage locations next to the production lines without supervision and the different storage locations within the warehouse decrease the traceability of the spares and the supervision possibilities.
3. **Lack of supervision at night and afternoon**; the lack of supervision at night and in the afternoon, and the number of old and superfluous spares make it hard to find the spares. The warehouse administrators are busy with helping people with their spares and 24 hour control would decrease the number of DSS and improve the service level of the TW.
4. **Unorganized warehouse**; one of the main causes of having a hard time to find a spare is that the warehouse is unorganized or the cleanliness of the warehouse is too low. Too many spares in the TW have no label or are not on the correct location, which decreases the traceability of the spares.

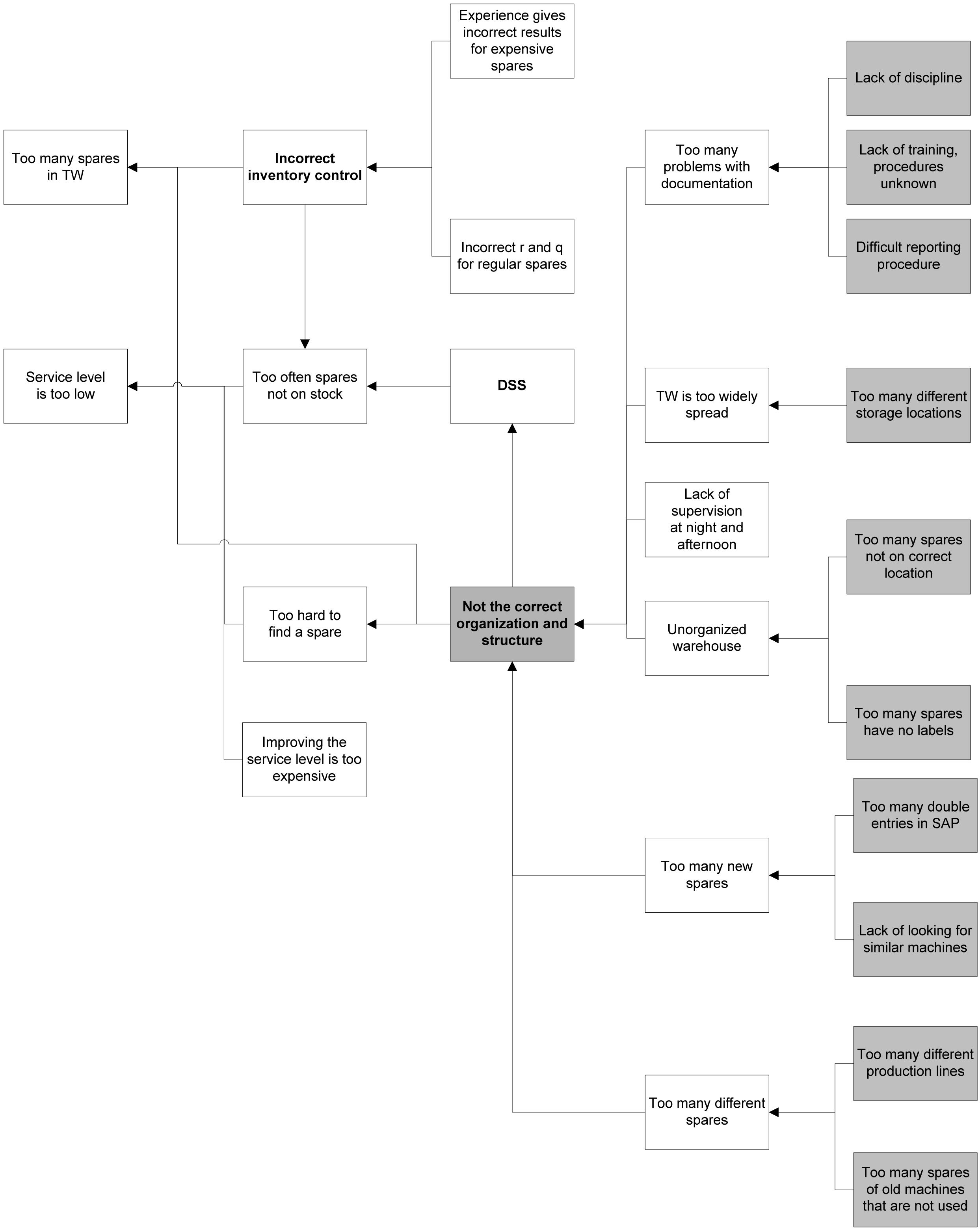


Figure 6: Problem tree with as starting point 'too many spares in TW' and 'service level is too low', and the core problem and the right hand side problems shown in grey boxes (source: Unilever SU Oss)

5. **Too many new spares**; purchasing of new machines, where in this process, the current machines are not used for this decision, results in a high number of new spares. Next to that, the number of double entries in SAP is too high, which means that some spares have two SAP codes, because they are added again after a new machine was bought.
6. **Too many different spares**; the last cause of not having to correct organization and structure is the amount of different spares, which is caused by the amount of production lines and machines at this moment, and old machine parts which spares are not removed from the TW. The number of lines will not decrease during this project, but old spares could be removed.

The second main problem according to the problem owners is that the number of spares in the TW is too high. The two main reasons for these problems are the incorrect purchasing policies, and not having the correct organization and structure.

The incorrect purchasing policies are caused by the current control. The current purchasing control, as mentioned in Section 2.2, is divided in regular spares handling and expensive spares handling. The replenishment of both types is not done correctly for all stock keeping units (SKUs) according to most stakeholders.

Conclusion of the problem tree

As can be seen in the problem tree, there is one core problem and one sub problem. The incorrect inventory control is a sub problem for the TW and is discussed briefly, but the main focus of this report is on the organization and structure of the warehouse, which is the core problem.

1. Organization and structure of the TW

Several of the points from the problem trees are influenced by the organization and/or structure of the TW. If people cannot find parts in the warehouse this is because of the fact that the warehouse is widely spread, but also because it is not well organized, and sometimes even a mess.

The control and supervision of the warehouse is also a part of this problem, as a lack of supervision could lead to DSS. Another factor for DSS is discipline, which is investigated at the first question, but the organization and structure of the warehouse can help with creating or maintaining discipline.

Old and deteriorated spares should be avoided by correct policies for purchasing spares, but also by making policies when a spare is old and tossing away the unneeded spares in a cleanup.

Cleaning up the warehouse will lead to a decrease in number of spares and therefore the holding cost, which are calculated in the next section. As mentioned by the warehouse administrators and the others who visit the warehouse regularly, the number of old spares is too high.

2. Incorrect inventory control

As mentioned before, the incorrect inventory control is discussed briefly. After the organization and structure is tackled and the solutions are implemented, the inventory control policies can be implemented. Therefore, the incorrect inventory control is not the core problem and the two causes are not used for the literature review and the alternatives in Chapter 3.

2.4. Current performance

In this section, the current performance of the technical warehouse and the production lines of SU Oss are described. The performance is measured with several key performance indicators (KPIs) that are given in Section 2.3: DSS, level of service of the TW, and TW related costs.

These three performance indicators are also used in Chapter 4, the analysis, where the possible solutions are measured on those points. The most important performance indicators, which are used for the conclusion and recommendations, are the level of service of the technical warehouse versus the costs of the systems. Before these performance indicators are checked by literature and in a stakeholder analysis, they are used to describe the current performance of Unilever SU Oss and its technical warehouse.

2.4.1. Critical and non critical differences between stock and system (CDSS and DSS)

Differences between the number of spares physically in stock and the number of spares in stock according to SAP are undesirable. The number of DSS and their value should be calculated to find out the impact of these situations. According to the warehouse administrators 20 to 25% of the document handling of spares is not properly done and lead to DSS. Incorrect document handling includes forgetting to document the spares that are taken out of the warehouse and incomplete handling by not filling in all parts of the document.

The number of critical DSS is hard to determine, because they are not documented by the warehouse. In this research, only the number of DSS is used, as they are documented in SAP. In Table 3, the number of DSS per quarter in 2010, 2011 and 2012 is shown. There is no pattern in the number of DSS in the last years, but it is clear that the number of DSS is a problem if compared with the total amount of spares that is taken from the warehouse, which were 10.000 in 2011. This means that in 2011, 14.6% of the items taken out of the warehouse were DSS.

	2010	**2011**	**2012**
1st Quarter	467	256	637
2nd Quarter	371	342	Unknown
3rd Quarter	314	706	Unknown
4th Quarter	965	156	Unknown
Total	**2117**	**1460**	**637**

Table 3: Number of DSS at SU Oss per quarter in 2010, 2011 and the first quartile of 2012 (source: Unilever Sirius S1P)

In Table 4, the value of the DSS is shown. The value of DSS is calculated by summing the prices of all spares which have DSS. The cost of DSS in 2012 is the amount of DSS between 1-1-2012 and 1-4-2012.

Year	Cost of DSS (in Euro)
2010	250.000
2011	200.000
2012	(January – March) 80.400

Table 4: Cost of DSS at SU Oss in 2010, 2011 and the first quartile of 2012 (source: Unilever Sirius S1P)

2.4.2. Level of service of the TW

The level of service of the technical warehouse can be specified by its service level. There are three service level definitions: S_1, S_2, and S_3 (Axsäter, 2006) (Silver et al., 1998).

- S_1 = probability of no stock out per order cycle,
- S_2 = "fill rate"- fraction of demand that can be satisfied immediately from stock on hand.
- S_3 = "ready rate"- fraction of time with positive stock on hand.

This thesis defines the service level of SU Oss as its fill rate, as it is important that the demand immediately can be satisfied by the spares on stock according to the stakeholders of 'Operations'. Possible actions that decrease the fill rate are DSS, out-of-stocks and wrongly placed items. The calculation of the fill rate for SU Oss is hard, as shortages are not documented. The shortages that are the most important for this research, the DSS, are known and therefore used for the service level of the TW of SU Oss. The formula of fill rate: $\left(1 - \frac{DSS\ per\ year}{Demand\ per\ year}\right) \times 100\%$

In Table 5, the fill rate of the TW in 2011 is given.

Number of DSS in 2011:	1.460
Items taken from the warehouse:	10.000
Level of service in 2011:	85.4%

Table 5: Fill rate of the TW in 2011 (source: Unilever Sirius S1P)

2.4.3. Costs of the technical warehouse

The costs of the technical warehouse are divided in the holding costs, the cost of control and the number of superfluous and old spares and their costs. This section starts with the value of the spares, as it influences the holding costs.

- **Value of the spare parts in the TW**

In Table 6, the amount of spares in the warehouse and the value of those spares are shown. The value of a spare part is equal to the purchased price and no depreciation is done. Total value of the stock is one of the most important criteria for this research. The T&I Manager and the maintenance manager both want this amount reduced.

Number of unique spares in stock	12.500
Total amount of spares in stock	207.000
Total value of spares in stock	€ 3.650.000

Table 6: Amount of spares in TW and the costs of those spares (source: Unilever Sirius S1P)

- **Holding costs of the TW**

The relevant costs that should be considered when determining optimal stock levels consists of holding costs and ordering costs according to Drury (2007). Holding costs are seen as a percentage of the total value of the spare parts and usually consists of the following:

1. Opportunity cost of investment in stocks
2. Incremental insurance costs
3. Incremental warehouse and storage costs
4. Incremental material handling costs
5. Costs of obsoletes and deterioration of stocks (Drury, 2007)

The percentage suggested by Lambert and Stock (1993) is between 12% and 34%, depending on the industry field. According to Winston (2003), the capital opportunity cost h_d is 20% of the value of inventory. Combining the 20% of Winston (2003) with 5% for insurance, warehouse, handling and obsolescence costs (Drury, 2007), results in a holding cost of 25%, which is used in this report. Concluding, the holding costs for the TW of SU Oss are 900.000 Euro per year.

- **Cost of control of the warehouse**

Cost of control of the warehouse is the costs of the TW personnel. The control of the warehouse is done by 2 warehouse administrators, who are at the warehouse between 07:30 and 16:00 hours. In these hours, the first operators, Toppers and TD can come with questions and problems, but after 16:00 hours and before 07:30 hours there is no real control over the warehouse.

According to the warehouse administrators and its clients, the number incorrectly documented spares is higher when the TW administrators are not around. The control of the warehouse is taken into account for the possible spare parts inventory systems and because around the clock control is than possible, it is good to take the costs of the warehouse administrators into account, which is 50.000 euro per FTE per year. Concluding, the cost of control of the warehouse is 100.000 Euros per year.

- **Superfluous and old spares**

The number of superfluous spares is calculated by adding four types of items:

- The portion of ND items, which are in the warehouse for over a year and have more than 1 spare on stock. The time limit of 1 year is chosen by the maintenance manager, so these spares are very slow movers.
- Not needed spares are the spares which belong to machine which are no longer used in SU Oss.
- Spares with a too high inventory level are the SKUs with an inventory level higher than the demand in a multiple of the lead time for ordering the spare.

For example, if the demand for a spare part is 10 per month and the lead time is 2 weeks (0,5 month) and the inventory level is 100 spares, than there is 100/10 – lead time = 10 – 0,5 – 9,5 months of inventory available, which is a waste of space and opportunity costs.

- The number of old spares is calculated by adding the number of spares that are in stock for over 3 years, so the items that haven't been used in 2010 and 2011. This number of years is chosen because of the change of ERP system in 2009, and therefore the information is not reliable in the years before 2010.

Concluding, the precise number of superfluous and old spares is unknown, but is estimated on at least 500.000 Euro. The cost for SU Oss per year is unclear, but it results in too many spares and possible DSS.

2.5. Summary of the chapter

In this chapter, the answer to the first research question was searched.

What is the current system for the inventory management of the spare parts warehouse?

The technical warehouse of Unilever SU Oss is a single-site model with a central warehouse and several sub-locations for spares that are not controlled by the warehouse. The number of unique spares in the warehouse is 12.500 and the total value of the inventory of the TW is 3.6 million Euros, which leads to a holding cost of about 900.000 Euro (excl. personnel). The total number of spares in the warehouse is over 200.000. The number of old and superfluous spares in unknown, but the estimated value of those spares is 500.000 Euro.

The core problem of the warehouse is not having the correct organization and structure, which leads to DSS and therefore decreases the service level.

A lack of discipline and a difficult reporting procedure is one of the causes of DSS, which is the biggest difficulty in the TW's operations. The inventory of the TW is too widely spread throughout the warehouse, which leads to difficulties in finding the spares for the clients. 70 clients can enter the warehouse and take spares, and after they take spares they are all responsible for the document handling of the spares. Because this is not done correctly by everyone, a lot of DSS occur. The number of DSS in 2011 is 1.460. This among other factors resulted in a fill rate of 84.5 %.

This could be because of a lack of supervision in two of the three shifts, as the warehouse is supervised by two TW administrators who are only at the TW during the day (07:30 hour – 16:00 hour). The rest of the day the TW is unsupervised.

In addition, the organization and structure of the warehouse lack clarity, which makes it hard to identify new and different spare parts.

Last, the **inventory control** of the SKUs is investigated. Incorrect inventory control could lead to high number of spares in the warehouse and a lot of superfluous spares. Alternatives for the organization and structure of the warehouse are investigated in Chapter 3.

3. Alternatives

In this chapter, the search for alternatives for the spare parts inventory system for Unilever SU Oss is described, which is based on the second and third research question.

2. *Which systems are available in literature for managing spare parts in production companies?*
3. *Which systems are used by other production companies in the Netherlands and at other Unilever sites with comparable complexity?*

The search for the solutions is done in two ways; answering the second research question by doing a literature research (§3.1) and answering the third research question by visiting similar companies and investigating their technical warehouse policies (§3.2).

After both researches are done, an overview of the alternatives is made (§3.3), which are used for the analysis in Chapter 4. The answers to the two research questions that are investigated in this chapter are given in Section 3.4, which is the conclusion of this chapter.

3.1. Literature research

In this section, the literature research is done, which answers the second research question: *Which systems are available in literature for managing spare parts in production companies?*

The literature review follows an explicit and systematic methodology, starting with the used databases or journals, than the search terms, followed by the selection and prioritization of criteria. The total review is shown in Appendix 3. The literature review is divided in three subjects, the problems of Section 2.3: discipline and documentation, organization and structure of the TW, and inventory control.

3.1.1. Discipline and documentation

Two reasons of DSS are discussed in this section: problems with documentation and problems with discipline. The third reason according to the problem tree "too many spares have no label" is discussed in Section 3.1.2.

The problems of SU Oss with DSS are some of the most common problems with documentation according to Kelly (2006). He describes five major problems. Several of those problems can be used to describe the problems of SU Oss and are used in this section. DSS occur because somebody takes parts out without booking, which can be because of the lack of a warehouse administrator overnight or the open stores policy. Booking spares can be made easier with the use bar-code readings or RFID (Kelly, 2006).

The second group of problems is because of the use of an ERP system. According to an extensive research by Deloitte (1999), the main reasons for unsuccessful use of an ERP system are:

- Lack of Discipline
- Lack of Change Management
- Inadequate Training
- Poor Reporting Procedures (Deloitte, 1999)

These four problems are the main problems with DSS in SU Oss and are investigated in this section. At the end of this section there is a conclusion of the methods and/or ideas that can be used for Unilever SU Oss.

3.1.1.1. Discipline

The main reason for DSS is the lack of discipline to handle the booking of a spare correctly. Lack of discipline and other change management issues are the largest barriers to successful 'second wave' implementation of ERP, like supply chain management and inventories. 'Second wave' is the process of achieving additional benefits from an ERP implementation (Hawking et al., 2004).

Motivation is one of the indicators of discipline, as a motivated worker has more chance to do a disciplined job. Worker motivation can be divided in the three categories of Frederick W. Taylor (1911):

1. The "carrot". System in which workers would get paid a lower basis rate and through rewards could get a higher reward for their work.
2. The "stick". Punishment for not doing the job properly. This can result in discharging or fines.
3. Factory ethos. Factory ethos is the 'us' feeling that workers and management can have.

The incentives for work are strategic actions of a company. Decisions on an incentives policy have to be made by management and the height of those incentives is not discussed in this research.

Another way to create discipline in the technical warehouse is by using one of the philosophies that is used in the rest of the sourcing unit: 5S, which is the fundament of TPM (Sugimori et al., 1977). The English expression for 5S is CAN DO, of cleanliness, arrangement, neatness, discipline, and order (Willmott & McCarthy, 2001). The idea of discipline is here "to pass on that discipline and order to your colleagues so that we *all* strive for a dust-free and dirt-free plant" (Willmott & McCarthy, 2001). An explanation of TPM, 5S and the use of discipline is given in Section 3.1.3.

Concluding, using incentives and TPM can decrease the discipline 'problems' at SU Oss.

3.1.1.2. Training and communication

Effective communication is a major issue throughout the plant according to Umble (2003). In the implementation of Baan, an ERP system that he describes, most employees felt that the Baan system has great potential, but many found it necessary, or convenient, to go around the system. This caused a "domino effect" of poor information flows throughout the entire company.

Additional training is commonly identified as a significant need across the organization. According to Bingi et al. (1999) additional training is one of the important success factors of implementation, but the lack of change management is nearly an equal problem. The report of Deloitte (1999) also acknowledges this problem, that implementation cannot be done on a Big Bang way, but has to be implemented in steps (Deloitte, 1999) (Bingi et al., 1999).

Another common complaint at Baan was that the process of finding needed information was too time consuming. As a result, many users had developed numerous effective, but often inefficient, “workarounds” for problems they encountered. Another common complaint was “the system will not do that” which usually translates to “I do not know how to do that within the system” (Umble, 2003).

Concluding, training has to be done after the implementation and not only during the implementation of a new system. For Unilever SU Oss, workarounds are also done according to the maintenance manager and the TW administrators, where the training for the use of SAP occurs only at the beginning of the use of SAP for every user. Showing regularly how it is done and other trainings can be of added value.

3.1.1.3. Reporting Procedures - Automatic Identification Technologies

Documentation of spares has to be done to know that a spare is taken from the warehouse and to know who has taken it. This is particularly important for the budgets of the team leaders, also because all DSS are divided amongst them. The current reporting procedure can very easily be affected by a lack of discipline, as it is a task that is not part of the basic activities. Other ways to handle the documentation of spares are discussed in this section, bar codes and RFID. Kanban is another method, but is discussed in Section 3.1.2 under “Push vs. Pull”.

Bar Codes

A bar code system includes a bar code *symbology* to represent a series of alphanumeric characters, bar code *readers* to interpret the bar code symbology, and bar code *printers* to reliably and accurately print bar codes on labels, cartons, and/or picking/shipping documents (Frazelle, 2002). When a barcode system is implemented, barcodes are put on the containers of the spares or their place on the shelf. When a client needs a spare, he takes a barcode scanner and scans the barcode on the shelf. On this way, the documentation becomes a lot quicker than the current procedure, which will result in a decline of DSS.

Radio Frequency Identification (RFID)

Radio frequency tags encode data on a chip encased in a tag. When a tag is within range of a special antenna, the chip is decoded and read by a tag reader. Many types of RFID exist, but at the highest level, RFID devices can be divided into two classes: *active* and *passive*. Active tags require a power source—they’re either connected to a powered infrastructure or use energy stored in an integrated battery. Passive RFID is of interest because the tags don’t require batteries or maintenance. The tags also have an indefinite operational life and are small enough to fit into a practical adhesive label (Want, 2006).

Next to the advantages of RFID, there are three main issues that are holding back RFID’s widespread adoption, of which the first is cost. Most companies that sell RFID tags do not quote prices because pricing is based on volume, whether the tag is active or passive and much more. Generally speaking, active tags are $25 and up. A passive chip costs from 7 to 15 U.S. Dollar cents. If the tag is embedded in a thermal transfer label on which companies can print a bar code, the price rises to 15 cents and up. Low- and high-frequency tags tend to cost a little more (RFID Journal, 2012). The others disadvantages are design and acceptance, where acceptance is a privacy issue (Want, 2006).

Concluding, RFID and bar codes are both interesting methods to decrease the chance for DSS. The differences between the systems are the costs and discipline. RFID is the more expensive option of the two, but does not require any discipline as it automatically scans every spare part. Bar codes and scanners are a bit cheaper, as the tags are easy printable, but still require some discipline to scan every spare part.

3.1.1.4. Conclusion of DSS for Unilever SU Oss

At this moment, there are no incentives for good or bad behaviour. Using incentives could be promising according to all stakeholders, so this can be used for one or more of the alternatives in the analysis.

Training and communication is also something that can be beneficial for Unilever SU Oss, as some of the clients have problems with the reporting procedures. Several options for reporting procedures are the use of barcode scanners, RFID, Kanban, or just more training.

The use of an electronic reporting procedure could be very beneficial for SU Oss, but the high cost should be analyzed and compared with the increased output, so the decrease of DSS.

Concluding, the use of barcodes, RFID, and Kanban are used for the alternatives that are given at Section 3.3. The use of training and communication is used for all the alternatives and the use of incentives is also included in the formation of alternatives.

3.1.2. Organization and structure of the TW

The problems with the current organization and structure of the technical warehouse can be divided into several parts, which influence the traceability, maintainability and control over spares. Low traceability is when the clients find difficulties in finding a part in the TW because of poor part descriptions. This can be overcome by using colloquial names linked to standard description (Kelly, 2006). According to the warehouse administrators and the trade-force (Toppers, first operators and mechanics) the descriptions of the spares in SAP are not clear, which resulted in longer searching times.

According to all stakeholders, there is overlap between the organization and structure, and discipline. In an organized and structured warehouse, the chance of DSS decreases.

At the end of this section there is a conclusion of the methods and/or ideas that can be used for Unilever SU Oss.

3.1.2.1. Cycle counting

As a check on records, some physical counting of SKUs actually in stock has always been deemed necessary according to Silver et al. (1998). But physical counting has proven to be time-consuming and expensive. A more efficient method of physical stock counting is known as *cycle counting*. In cycle counting, a physical inventory of each particular item is taken once during each of its replenishment cycles. There are several different versions of cycle counting, but the most efficient is counting when the replenishment arrives. The main advantage is that the warehouse administrator is already at that location, so no extra trips are needed (Silver et al., 1998).

Concluded, cycle counting has to be included in the main jobs of the warehouse administrators. A total physical count of the entire warehouse can be done once or twice per year for baseline measurement, but daily counting keeps the warehouse better up-to-date and DSS can be detected before they become critical DSS.

3.1.2.2. Deterioration / old parts

One of the problems Kelly (2006) shows in his book is deterioration. Products and spares deteriorate and become useless for the production, but the extra problem is that they are still in the warehouse. If a spare deteriorates, the production line is removed or a better spare has become available on the market and the old spare has to be removed from the warehouse.

Deterioration should be documented by storing the spares on a first-in-first-out (FIFO) base and to add expiration dates on the spares. This would decrease the number of stock outs because of deteriorated spares and therefore decreases downtime.

Old parts should be removed if they are not used for several years and are not vital to the organization. The number of years to use in this case is to be filled in personally and several options are discussed in the analysis (Roy & Guin, 1999) (Devnani et al., 2010).

3.1.2.3. Magpieing problem

The next problem is the "magpieing problem", which results in setting up of unofficial stores. The magpieing problem is the result of the negative image of the warehouse and the number of DSS. When someone of the trade-force enters the warehouse to find a certain spare, other spares are withdrawn to hold in their own 'unofficial stores'. Some of these spares are not booked and result in DSS, but withdrawing spares when they are not needed also influences the demand figures (Kelly, 2006).

The best way to prevent the rise of unofficial stores is to have a reliable warehouse. Another method is to control the unofficial stores and make them 'official' by having decentral storage locations. Having decentral warehouses has its advantages, but if the travel time decreases with less than 10 minutes, it is not beneficial and the amount of paperwork outweighs them.

Concluded, the magpieing problem will decline if the warehouse becomes more reliable.

3.1.2.4. Supervision / Control

One of the parts that is important for organization and structure, and also for DSS, is supervision and control. The supervision and control of the warehouse and its spares can be divided into two obvious parts: supervision and control. The supervision of the warehouse is displayed as the number of warehouse administrators that are present during working hours, which is 2 at the moment.

According to them and several other stakeholders, the number of DSS that are created during the presents of the warehouse administrators is lower than when they are not present, so total supervision could decrease the number of DSS. The problem with total supervision, 3 teams of administrators, is that it is expensive and does not solve the root of the problem, as clients are still responsible for the documentation.

The only possible solution is to make the four-wall inventory management only part of the administrator jobs. Four-wall inventory management is the management of inventory within the four walls of a warehouse or distribution centre, the picking, counting and booking of the spares (Frazelle, 2002).

In this solution, the control over the spares is done by the administrators. The control can be done by methods that are already described: RFID, barcode and scanners, Kanban systems, and cycle counting.

3.1.2.5. Total Productive Maintenance

One of the main problems of the organization and structure of the TW is the lack of discipline and the lack of cleanliness of the warehouse. At the moment, the TW is seen as an auxiliary function of the production lines and gets easily neglected. One of the possibilities to increase the cleanliness of the TW and the discipline is total productive maintenance (TPM).

TPM is a kind of physical check up and preventive medicine for equipment. Plant equipment life can be prolonged by preventing equipment failure beforehand (Chan et al, 2005). The ultimate goal regarding equipment and production is being free of breakdowns and defective production. Together, these activities are generally called ‘‘productive maintenance’’ (Nakajima, 1986).

Nakajima (1986) established five pillars for the application of TPM:

1. Adopt improvement activities designed to increase the overall equipment effectiveness by attacking the six losses.
2. Improve existing planned and predictive maintenance systems.
3. Establish a level of self-maintenance and cleaning carried out by highly trained operators.
4. Increase the skills and motivation of clients by individual and group development.
5. Initiate maintenance prevention techniques (early equipment management).

One of the first and crucial steps towards asset care comes from the application of 5S. Problems cannot be clearly seen when the work place is unorganized. Cleaning and organizing the workplace helps the team to uncover problems. Making problems visible is the first step of improvement.

Seiri (organization) is the practice of dividing needed and unneeded items and removing the unneeded ones. It also means integrating material flow with the best known operational methods. Unneeded items are defective products, not useful items, and not urgent objects.

Seiton (orderliness) means orderly storage, putting things in the right place. Those things can then easily be found, taken out and used again when they are needed. The locations of equipment, tooling and materials are clearly defined, displayed and maintained.

Seiso (cleaning) refers to cleaning the workplace regularly, to make work easier and to maintain a clean and safe workplace.

Seiketsu (cleanliness) means being aware of the need for maintaining a clean workplace, not just through cleaning programs but through ensuring that spillage of liquids and dropping of materials, packaging, etc. is avoided.

Shitsuke (discipline) means to formalize and practice the above items continuously each day as you work, to have the discipline to always work to these principles. The initial plant clear and clean process is described as follows:

Clear out

1. Zone the plant into clear geographical areas with clear management responsibility.
2. Carry out a first-cut physical run for items that can be immediately thrown away.
3. Carry out a second label and sticker run, which needs to be more structured and thoughtful.
4. Get a great many waste disposal containers are needed.
5. Paint clear walkways and clear markings on the floor for anything mobile. Correct racking, shadow boards, labelling and other visual storage aids form an important part of this stage.
6. Keep the workplace organization under a permanent microscope.

Clean Up

7. Do the obvious sweeping and vacuuming of the work area.
8. Inspect and clean every square centimetre of the equipment.
9. Identify the points of accelerated deterioration.
10. Get to the *root causes* of dust, dirt and scattering and *eliminate* those reasons. An dust-free plant will be achieved if- and only if- this step is achieved.
11. Revisit steps 1 to 10 and continuously improve. (Willmott & McCarthy, 2001)

Concluding, the use of TPM is done in several areas in Unilever SU Oss, both not yet in the technical warehouse, which would be relevant. A clean and clear TW is beneficial, the task of the 'clients' are easier and the lack of discipline reduces.

3.1.2.6. KPIs and visibility

When the equipment has been cleaned, the next phase of the TPM process is to draw attention to the right way of doing things by clear visual aids (Willmott & McCarthy, 2001). Some examples of visual marking to encourage ease of inspection, discipline, order and tidiness are as follows:

- Make walking paths with line indicators
- Indicate the maximum and minimum number of spares per container. If a 'client' sees that the spare level is below the minimum or above the maximum, he can report it.
- Indicate which spares are in a container by putting a photograph on the container.
- Display charts of the performance of the TW.
    - Total value of the spares in the TW.
    - Number of DSS per month.
    - Number of old spares, which haven't been used for 3 years.
- Make a location where unidentified spares can be stored for a short while.

Concluding, the use of KPIs is beneficial for the TW and will increase the discipline and attention for the TW and its performances.

3.1.2.7. Consignment

The next inventory control policy is consignment. Some of the most favourable terms imaginable are incorporated into consignment inventory programs in which payment for supplier inventory is not released until goods have been sold at the customer location (Frazelle, 2002). Under such contracts, items are sold at a retailer's but the supplier retains the full ownership of the inventory until purchased by consumers; the retailer pays the buyer what is used (Adida & Ratisoontorn, 2011).

The two consignment methods that are used most in practice are mentioned here. On the one hand, in Wang et al. (2004), a Stackelberg game model is proposed in which the retailer, acting as the leader, offers the supplier a consignment contract which specifies the supplier's revenue share as a percentage of the retailer's revenue for each unit sold (Wang et al., 2004).

On the other hand, in Ru and Wang (2010), the supplier is the leader and selects a fixed consignment price, specifying the amount of payment to the supplier for each unit sold at the retailer. The retailer acts as a follower and, based upon the consignment price selected (Ru & Wang, 2010).

Under a consignment contract, the following simple rules are used:

- The supplier guarantees the company the continuity of an available stock
- The stock is stored in the company's raw material depots
- The supplier is paid for the used materials according to their agreement.

Next to the rules and ideas of consignment, there are several downsides that should be mentioned. Consignment stock has the same problems with peaks in demand as other replenishment schemes, as it uses one of those policies, and therefore can lead to stock outs. The second downside is that consignment stock only functions well with normal- and fast-moving spares, as turnover is high enough to be interesting for several suppliers. The inexpensive and/or slow moving products are not financially interesting for possible consignment partners (Valentini & Zavanella, 2003). The last downside is the loss of control over the stocks in your warehouse and the fact that intervening is no longer possible.

For Unilever SU Oss, an extra problem with consignment arises, the number of different spares. In the technical warehouse of SU Oss, there are electronic parts, engines, tires, and nuts and bolts, which all have different suppliers.

3.1.2.8. Different spare part types

There is a difference between the different parts. This difference is not between electrical or mechanical spares, but in classifications of selective control policies. From the selective control point of view all the items in the store are classified in groups: ABC, FSN, and VED (Devnani et al., 2010).

ABC analysis is a method of classifying items according to their relative importance. The analysis classifies the items into three categories: the first 10-15% of the items account for approximately 70% of cumulative value (cost) (A items), 20-25% are B items that account for a further 20% of the cumulative value and the remaining 65-70% are C items, amounting for a mere 10% of the total value (Ernst & Cohen, 1990).

FSN (*Fast*, *Slow*, *and the Non-moving) grouping* is based on the movement of materials or their rates of consumption. An item is said to have made one move if it is picked from the warehouse once or more in a month. According to this rule if the material has made 12 moves in the last 24 months then it is a fast moving item or else it is slow moving. If the material has not moved at all in five years then it is treated as a non-moving item. Maximum attention is paid to the fast moving (Roy & Guin, 1999).

VED (vital, *essential and desirable) grouping* is based on the criticality of the item. Maximum control is exercised on the vital few than on the trivial many (Devnani et al., 2010).

Concluding**,** the use of different spare part types for storing, ordering can be very beneficial. Several different approaches per spare type are shown in Appendix 4.

3.1.2.9. Conclusion of organization and structure for Unilever SU Oss

The organization and structure of the TW of Unilever SU Oss should improve to make the warehouse better accessible and decreases the chance of DSS. The use of yearly counting, removing useless and old parts, showing KPIs, and the first steps of 5S should be used at SU Oss.

When these ideas are implemented at the TW, magpieing behaviour will decrease and the traceability of the spares will increase. Also maintaining the TW with regard to discipline will be easier, as the warehouse will be easier to control and maintain when it is organized.

The use of daily counting, total supervision, different spare part types and the rest of the possibilities of TPM are used in the alternatives in the analysis or in the recommendations. The possibility of consignment is also used for the analysis, as mentioned in the scope of this research.

An organized and structured TW results in less DSS and frustrations, so therefore some steps have to be taken in SU Oss.

3.2. Comparing companies

For the comparison between Unilever SU Oss and several other technical warehouses in real life, three technical warehouses are visited at other companies. The following companies are visited: Unilever SU Rotterdam, Heineken Den Bosch, and Johma Losser and were selected after answering these two sub questions:

1. What kind of company is Unilever Sourcing Unit Oss?
2. Which sectors are comparable with SU Oss?

The answers to those questions are given in Appendix 6, and in Appendix 7 the interview questions for visiting the other technical warehouses are given. Next, the three companies that are visited are briefly described, the situation of the TW as well as the type of company, and after that the literature methods are tested at those companies.

Johma

Johma Salades B.V. produces and markets spreadable salads in the Netherlands. The company was founded in 1968 and is based in Losser, the Netherlands. Johma Salades B.V. operates as a subsidiary of Johma Nederland B.V.

The technical warehouse of Johma is controlled by 1 person, who was responsible for the changes of the last years. The total value of the spares was around 1 million 10 years ago and is now reduced with 60%. The number of SKUs is 6.500 and all spares are labelled and barcodes are used for the document handling of the spares.

In the value of the spares, the values of the machines are excluded. All machines have each one spare on stock and the total value of all machine spares is around 100 thousands Euros.

Heineken

Heineken N.V. engages in brewing and selling beer. It offers beer, cider, soft drinks, and other beverages. The company provides its products through distributors and breweries under several brands. Heineken N.V. sells its products through a network of distributors, as well as through 140 breweries in approximately 71 countries worldwide. The company was founded in 1864 and is headquartered in Amsterdam, the Netherlands. Heineken N.V. is a subsidiary of Heineken Holding N.V.

The technical warehouse of Heineken is larger than those of Unilever SU Oss and Johma Losser, with 4.0 million Euros of spares and 13.000 different spares. There are three persons responsible for the technical warehouse, which is open only during the day, and is open for cardholders. When entering the warehouse, there are four barcodes scanners, which are used for the document handling of the spares.

The use of TPM and the KPIs of the warehouse are visible and shown clearly. The number of old spares, superfluous spares, DSS and service level are shown at the entrance of the warehouse and they use a Japanese garden for the unknown spares. In this garden, items are put on a designated location, where they stay for at most a month. After this month, the spares are removed from the warehouse.

Unilever SU Rotterdam

Unilever SU Rotterdam is the margarine factory of Unilever in Rotterdam, as mentioned in the introduction. Next to margarine, they make peanut butter.

The technical warehouse is in value and numbers a little smaller than the warehouse of Unilever SU Oss, which is mainly because of the renovation of the warehouse. With clearer documentation and photos of the spares on their locations, the spares are easier to find. Next to that, there are minimum and maximum values shown on the location, so DSS can be reported.

The documentation is done by the two warehouse administrators, who collect all the documents of spares taken from the warehouse, instead of all the clients. At certain moments in the day, the documents are processed in SAP, so the MRP system can run optimally overnight. This is a unique attribute of the warehouse of SU Rotterdam, where all ‘clients’ are responsible for the document handling in SU Oss, at Johma and at Heineken.

Comparison between the three visited warehouses with literature

	Unilever SU Rotterdam	**Heineken Den Bosch**	**Johma Losser**	**Unilever SU Oss**
Number of SKU	6.600	13.000	6.500	12.500
Value of spares	2.3 million	4.0 million	0.4 million	3.6 million
Number of FTE	2	3	1	2
Central/decentral	Central	Central	Central	Central
% DSS	5%	1%	1%	15%
Scanners/barcodes	No	Yes	Yes	No
Consignation	No	Some	No	No
Repair	Repair when repairing is cheaper than 40% of new price	Repair when the spare is more expensive than 500 euro	Repair when cheaper than buying	Value higher than 1.200 euro and repair is cheaper than buying
Daily counting	Yes	Yes	Samples	No
Total counting	Annually	Annually	Annually	No
Number of ‘clients’ of the warehouse	130	100-200	< 25	70
Number of ‘clients’ responsible for document handling	2	All the ‘clients’ are responsible	All the ‘clients’ are responsible	All the ‘clients’ are responsible
ABC, VED, or FSN	ABC	ABC	ABC	ABC

Conclusions of the comparison

The warehouses of Unilever SU Rotterdam and Heineken Den Bosch are comparable in size with SU Oss. The percentage of DSS in those warehouses is lower than in Oss, which can be because of better policies. One of these policies can be the number of times that spares are counted, which is never in Oss.

The use of scanners, which is done at Heineken and Johma, gives also good results, according to the persons there. Their DSS figures and experiences with these machines were also very positive. The problem with discipline remains, because it is still an extra action, but it is easier than document handling on paper or by an ERP system.

Using minimum stocks improves the number of DSS. If there is only 1 spare available, the chance of correct document handling is higher according to all three companies. Superfluous spares would increase the chance of DSS.

Having a clean and clear office for the technical warehouse administrators and a clean and clear warehouse increases the chance that it stays clean. The use of TPM can help and the Japanese garden of Heineken gives good results, but is expensive because of depreciation.

Concluding, the three warehouses score better on DSS than SU Oss, which can have several reasons. The use of barcodes, cycle counting, and TPM are already discussed in Section 3.1 and are used for the alternatives as they already provide good results at other warehouses. Also consignment is used for the alternatives, while the use of consignment was not done or a success at the other warehouse.

3.3. Alternatives for Unilever SU Oss

In this section, the alternatives for the TW of Unilever SU Oss are given. In the previous section, several methods are described, some of which are beneficial for the TW of SU Oss. Before showing the alternatives, the methods that are used for each alternative are given. These methods are always beneficial and are a good starting point for the implementation process.

3.3.1. First implementation steps

- First two S's of 5S
    - *Seiri (organization)*: remove the unneeded spares, deteriorated, not useful and not vital/essential spares
    - *Seiton (orderliness)*: order the spares, put them in the right place and label the spares
- Cycle counting: zero-count of the spares to get to know the real amount of spares in the TW.
- Use of KPIs: To create awareness and increase discipline, the KPIs of the TW must be displayed.

After a first shift of organizing and ordering the warehouse, 150.000 Euros worth of spares is thrown away after cleaning only 1 of the 5 production lines. Using it on all five can exceed the 500.000 Euros.

The next steps for the implementation steps are depending on the chosen alternative. The first 'alternative' is the current situation, which is already described in Chapter 2.

3.3.2. The six alternatives

Alternative 1: Current Plus

As mentioned in Chapter 2, the current situation involves a technical warehouse which is controlled by 2 warehouse administrators. The current number of different spares is 12.500 and the total value of those spares is 3.6 million Euros. The 1500 DSS every year result in a fill rate of 85%.

In this alternative, the first steps of the implementation plan have already been started, as mentioned before. Cleaning, organizing, the use of KPIs and annual counting all the spares are the steps that are done no matter which alternative is chosen.

Alternative 2: Total supervision

In this alternative, the warehouse is controlled by 2 technical warehouse administrators 24 hours a day and the spares are removed from the warehouse only by those 2 administrators. The number of DSS will drop to around 0, because discipline problems are lower for the TW administrators. The disadvantage of this alternative is the increased cost for supervision, as 8 FTE is needed.

The number of shifts per week becomes 20, as there are 3 shifts per day of the week, 3 on Saturday, and 2 shifts on every Sunday. At this moment, there are 2 FTE for 5 shifts per week, and if all 20 shifts per week are planned, than 20/5 = 4 teams of 2 FTE are needed, which results in the 8 FTE mentioned before.

Alternative 3: Consignment

In this alternative, there are two possibilities or sub-alternatives: a) total outsourcing and b) some consignment stocks. The number of suppliers to outsource the spares to is one of the important factors of these alternatives.

a) **Total outsourcing;** Total outsourcing is outsourcing all the spares to one single supplier. This supplier, preferably one of the largest suppliers, has to handle all the spares and maintain the stock levels. A service level should be agreed on beforehand, so the supplier can adjust the replenishment system.
b) **Some consignment;** Instead of total outsourcing, some consignment could also be done. The largest suppliers can be used to outsource all their spares to, this way the supplier knows all the spares and can start with the current replenishment system and adjust it to his wishes. In this alternative, several suppliers are used for outsourcing spares.

The alternative that is chosen for the analysis in this research is total outsourcing of all spares. The control remains at SU Oss and the 2 FTE that are now, so the warehouse administrators keep their job. The problem owners and the other stakeholders of SU Oss have no faith in partial consignment, because the warehouse becomes more complicated when that happens.

Alternative 4: Barcodes

With the use of barcodes and scanners, handling the documentation of the spares becomes easier, so fewer mistakes are made. Clients still need to have the discipline to use the barcode scanners, but it is easier and the explanations can be put on the wall, so less training is necessary. At Heineken and Johma this has resulted in a lower number of problems with discipline.

Alternative 5: RFID

The use of RFID takes care of the discipline problem. If a client walks out the warehouse, the system automatically decreases the inventory level of that spare, so DSS will not occur. The costs of the RFID system are higher than those of barcodes and scanners, and higher than in the current situation.

Alternative 6: Kanban

Next to the automatic identification technologies, the possibility of using Kanban cards is an alternative. This can be done as a back-up, as is done at Johma, at certain product types only, or for every part. At Johma, there is a Kanban card in every container, which is tossed in the 'order container' which is emptied every day.

3.3.3. First implementation steps for all alternatives

Next to the first implementation steps and the implementation steps that arise from the chosen alternatives, there are a couple of implementation steps that are taken to complete the implementation plan. These parts are briefly described here to make clear why they are not used in the analysis.

- Replenishment scheme

Using the correct replenishment scheme to reach optimal storage levels is beneficial to the TW of SU Oss, but it is not relevant at this moment. The lack of a good organization and structure of the TW and the number of DSS this results in, is more important at the moment. When the organization and structure of the TW are improved, the correct replenishment scheme can be applied. This is described in the implementation plan in Chapter 5.

- Use of incentives

The use of incentives can be beneficial for increasing the discipline of the clients of the TW of SU Oss, but is something that has to be implemented on the entire site for optimal implementation results. The use of incentives can have both positive as negative results, so has to be carefully implemented and this is discussed in the implementation plan in Chapter 5.

3.4. Conclusion

In this chapter, the answers to the second and third research question are given.

2. Which systems are available in literature for managing spare parts in production companies?

The literature research results in several options for improving the organization and structure of the technical warehouse and for declining the number of DSS. The use of incentives, using a carrot and/or stick, training and communication, barcodes, RFID, and Kanban are the solutions for discipline and documentation at the technical warehouse.

The solutions for the organization and structure are cycle counting, removing old spare parts, the magpieing problem, supervision, TPM, KPIs and visibility, SKU categories and consignment. All these solutions are used for the alternatives and for the list of questions of the company visits.

3. Which systems are used by other production companies in the Netherlands and at other Unilever sites with comparable complexity?

Next to the literature research, three other technical warehouses are visited in the Netherlands. Unilever SU Rotterdam, Heineken Den Bosch, and Johma Losser are the locations that are visited and interviewed for the use of systems, which are described in the literature.

The conclusion is that the other warehouses perform a lot better on the number of DSS and this can be because the use of barcodes and scanners, the use of less people responsible for the documentation, or the cleanliness of the warehouses. Usage of TPM and KPI boards give also good results for those warehouses.

Combining the answers of question two and three, results in six alternatives for managing the spare parts in technical warehouses: Current Plus, Total Sup, Consignment, RFID, Barcodes, and Kanban. The main differences between the systems are the documentation method and other methods that decrease the chance of DSS. These six alternatives are compared to find the ideal solution or the 'To Be' situation, which is done in Chapter 4.

4. Analysis

In this chapter, the alternatives given in Section 3.3 are used to determine the ideal situation for the TW of SU Oss. Before this ideal situation can be found, the fourth research question is answered.

4. What are the criteria that are needed for scoring the solutions?

The approach to answer this question is divided in four parts, the criteria needed for the analysis (§4.1), the method used for the analysis (§4.2), the scores of the analysis (§4.3), and the determination of the ideal situation (§4.4). At the end of this chapter, the conclusion is given in Section 4.5, in which the final answer to the fourth research question is given.

4.1. Criteria

In this section, the criteria for the analysis are given. To determine these criteria, the ten causes of "Organization and structure" of the problem tree of Section 2.3 are used, as well as the results from Chapter 3. The alternatives for the core problem, having not the optimal organization and structure for the TW, are scored on their input and output, which is used for grouping the criteria. The input criteria are the criteria which influence the cost of implementing an alternative at SU Oss and the output criteria are those that influence the chance of DSS, which is the result of the core problem.

4.1.1. Input: Costs

The costs of implementing an alternative can be divided in several cost factors, and can be summed at the end, so the total input needed when choosing an alternative is clear for decision making.

Six cost factors are investigated: holding costs, ordering costs, administrators FTE, purchasing costs, implementation costs, and costs of training and education. Two of these factors are not used in the analysis; which are holding costs and ordering costs. The holding costs of an alternative are influenced by the total value of the spares in the TW. For this research, it is not possible to find the exact value of the TW after implementing one of the alternatives. Expected values are also unclear, and all alternatives will decrease the total value mostly by the first implementation steps of Section 3.3, so no big differences are made by adding holding costs.

The other factor that is not included in the analysis is the ordering costs. Every day at least one truck arrives at the TW of SU Oss, so extra ordering and ordering in higher numbers, will not change the costs of making orders. This factor is therefore also excluded.

The four cost factors that are included are explained one-by-one and the corresponding values are shown after each section. In some of the factors, the costs will be zero, which does not mean that there are no costs. In such a case, there are no extra costs compared with the current situation.

In Section 4.4, the total costs of the alternatives and the output values of Section 4.3 are used for an efficient frontier. The graph used for this frontier shows the input versus the output for all the alternatives, and the best alternatives are used for the efficient frontier.

1. Costs of warehouse administrators

The cost of warehouse administrators is the number of warehouse administrators that are needed in the solution multiplied by the costs per administrator. As mentioned in Section 3.3.2, the number of warehouse administrators in the 'total sup' alternative is 8. The other alternatives use the 2 warehouse administrators that are currently available. At consignment, using 2 administrators is chosen instead of outsourcing the personnel. This is done because of the expertise of the current warehouse administrators and the extra costs outsourcing the warehouse administrators would result in. Their expertise is important for SU Oss because the high number of questions the administrators get every day. Therefore, the costs of warehouse administrators are 400.000 Euro for 'total sup' and 100.000 Euro for the other alternatives.

2. Purchasing cost factor

The purchasing cost factor is the factor by which the order cost for consignment increases. If the spares in the TW are outsourced, suppliers will ask for a price which is higher than the current price, because of their increased risk, and the lack of experience with a lot of spares. According to the Technical & Implementation manager, the maintenance manager and the TW administrators of SU Oss and the other warehouses, this factor will be around 10%. The total cost of ordering spares per year is on average 1.000.000 Euro. In Table 10, only the extra costs for purchasing are shown.

3. Annual cost and fixed implementation cost at the beginning

The alternatives have different implementation costs, which are divided in the yearly cost and the fixed cost at the beginning.

Fixed cost at the beginning

The fixed cost of implementation is the cost of the implementation at the start of the project. The fixed cost of Consignment and Current Plus are zero, as there is no need for an investment. For Kanban, barcodes, RFID, and total supervision, investments are needed. Kanban cards are not very expensive and with an estimated cost of 0,50 Euro per card, the cost at the beginning of the implementation would be 12.500 Euro. The number of SKU is 12.500 and 2 cards per SKU are needed for the use of Kanban.

Barcodes and RFID are more expensive, as both hardware and software are required for usage. According to Serac, a company which sells barcode scanners, the hardware costs of a scanner would be around 3.000 Euro and the software costs around 350 Euro per scanner (Serac, 2012). This price per scanner is comparable with the 6.000 Euro that Johma Losser paid for their two hand scanners and software.

The fixed costs at the beginning for RFID are harder to estimate, as there are multiple possibilities for RFID readers. The system that is used in this alternative is the use of RFID gates, which are gates that can be found at airports or libraries. According to RFID journal (2012), the cost of a RFID gate is around 21.500 Euro. The fixed software cost would be equal to the hardware cost (RFID Journal, 2012). According to the Galecia Group, the hardware cost is around 15.000 Euro and the software costs would be 25.000 Euro in total (Ayre, 2008). In this report, 100.000 Euro is used as the implementation costs for RFID.

The investments for the total supervision alternative are harder to estimate, as it requires a couple of walls to shield the warehouse, and a window where the required spare parts can be collected. The fixed and annual costs for this alternative are between 15 and 25 Euro per m2 according to several websites. With an estimation of 100m2, the investment costs are 2000 Euro.

Annual cost

Next to the fixed cost at the beginning, there could be several costs per year after the implementation. For the most alternatives there are no extra costs related to the implementation, only when using chips. The use of chips is done both at RFID and barcodes. On each spare part there has to be a chip for the use of RFID and for barcodes it is recommended to put a barcode on each container. With a cost of 0.10 Euro cents per barcode and an annual demand of 10.000, the annual cost of RFID is 1.000 Euro. For barcodes, only new chips are needed for new spares, and the costs for RFID are very low compared to the implementation costs, so the annual costs are negligible.

Combining all the implementation costs, gives the results that are shown in Table 7.

Implementation	**Current Plus**	**Total sup**	**Consignment**	**Barcodes**	**RFID**	**Kanban**
implementation cost	0	2.000	0	20.000	100.000	12.500
Annual costs	0	0	0	0	1.000	0

Table 7: Implementation cost, annual and fixed (source: RFID Journal (2012), Ayre (2008))

4. Training and education resources

For the successful implementation of the alternatives, training and education is needed. As mentioned in Section 3.1, training is very important for the success of an implementation which involves the use of an ERP system.

In Table 8, the number of hours training per person per alternative is given. The cost of an operator per hour is around 40 Euro according to the team leaders and this is used for estimating the cost for training per alternative. The number of hours are multiplied by those cost per hour and multiplied by the number of responsible people for document handling. For total support, this is 8 persons, as only the warehouse administrators need training and the clients get no new tasks. For the other alternatives, 70 people need training.

	Current Plus	**Total sup**	**Consignment**	**Barcodes**	**RFID**	**Kanban**
Hours at start	2	8	2	2	2	4
Hours per month	0.5	1	0.5	1	1	1
Hours per year	6	12	6	12	12	12
Total hours	**8**	**20**	**8**	**14**	**14**	**16**

Table 8: Number of hours training needed per person per alternative (source: Unilever SU Oss)

Next to training and education hours, there are also several education resources needed, for example guides and textbooks. These costs have to be made one time, at the beginning of the implementation, and are here called 'fixed'.

Because the costs for the educational resources are very low and the differences between those costs for the alternatives are negligible, they are not used in the comparison.

Training and education costs	Current Plus	Total sup	Consignment	Barcodes	RFID	Kanban
Euros (x1000) p. year	20	2	20	20	20	20
Euros (x1000) fixed	0	0	0	0	0	0

Table 9: Cost for training and education resources per alternative (source: Unilever SU Oss)

Conclusion

Combining all the cost for the first year of implementation gives the following results (all x 1.000 Euro):

	Current Plus	Total sup	Consignment	Barcodes	RFID	Kanban
Administrators FTE	100	400	100	100	100	100
Extra Purchasing costs	0	0	100	0	0	0
Implementation	0	2	0	20	100	12,5
Training & education	20	2	20	20	20	20
Total	**120**	**404**	**220**	**140**	**220**	**132,5**

Table 10: Total costs per alternative in the first year (x 1.000 Euro) (source: Unilever SU Oss)

Concluding, implementing total sup will be the most expensive alternative, followed by RFID and consignment. The least expensive alternative is Current Plus, followed by Kanban and Barcodes.

4.1.2. Output: Chance of DSS

To make a comparison between the six alternatives, the output scores are needed to compare with the input scores. The output scores are harder to combine, as criteria like 'SKU categories' and 'cleanliness' cannot be summed up easily. Therefore, a Multi Criteria Decision Analysis (MCDA) is done, which is described in Section 4.2. Before the MCDA can start, the names of the output criteria are needed.

After interviews with all the stakeholders, the following list of criteria arises. To give a clear overview of the chosen criteria and the criteria which are not used, Figure 7 is given. In this figure, the core problem and the ten causes of an incorrect organization and strategy are shown. These ten problems are grouped in four subjects: supervision, discipline, maintainability, and traceability. The ten problems of the problem tree are shown horizontally and under those problems the five subjects are shown, which result in the eight criteria used in this report. The criteria are shown in black boxes.

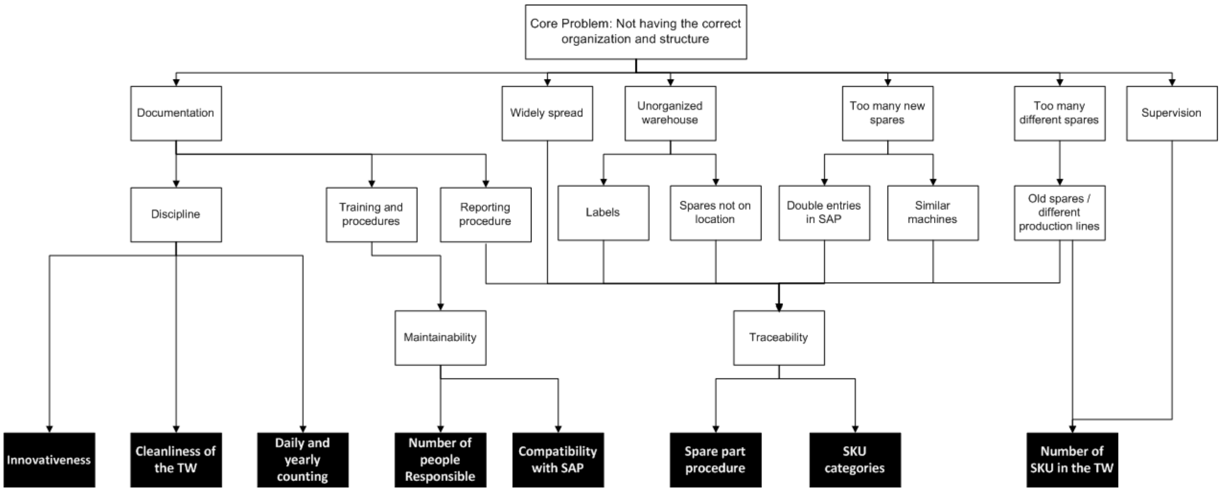


Figure 7: The output criteria used in this report (source: Unilever SU Oss)

4.2. Method

After finding the input criteria and their corresponding scores for the six alternatives, a different method is used for scoring the output criteria. To determine the ideal situation or situations, the input and output scores of the alternatives are compared in Section 4.4. Before this comparison can be done, the method to find the output scores is described in this section.

To determine the scores for the output criteria for the technical warehouse of SU Oss, a Multiple Criteria Decision Analysis (MCDA) is used. MCDA is an umbrella term to describe a collection of formal approaches which seek to take explicit account of multiple criteria in helping individuals or groups explore decisions that matter (Belton & Stewart, 2002). The purpose of an MCDA is to provide structure, provide focus and language for discussion, to help to learn about the problem, complement and challenges intuition, and assist in justification and communication.

MCDA methods are especially used when criteria cannot be summed as the input criteria can, as their scores are not comparable. For example, 100 and 10 Euros can be summed up to 110 Euros, but "very easy maintainable warehouse" and "not very innovative solution" are harder to sum.

A MCDA is used to make these types of output criteria comparable, so at the end a final output score can be given. There are several different categories of MCDA, as is described in Appendix 8, and the method that is used in this report is AHP (Analytic Hierarchy Process), which is described here briefly and more in depth in Appendix 9.

AHP is a fully compensatory method, which means that a very bad score on one criterion does not have to be crucial for the final score and can be compensated by good scores on the other criteria. The first step that is important for the use of AHP is the decision makers, which are the ten stakeholder groups in this research. These decision makers compare the alternatives on the criteria and tell if alternative A is preferred over alternative B. This can be done by giving it different scores, between equally important and very strongly important. For example, if coffee machine A makes very good coffee, and coffee machine B makes not so good coffee, coffee machine A is preferred very strongly over coffee machine B on the criterion taste of the coffee. The scores are combined by a mathematical method, which is shown in Appendix 10. The next step, after finding the decision makers, is the weights of the criteria. Not all criteria are equally important and the weights can be found on the same way as the scores of the criteria. For example, the taste of the coffee from a coffee machine is very strongly preferred over the colour of the coffee machine.

Combining the scores of the alternatives on the criteria with the weights of the criteria, makes it possible to compare the alternatives, as the total output score per alternative are found. The use of this method is used in the next section, which starts with the criteria used for finding the ideal situation for the technical warehouse of Unilever SU Oss.

4.3. Output variables

As mentioned in Section 4.1, the output of the alternatives is calculated by using several 'output criteria'. Finding the output scores of the alternatives is done by the AHP method as described in Appendix 9 and is executed in several steps, 1) calculation of the weights and 2) the calculation of the scores of the alternatives on the criteria. At the end of this section, the scores are shown and used for finding the ideal situation in Section 4.4.

4.3.1. Calculation of the weights of the criteria

In this section, the weights of the criteria are calculated in terms of 1,3,5,7, and 9, as mentioned in Appendix 9. For the calculation of the weights, the interest of the stakeholders as mentioned in the stakeholder analysis is used as the importance of the specific stakeholder. After determining the importance of the stakeholders, all ten stakeholder groups are asked for their preferences, by giving scores between 1 and 5, where 1 is very low and 5 is very high. At the end of this calculation, the total scores per criterion are given, and the differences are used for Table 11. The entire calculation is given in Appendix 11.

Because the scores are reciprocal, the score of alternative 2 compared to alternative 1 is 1 divided by the score of alternative 1 compared to alternative 2. In example, if alternative 1 scores 3 on relative relevance compared to alternative 2, than alternative 2 scores 1/3 on relative relevance compared to alternative 1. Using stakeholder interviews and results from literature, the scores can be found in Table 11.

Weight	SPP	# SKUs	Cleanliness	Number of Responsibles	SKU cat.	SAP compat.	Counting	Innova-tiveness
SPP	1	3	3	5	5	3	3	7
# SKUs	1/3	1	1	3	3	1	1	5
Cleanliness	1/3	1	1	3	3	1	1	5
# Responsibles	1/5	1/3	1/3	1	1	1/3	1/3	3
SKU cat.	1/5	1/3	1/3	1	1	1/3	1/3	3
SAP compat.	1/3	1	1	3	3	1	1	5
Counting	1/3	1	1	3	3	1	1	5
Innovativeness	1/7	1/5	1/5	1/3	1/3	1/5	1/5	1

Table 11: Calculation of the weights: Relative relevance of the criteria (source: stakeholders Unilever SU Oss)

4.3.2. The weights of the criteria

The weights of the eight attributes are calculated using the following two steps:

- Divide each number in a column of the pair wise comparison matrix by its column sum.
- Average each row of the normalized matrix. These row averages form the priority vector of alternative preferences with respect to the particular criterion. The values in this vector sum to 1.

The calculation as described in the previous two steps is given in Appendix 11. Also the consistency check is given in Appendix 11, and also the next consistency checks are given in that appendix. All scores used in this report are consistent. The weights that are used are shown in Table 12.

Criteria	SPP	# SKUs	Cleanliness	# Responsibles	SKU cat.	SAP compat.	Counting	Innova-tiveness
Weight	0.32	0.14	0.14	0.05	0.05	0.14	0.14	0.03

Table 12: Weights of the criteria used in the analysis (source: Unilever SU Oss)

4.3.3. Calculation of the scores of the alternatives on the criteria

The scores for the criteria are calculated in the same way as the weights, 1) find a way to compare the alternatives on the criterion, 2) Calculate the relative importance of the alternatives on the criterion, and 3) calculate the score on the criterion.

The calculation is done in 8 steps and finished with an overview of the results, in which becomes clear which of the alternatives has the highest score.

4.3.3.1. Spare part procedure (SPP)

The 'spare part procedure' is defined as the actions from searching the spare on SAP at the production lines to the moment the documentation of the spare part is done after it leaves the warehouse. The time of the spare part procedure is divided in three parts: walking in the TW, the average amount of time spent with questions to the warehouse administrators, and the documentation procedure. In Table 13, these three pieces are calculated by measuring the times in minutes by stopwatch.

	Current Plus	**Total sup**	**Consignment**	**Barcodes**	**RFID**	**Kanban**
Walking in TW	5	2	5	3	2	5
Average minutes of questions	2	5	2	2	2	2
Documentation procedure	5	1	5	1	0	1
Total	**12**	**8**	**12**	**6**	**4**	**8**

Table 13: Time of the alternatives on the spare part procedure in minutes (Unilever SU Oss)

Concluding, the use of RFID results in the shortest SPP and has therefore the best score on this criterion. Because the first minutes extra will result in a higher chance of DSS, RFID is preferred weakly over Barcodes, strongly above Total Sup and Kanban, and very strongly over Consignment and Current Plus.

4.3.3.2. Number of SKU in the TW

The number of SKU in the TW is the chance of successful maintainability of the TW related to the amount of spare parts. A lower number of SKU and spare parts will result in a more maintainable warehouse and will increase the traceability of the spare parts for the clients.

The difference between the alternatives on this criterion is the amount of people that are responsible for the warehouse, which is different than the number of people responsible for documentation. In the current situation and in all alternatives besides 'total sup' and 'consignment' the amount of spares decreases because of the cleaning actions as mentioned in Section 3.3. The amount of work that can be done depends on the number of people that feel responsible for the warehouse.

In the total supervision and consignment alternative, the 'clients' of the warehouse will behave as clients only and have no responsibility over the warehouse, so the cleaning actions and continuously controlling the number of spares will be less successful.

Concluding, Current Plus, Barcodes, RFID, and Kanban, are preferred weakly over than Total Sup and Consignment on this criterion.

4.3.3.3. Cleanliness of the TW

Having a clean and clear TW increases the visibility in the TW and increases the traceability of the spares in the TW. As the first steps of 5S are implemented for all the alternatives, the cleanliness of the TW is around the same for all the alternatives. The only differences are for the total supervision and the consignment alternatives. At consignment the ownership over the TW of the administrators and its clients decreases and keeping the TW will be harder. At total supervision, the cleanliness will be determined and maintained by the warehouse administrators, so because of this ownership, the TW will be cleaner.

Concluding, Total sup is preferred weakly over Current Plus, RFID, Barcodes, and Kanban on this criterion, and strongly over Consignment.

4.3.3.4. Number of people responsible for documentation

Next to the number of people that are responsible for the warehouse and the ownership of the clients, the number of people responsible for documentation is the next criterion which involves the chance for DSS. The number of people responsible for documentation is equal for all alternatives except the 'total sup' alternative. In this alternative, the warehouse administrators are the only persons who are responsible for the documentation.

In RFID, there are a lot of clients responsible for the documentation, but they do not have to handle the documentation themselves, the RFID gates handle that. However, the clients still have to use a pass to show who they are, or have a badge on them which is visible for the gates, and both methods have a possibility for foul play. Therefore, RFID scores equal to the other alternatives.

Concluding, Total sup is preferred weakly over all other alternatives on this criterion.

4.3.3.5. SKU category

At this moment, the spares and their locations are organized based on an ABC category. As mentioned in Section 3.1.3.6, using only ABC has several disadvantages.

Total supervision uses FSN, where the fast moving spares are closest to the location of the desk where the clients stand. This method has, as also mentioned in Section 3.1.3.6, several disadvantages.

The disadvantages of ABC and FSN can be prevented by using a combination of ABC, VED, and FSN. This is done in the alternatives ‘barcodes’, ‘RFID’, and ‘Kanban’. Because these combinations can look at vital and fast moving spares for example, they can have proper strategies for both types and score a little better on this sub criterion. The use of different SKU categories cannot be controlled at the consignment alternative, which is not preferable for the controllability of the alternative.

Some of the possibilities of combinations are shown in Table 14.

Combination	Explanation	Action and location
AF-	(very) fast moving spares or fast expensive spares	Close to the entrance of the TW
CV- / NV- / SV-	Vital spares who move (very) slowly	Have at least one on stock, but not close to the entrance of the TW
CD- / DN-/ CN-	Items who are almost never used and not vital for the organization	Finding other spare parts for the function of the specific part, or place not close to the entrance of the TW

Table 14: Possibilities with combinations of SKU categories (source: Unilever SU Oss)

Concluding, RFID, Barcodes, and Kanban are preferred weakly over Current Plus and Total sup, and strongly over Consignment on this criterion.

4.3.3.6. Compatibility with SAP

Next to the number of people responsible for document handling, the compatibility with SAP is important for the controllability of the TW. Mistakes with documentation can be caused by both points, so making it easier will result in a decreased number of DSS.

The consignment alternative has the lowest compatibility with SAP as the use of documentation will be done equally to the current situation. Current Plus and Kanban show little improvements for the compatibility with SAP compared with the current situation, as the method of documentation and the number of client do not improve, but the controllability is weakly more important at this criterion than consignment.

The control when using RFID is very good, as automatic documentation is ideal for the control of spare parts in the TW and the number of actions a client has to do is one, which is signing in to the system. Consignment of the warehouse is less compatible with SAP as the lack of new ideas and changes will result in less compatibility compared to the other alternatives.

Supervision is also very important for the compatibility, as the SAP usage is done with less persons and persons with more rights in the system. Therefore, total supervision scores equal to RFID, while barcodes score a bit less. The use of barcodes requires more steps in SAP by more persons, as the documentation has several manual steps, so the score is not as good as the previous two alternatives.

Concluding, RFID and Total Sup are preferred weakly over Barcodes on this criterion, preferred strongly over Current Plus and Kanban, and very strongly over Consignment.

4.3.3.7. Daily counting

In all the alternatives, yearly counting is used. The results of this yearly counting are that at the beginning of each (financial) year, there is a baseline measurement and the number of DSS is brought to zero after that.

The use of daily counting is done at the total supervision, barcodes, RFID, and Kanban alternatives. There are three ways of daily counting, which all lead to equal results.

1. Daily counting at MRP run
   In this counting procedure, the warehouse administrators count the spares that have to be ordered according to the MRP run, which runs overnight. With this procedure, the number of spares ordered is correct and can be altered if necessary.

2. Daily counting of SKU that left the warehouse the previous day
   In this counting procedure, the warehouse administrators count the count that left the warehouse the previous day. With this procedure, the number of spares of the SKU that are used is checked regularly.

3. Daily counting of the delivered SKU
   In this counting procedure, the warehouse administrators count the spares of the SKUs that are delivered during the day. The amount of spares that have to be counting is the lowest of the procedures, but the orders cannot be altered beforehand.

Concluding, all the procedures have advantages and disadvantages. The main disadvantage is that the spares that are taken from the containers that do not show on the MRP or picking lists are not counted and DSS cannot be prevented. Counting according one of the three procedures and doing some extra counting is the most beneficial to the maintainability, but is also the most time consuming.

So, Total Sup, Barcodes, RFID, and Kanban are preferred weakly over Current Plus and Consignment on this criterion.

4.3.3.8. Innovativeness

The innovativeness of the alternatives is determined by the innovativeness and the chance that other warehouses will use this TW as their role model. The three visited warehouses were all innovative on their own aspects and the people of SU Oss would visit them instead of the other way around. The warehouse administrators of Unilever SU Rotterdam, Heineken Den Bosch, and Johma Losser were all proud of their warehouse and this resulted in better performance of them and their clients.

The most innovative alternative is RFID as it is a relatively new way of organizing the warehouse. Next, the use of consignment, barcodes and Kanban are innovative, as they are more innovative than the current system. Less innovative than the current situation, which is equal in the Current Plus alternative, is the use of total supervision, as it is the old way of organizing a warehouse.

Concluding, RFID is preferred weakly over Consignment, Barcodes, and Kanban on this criterion, strongly preferred over Current Plus and very strongly over Total Sup.

4.3.3.9 Overview of the results

The alternative with the best output is RFID, which is a result of the least time spent in the TW, the compatibility with SAP and its innovativeness. RFID has no bad scores in Table 15, but is quite expensive, as can be seen in Table 16. The cheapest alternative is Current Plus and Total Sup is the most expensive alternative, because of the extra number of FTE.

Combining the relative importance interpretation values on all the criteria for the alternatives, gives the results as shown in Table 15.

Criteria	Weight	Current Plus	Total sup	Consignment	Barcodes	RFID	Kanban
SPP	0.32	0.05	0.11	0.05	0.24	0.45	0.11
Number of SKUs	0.14	0.21	0.07	0.07	0.21	0.21	0.21
Cleanliness	0.14	0.14	0.38	0.05	0.14	0.14	0.14
# People responsible	0.05	0.10	0.50	0.10	0.10	0.10	0.10
SKU category	0.05	0.10	0.10	0.04	0.26	0.26	0.26
SAP compatibility	0.14	0.07	0.33	0.03	0.16	0.33	0.07
Daily counting	0.14	0.07	0.21	0.07	0.21	0.21	0.21
Innovativeness	0.03	0.07	0.04	0.16	0.16	0.40	0.16
	Total	0.094	0.204	0.058	0.199	0.299	0.146

Table 15: Scores of the alternatives on the eight criteria (source: Unilever SU Oss)

4.4. Description of the ideal situation

In this section, the ideal situation is described. For this description can be given, the input and output scores of the alternatives are combined and an efficient frontier is given. The scores for this frontier are shown in Table 16.

	Current Plus	Total sup	Consignment	Barcodes	RFID	Kanban
Input (x 1.000 Euro's)	120	404	220	140	220	132.5
Output	0,094	0,204	0,058	0,199	0,299	0,146

Table 16: Total costs per alternative (source: Unilever SU Oss)

In this section, the ideal situation is described. For this description, the input (costs) and output (chance of DSS) variables are shown in Figure 8, which also shows the efficient frontier.

The efficient frontier, which shows the Pareto optimal solutions, includes four of the six alternatives. An alternative is called Pareto optimal if no other feasible alternative is at least as good as the alternative with respect to every objective and strictly better on at least one objective (Winston, 2003). In this efficiency frontier, the objectives are input (costs) and output (chance of DSS) and the alternatives are on that frontier when there is no cheaper and better solution.

Therefore, Consignment is outranked by Current Plus, as the last one gives a higher output for less input. Total Sup is outranked by RFID, as it has a lower output and a higher input. Total Sup could be on the efficiency frontier, but then 2 extra FTE instead of 6 should be used. This would not give the same good output, so Total Sup is no option for SU Oss.

The options where the management of SU Oss can choose from are shown in **Error! Reference source not found.**, where the alternatives that are on the efficiency frontier are shown from the cheapest alternative on the left to the most expensive alternative on the right.

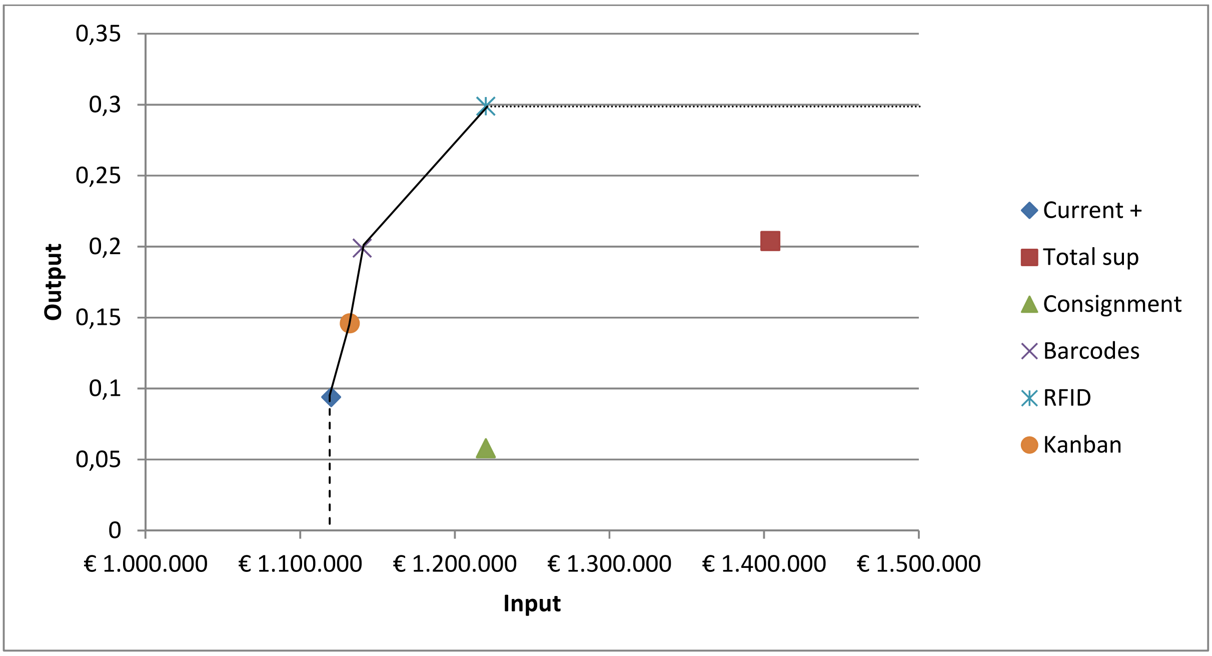


Figure 8: Input vs. output variables of the alternatives with efficient frontier (source: Unilever SU Oss)

For determining the ideal situation, a sensitivity analysis is used and the four alternatives on the efficient frontier are compared to find out if the extra output is worth the extra investment.

4.4.1. Sensitivity Analysis

In this section, the scores of the alternatives are checked for robustness. The robustness of the scores is found by changing the weights of the criteria and some of the factors that involve the scores of the alternatives on specific criteria. For example, a check is done by how much the cost of one warehouse administrator has to decline, so Total Sup becomes part of the efficient frontier.

Total sup

The most expensive alternative can become part of the efficient frontier if the costs of FTE decline from 400.000 euro to 216.000 euro. In this situation, the input scores of Barcodes and Total Sup become equal (1.140.000 Euro), while the output scores of Total Sup are higher than those of Barcodes. In that situation, Total Sup becomes part of the efficient frontier.

This can be done on two ways, less FTE or less expensive personnel. So, or the 8 FTE have to cost 27.000 euro per person, or the number of FTE should become 4. The first option is not preferable, as those costs will not result in qualified personnel and the second one is not preferable, as the output score will decline when there is only 1 warehouse administrator. The cleanliness, counting, and answering questions will be a lot harder with only 1 FTE. Concluding, Total sup is not the ideal situation.

Consignment

The second alternative that is not on the efficient frontier of Figure 8Figure 10 is Consignment. Both its input as output is worse than Current Plus, so one of these has to improve. Consignment can be on the efficient frontier because of input only by reducing the order cost. This is not possible, as cost reductions can only be done by having one supplier for all spares, which is not possible for SU Oss. On output, Consignment scores only better than Current Plus on innovativeness, and worse or equal on the other criteria. Changing the weight from 0,03 to 0,4 will result in total scores of 0,120 on both alternatives, but this is not reasonable, so also Consignment is not the ideal situation.

Kanban

The alternative Kanban is on the efficient frontier, but it does not score higher on a criterion than barcodes. Also RFID outranks Kanban on all criteria, so the output of Kanban cannot be higher than those alternatives. If the 7.500 Euro extra input is worth the output, is calculated in Section 4.4.2, so no conclusion can be given by the sensitivity analysis.

Current Plus

Current Plus is the cheapest alternative, as no big investments have to be made. The output results are lower than Kanban, Barcodes, and RFID, so the decision has to be made based on input. The question that has to be answered is “does the extra implementation costs give enough results to satisfy the implementation?” This question is answered in Section 4.4.2.

Barcodes and RFID

The two most expensive alternatives on the efficient frontier have a lot of similarities and two big differences; RFID is more expensive and Barcodes results in more DSS than when implementing RFID. The choice is therefore also made in the last comparison in Section 4.4.2.

4.4.2. Swings in output

In this section, the question "does the extra output justify the input?" is answered. This question is answered by comparing two of the alternatives on the efficient frontier, and a calculation is made if the lower chance of DSS is worth the extra costs. This section starts with Current Plus. This alternative, which results in the current 1.500 DSS, is the cheapest alternative, but has the lowest score of the four alternatives that are on the efficiency frontier.

Kanban versus Current Plus

The next alternative on the efficiency frontier is Kanban, which scores 0,051 better on output (0,1455 – 0,0944), but is also 12.500 Euro more expensive. The difference in chance of DSS results in a lower expected amount of DSS, and to calculate if this is enough, the following estimations are used.

In SU Oss, the costs of one hour downtime are estimated on 250 Euro and an investment has a payback time of 2 years. The Kanban alternative should therefore decrease the hours downtime for SU Oss with 12.500 / 250 = 50 hours. Because the number of minutes downtime for DSS is not known, three possibilities are used, 5, 10 and 15 minutes. These numbers are estimated by the 'clients' of the warehouse.

- 5 minutes per DSS: the use of Kanban should decrease the number of DSS by 300 (compared with the 1.500 DSS of Current Plus)
- 10 minutes per DSS: the use of Kanban should decrease the number of DSS by 150.
- 15 minutes per DSS: the use of Kanban should decrease the number of DSS by 100.

The decreased number of DSS by Kanban will be 256 when using a linear relation between output and DSS. If 0,299 (output of RFID) results in 0 DSS and 0,0944 (output of Current Plus) results in 1.500 DSS, than 0,1455 (output of Kanban) results in 256. Conclusion, the Kanban alternative is in 2 of the 3 estimations better than Current Plus.

Barcodes versus Kanban

The next alternative on the efficiency frontier is 'Barcodes', which scores 0,046 better than Kanban and 0,091 better than Current Plus, but is also 7.500 Euro more expensive than Kanban.

Using the same calculation as used with Kanban gives the following estimations:

- 5 minutes per DSS: the use of Barcodes should decrease the number of DSS by 480 (compared with the 1.500 DSS of Current Plus)
- 10 minutes per DSS: the use of Barcodes should decrease the number of DSS by 240.
- 15 minutes per DSS: the use of Barcodes should decrease the number of DSS by 160.

The decreased number of DSS by Barcodes will be 768 when using a linear relation between output and DSS. Therefore, Barcodes scores better on all estimations compared with Current Plus.

Compared with the Kanban alternative, the Barcodes alternatives should decrease the number of DSS with 129, 64, or 43 when using the same number of minutes per DSS as before. Because the estimated difference between the number of DSS of the two alternatives is 512, Barcodes score better than Kanban. Conclusion, the Barcodes alternatives scores better than the Kanban alternative.

RFID versus Barcodes

The next alternative on the efficiency frontier is 'RFID, which scores 0,100 better than Barcodes and 0,205 better than Current Plus, but is also 80.000 Euro more expensive than Kanban.

Using the same calculation as used with Barcodes gives the following estimations:

- 5 minutes per DSS: the use of RFID should decrease the number of DSS by 1.920 (compared with the 1.500 DSS of Current Plus)
- 10 minutes per DSS: the use of RFID should decrease the number of DSS by 960.
- 15 minutes per DSS: the use of RFID should decrease the number of DSS by 640.

The decreased number of DSS by RFID will be 1500 when using a linear relation between output and DSS. Therefore, RFID does not scores better on all estimations compared with Current Plus. Conclusion, RFID scores worse than Barcodes, and Barcodes is the best alternative for Unilever SU Os.

4.4.3. Conclusion

The alternative which uses barcodes is the ideal situation, as is shown in the previous part of this section. The barcodes alternative scores better than Current Plus and Kanban with a low increase in costs and is so much cheaper than the RFID alternative that it outweighs the difference in output.

This alternative is also preferred by the problem owners of this research, which confirms and enhances the conclusion. Therefore, the answer to the main research question is using barcodes.

4.5. Conclusion

In this chapter, the fourth research question is answered and used to find the ideal situation by comparing the six alternatives of Chapter 3 by using a MCDA method.

4. What are the criteria that are needed for scoring the solutions?

The criteria that are used are input- and output based. The input based criteria all involve costs that are made when an alternative is implemented. The output criteria influence the chance of DSS. Time spend in TW, Number of SKUs, Cleanliness, # People responsible, SKU category, SAP compatibility, Daily counting, and Innovativeness are the output criteria.

The alternative that has the highest score on output is RFID, followed by total sup and barcodes. Total sup and RFID have the highest input, so sensitivity analysis is used to find the ideal situation.

Because the use of barcodes results in the largest decline in DSS for the relative lowest implementation costs, it outranks the other alternatives on the efficient frontier. For the implementation of barcodes, all containers of small spare parts and the locations of the larger spare parts have to be tagged by a chip, and several barcodes scanners have to be purchased.

The use of barcodes and scanners will make the electronic documentation a lot easier and quicker, which will result in less DSS, as discipline will not be a problem. Combining this with the 5S steps of Section 3.3.2, will result in a clean, maintainable technical warehouse, with easy traceable spares, which are easy to document by barcodes.

In the next chapter, the implementation plan for using barcodes is given, followed by the discussion and conclusions of this research in Chapter 6.

5. Implementation Plan

In this chapter, the implementation plan for the recommended solution is given. The implementation plan starts with the first steps determined in Section 3.3 and followed by the steps from the chosen alternative: Barcodes. Last, the implementation steps of inventory control policies are given.

For all steps it is important to have the tasks clear, so who is responsible for which part of the implementation. A project team is recommended and in this team the maintenance manager, warehouse administrators, technical planners, TD and mechanics should be included, where the maintenance manager is the project leader.

The success factor of this implementation is that everybody knows what is required from them and to work together to keep the warehouse clean and organized. In Appendix 13, the time schedule is given.

First implementation steps

- Cleaning
    - Remove deteriorated spares
    - Remove spares that are not used anymore
    - Remove not vital spares from automatic ordering in SAP

This step has to be done with the entire project team and, if possible, some extra support from mechanics. The warehouse administrators do not know all the spares, so the expertise of the mechanics and technical planners is required to know which items are not used or usable.

- Ordering
    - Put the parts in the correct location according to SAP
    - Label all spares that are too large for a container

This step also requires the help from the entire project team because of expertise. Every technical planner can handle his or her own part of the warehouse.

- Counting
    - Zero-count of the spares to get to know the real amount of spares in the TW.
    - Make several counting groups for yearly counting, so yearly counting can be done by checking $1/12^{th}$ every month instead of everything at one time.

This step can be combined with the ordering step. When all the spare part containers are checked for correctness, they can simultaneously be counted.

- KPIs
    - Number of DSS per month or fill rate, with requested amount (for example 95%)
    - Cost of DSS per month, with requested amount
    - Total value of all spares, with requested amount (for example 25% reduction)
    - Total value of all spares that are not used in the last year

The KPIs that are the most important for the warehouse are given in this step and the results on those indicators should be visible for everybody who enters the warehouse. The project team must decide who enters the new data on the KPI boards. Recommended is that the warehouse administrator or the maintenance manager are responsible for the KPIs, as they have all the information.

- Information
  - Clear signs for which type of spares in a row or which production line
  - Easy recognizable description of the spare in SAP (for SU Rotterdam, this step costs several years)

At this moment, there are a lot of stickers and little signs in the warehouse, which all have a different layout. These information signs should all be removed and new signs should be used. When all information is in the same layout, it is clear that all information is applicable at this moment and not outdated. This step can be done by the project team and all members can put the information on the parts of the warehouse where they are responsible for.

The second part of this implementation step is more time consuming, as can be seen at SU Rotterdam. It is important that SU Oss compares their required information on the description with those of SU Rotterdam, so one uniform description method can be used.

Organization and structure

- Organization
  - Number of clients

This step is important for the possible amount of DSS, as a lot of people responsible would increase the chance of DSS. If only 1 or 2 persons per shift per production line can enter the warehouse, the number of times they visit the warehouse increases. This increase results in more experience with the documentation procedure and the creation of a little ownership to keep the TW clean and organized.

  - Responsibilities
    - Technical planners
    - First operators and Toppers
    - Warehouse administrators
      - Daily counting

As mentioned in the beginning of this chapter, the responsibilities are very important. The technical planners, who are also judged on the results of the warehouse by their operators, should be involved more in the TW. They should process all suggestions from the mechanics on certain parts and then make a proposal for a change in spare parts or the reorder quantities for example to the maintenance manager.

The daily counting is one of the new tasks for the warehouse administrator, where the counting of the SKUs in the MRP run is the more suitable for the TW of SU Oss. Monthly or weekly counting certain parts of the TW are also recommended, so the spares level are incorrect less and DSS are prevented.

- Electronic documentation system
    - Barcodes and scanners
        - Barcodes on all spare part locations
        - Software for barcode scanners and SAP
        - Numbers for production lines and machine parts, so the costs can be put on the associated location.
    - Training and education

This step is the recommendation on the alternative and therefore important for this research. The success of this implementation step depends however more on the previous steps than on this actual step, as an unorganized warehouse with a good documentation system still leads to DSS.

During the first implementation steps, the barcodes can be put on the containers of the DSS and on the shelves where the spars should be placed. Also, the software for the barcode scanners must be applicable to SAP, so it must be ordered and customized for Unilever SU Oss. When these two steps are complete, the barcode scanners can be put in the warehouse and the documentation can be done by scanning from that moment on.

The second step is the training and education for the clients to work with this system. Because documentation by barcode scanners is relatively easy, this is not a time consuming step. The most important is that every client knows his 'number'.

- Structure
    - SKU categories locations

The last implementation step of this part is the structure of the TW, the warehousing part. In the next section, some recommendations on the use of SKU categories are given combined with an inventory control policy.

Inventory control policies

- Safety stocks
    - Safety stocks for vital spares
    - No safety stock for desirable spares
    - Safety stock for fast movers
    - No more than 1 spare on stock for (very) slow and non movers

The safety stocks of the different SKU categories are the first implementation step. With three times the yearly amount of spares demanded on stock, the current safety stock levels are not correct. Safety stocks are important for the vital spares and spares with a high lead time.

In Section 2.3.4, an explanation of superfluous spares is given. Having 3 months supply is normally not necessary. In Winston (2003), the order costs are an important factor for deciding safety stocks and reorder levels, but at SU Oss, there are more than two deliveries every day, so this is not the important *factor for SU Oss. If there is one part of a SKU used in a machine, it breaks normally once a month, and the lead time is 2 weeks, the required safety stock is 1.*

The most important part for SU Oss is that the demand figures are clear and become better in the coming months / years. At this moment, there is only information about the last 3 years, and it is hard to say if a part breaks down once a year or that there is a lot of 'bad luck'.

- Reorder levels
  - (s,S) for fast moving spares
  - 1 for (very) slow and non-movers

As mentioned in the organization and structure implementation steps, it is important that the technical planners and maintenance manager take a look at the reorder levels. The number of spares in stock can be minimized, as long as there is a safety stock for vital and essential parts. This step is not a normal implementation step, as it is a continuous step in the warehouse process.

- ND and Z6
  - All fast movers: Z6
  - All (very) slow movers and desirable spares: ND

The current number of ND and Z6 are odd. At this moment, there are ND spares with values under 10 euro and ND SKUs with more than 1 spare in stock. Recommended is a clear difference in Z6 and ND, where as much SKUs as possible should be Z6, so no expertise mistakes can be made.

All (very) slow movers and desirable spares should be made ND items, where the technical planner has to decide whether or not to reorder a certain spare. The other items should be Z6, which works correctly if the demand figures are correct.

- Control
  - Every year a check for new reorder points and levels by checking the demand of the last years.
  - Frequent control at new spares

As with most implementation plans, it is important that the implementation does not stop after the last implementation step, but that it remains a continuous improvement process. This last step is that continuous improvement step, as the reorder points for example should be checked every year for correctness.

Next, the new spares should be checked frequently, as their demand is not certain. A supplier gives the demand figures, but these can differ from the actual demand figures when implemented at SU Oss. Also, the control over new parts that are ordered should be improved. When a supplier gives a spare parts list at the purchasing of a new machine, these spares have to be checked if they already exist in the TW. This will reduce the number of double spares, so after implementation of all these steps, the warehouse will be structured and organized, and the number of spares and SKUs will be decreased.

6. Conclusion & Discussion

In this chapter, the conclusions of this research are given. Next to the conclusions, there are several recommendations drawn in Section 6.2, and finally, the discussion is given in Section 6.3. In that section, the limitations of this research are given.

6.1. Conclusion

In Chapter 1, after the goal of this research, several research questions are defined and a main research question is given. In this section, the main research question is answered by first answering the six sub questions and finally the main question.

The main research question, as given in Section 1.6, of this research is:

What is the best possible spare parts system for the technical warehouse that can be implemented at Unilever Sourcing Unit Oss?

To answer this main research question, the six research questions are answered one-by-one first.

Research question 1: *How are the spare parts in the technical warehouse currently managed?*

The technical warehouse of Unilever SU Oss is currently managed by two warehouse administrators, who have 70 'clients' or people that take spare parts from the warehouse. Because the documentation that belongs with the taking of spares is not done correctly, the warehouse administrators have a lot of DSS which have to be corrected. DSS causes a lot of frustrations at the clients, as they get longer downtime at a breakdown of one of the machines.

The frustrations and other factors influence the discipline of the clients, who are responsible for the documentation of the spares, and therefore the traceability and cleanliness of the warehouse decreases. The current organization and structure of the warehouse have to change before the warehouse can run properly again.

Research question 2: Which systems are available in literature for managing spare parts in production companies?

The literature research that is done in Chapter 3 of this report is divided into two parts, DSS and electronic documentation, and structure and organization. The systems that are available in the DSS literature are the use of electronic mechanisms, incentives, and training. At electronic mechanisms, RFID and barcodes are described and also the non-electronic Kanban is researched.

Next, the systems that are available in the organization and structure literature are described. The use of total supervision, magpieing behaviour, TPM, and KPIs is researched and used for the formation of alternatives.

The findings of the two literature parts are used for the third research question, as they are the focus points during the visits of the other technical warehouses. The results of the visits are combined with the possibilities in literature and are formed into six alternatives. These alternatives are given at the answer of the fourth research question and used in the analysis.

Research question 3: Which systems are used by other production companies in the Netherlands and at other Unilever sites with comparable complexity?

Next to the literature research, three other technical warehouses are visited in the Netherlands. Unilever SU Rotterdam, Heineken Den Bosch, and Johma Losser are the locations that are visited and interviewed for the use of systems, which are described in the literature.

The conclusion is that the other warehouses perform a lot better on the number of DSS and this can be because the use of barcodes and scanners, the use of less people responsible for the documentation, or the cleanliness of the warehouses.

Research question 4: What is the best possible spare part system for the technical warehouse of Unilever SU Oss?

The second and third research question are formed into six alternatives at the end of Chapter 3: Current Plus, Total Sup, Consignment, RFID, Barcodes, and Kanban. These alternatives are analyzed to find the ideal situation for the technical warehouse of Unilever SU Oss. This analysis is done by scoring the input criteria, cost factors, and the output criteria of the alternatives.

The criteria for scoring the solutions are based on the literature and the stakeholder analysis. There are two main groups of stakeholders, operations and technical & innovation, which have different interests, and both these groups have to be satisfied with the results. In Table 17, the output criteria are given, as well as the weights the criteria received at the AHP method. AHP, which is described in Section 4.2, is the method that is used for the entire analysis.

Criteria	Weight
Time spend in TW	0.32
Number of SKUs	0.14
Cleanliness	0.14
# People responsible	0.05
SKU category	0.05
SAP compatibility	0.14
Daily counting	0.14
Innovativeness	0.03

Table 17: Criteria that are used for the analysis of the alternatives (source: Unilever SU Oss)

After the criteria are given, they are used for the MCDA analysis. The criteria gave the output scores of the alternatives and the costs of implementing is the input of the alternatives. In Table 18, the input and output scores are given.

Weight	Current Plus	Total Sup	Consignment	Barcodes	RFID	Kanban
Output:	0,094	0,204	0,058	0,199	0,299	0,145
Input (x 1.000 Euro)	€ 120	€ 404	€ 220	€ 140	€ 220	€ 132

Table 18: input and output scores of the alternatives (source: Unilever SU Oss)

After finding the output and input criteria, four alternatives became part of the efficient frontier, which shows the possible ideal situations: Current Plus, Barcodes, RFID, and Kanban. A sensitivity analysis and comparisons between the alternatives resulted in the ideal situation, which is Barcodes.

Because the use of barcodes results in the largest decline in DSS for the relative lowest implementation costs, it outranks the other alternatives on the efficient frontier.

Research question 5: How can the recommended system be implemented at SU Oss?

The use of barcodes and scanners is already done at Johma Losser and Heineken Den Bosch, so there is a good chance of successful implementation. The most important part of the implementation are the first steps: organizing the warehouse and keeping it organized and clean. If this is done, barcodes can be implemented, the amount of DSS decreases, the warehouse will be easier to control, and spares are easier to find.

Main research question

The answer to the main research question is that using barcodes for the electronic documentation gives the best results for the technical warehouse of Unilever SU Oss. The use of barcodes and the first implementation steps of Section 3.3.2 result in a decline of total spare part value of 500.000 Euros, as cleaning one of the five production lines resulted in 150.000 Euros of old, superfluous, and broken spares parts that are tossed away.

6.2. Recommendations

In this chapter, the recommendations for Unilever Sourcing Unit Oss are given. The recommendations for other research and recommendations which do not involve an alternative are given in respectively Section 6.2.2 and Section 6.2.3.

6.2.1. Recommended alternative

In this section, the recommended alternative is given. In Section 4.3 all the alternatives are investigated if their scores are better than the other alternatives. The concluded alternative, barcodes, is also recommended, as it is worth the implementation costs.

Next to barcodes, the first implementation steps have to be done, as they are crucial to the success of the barcodes alternatives and influence the results of the TW. Also the use of KPIs is recommended, as visualisation results in more interest in the action of the TW, so maintaining will be only easier.

6.2.2. Recommendation for further (related) research

In this section, the recommendations which involve new possible research are given. There are three research recommendations.

RFID

Next to the use of barcodes, the use of RFID for spare parts documentation is a really interesting alternative, which is usable for all purposes in the factory of SU Oss. Checking in personnel, raw material entrances, and the production process can also be monitored by using RFID. The costs of RFID can decrease when it is used more, so an Unilever broad investigation for the possibilities of RFID can be beneficial.

Concluding, the barcodes alternative is recommended, but the use of RFID at Unilever SU Oss or at Unilever worldwide should be investigated, as the output scores of that alternative are the highest of all six alternatives.

Replenishment scheme

As mentioned in Chapter 3, the use of the correct replenishment scheme and safety stocks is important for a technical warehouse. In this research, it was not one of the core problems and is not further investigated.

The spares can be divided in different groups or SKU categories, which all get a different replenishment scheme. For fast moving spare parts, a (s,S) scheme is preferable, as it can handle the demand between review periods. For slow movers and SKUs with one spare on stock, the s and S could be one or even zero, but this can be investigated. Needed for this investigation is a lot of correct data on the demand of the spares parts, their lead time and vitality to the organization.

Floor stock

The second recommendation for further research is the possibility of grabbing spare parts which do not have to be documented. No documentation leads to no DSS on these spares. The warehouse administrator, or supplier, checks every review period the stock levels and orders according to a (R, s, S) replenishment scheme. Because the amount of reviews have to be high to make this reliable, this is only possible for fast moving spare parts.

Needed for this research are a lot of correct data on the demand of the spare parts, their lead time, vitality and costs, so an assessment can be made if it is possible to make it floor stock or not.

Incentives

One of the recommendations that is said the most by stakeholders is the use of incentives. Lack of discipline and ingrained habits can only be changed by using incentives according to most stakeholders, and this should be investigated.

A reward and penalty system could be preferable, so the personnel will be motivated to get the rewards. Problem with this idea is that the entire site should use incentives for optimal results.

6.2.3. Other recommendations

Next to the recommendations that require new research, there are several recommendations that are already announced in the previous chapters and other recommendations for Unilever SU Oss.

Tasks of TW administrators

One of the success factors on the implementation are the tasks of the warehouse administrators. As mentioned before, the current tasks of the warehouse administrators involve more than they should be.

Tasks that are done by the warehouse administrators:

- Daily and yearly counting (in the new situation)
- Checking MRP run
- Determining strategic stock
- Determining stock levels
- Adjusting price levels of spares
- Putting new spares on their location in TW
- Putting repaired or returned spares to their location in TW
- Documentation of the number of DSS
- Answering questions from clients

The tasks of a classical or normal warehouse administrator involve only the counting, putting spares on their location, and answering the questions. Handling the documentation of DSS is also ideal, then the DSS are quickly handled and maybe do not become critical DSS. The difference between the current and the ideal situation is large, as half of the tasks are extra. The number of FTE that are needed for handling all the tasks that are summed up remain therefore at 2.

In the ideal situation barcodes handle the documentation, the number of DSS is around zero, and counting is done by the warehouse administrator. In this situation, one warehouse administrator could be enough, but there should be at least one person for support and tactical decisions.

Repairables and preventive maintenance

As promised in Chapter 2, a recommendation for repairables and preventive maintenance is given. In Section 2.1.4 the differences between preventive maintenance and corrective maintenance is explained. The current system is breakdown based and therefore corrective maintenance, while preventive maintenance results in less downtime (Nicholas, 1998).

Using preventive maintenance can be done in several ways, but the recommended way is to replace the part in the machine if it does not function as requested and then repair the part that is taken from the machine. The repaired part can then return to the TW, so it can be used again. In this ideal situation, a spare part is always available and the number of spares ordered decreases rapidly.

Because it is hard to find out if a machine part functions as requested, the part can also be replaced at autonomous maintenance and then checked by the mechanics and Toppers. If the machine part needs repairing it can be done before breakdown and then be returned to the warehouse, which also happens when the part was not broken.

Generic machines

One way to decrease the number of SKUs is using generic machines for different production lines. Using the same production machines for packaging for example could lead to a decrease in SKUs, and this can also be used for other new machines.

Before a new machine is ordered, the current SKUs and spares should be inventoried, so spares which are already in the TW can be chosen. Those spares are most of the time cheaper than those of the supplier of the new machine according to the stakeholders, and again, the number of SKUs decreases.

More generic machines or generic spares decrease the number of SKUs which increases the maintainability of the warehouse and the traceability of the spares.

Combining powers with other SUs or industrial area Oss

One of the more radical ideas is combing powers with other factories. Combining powers can be done in two ways and with two types of other factories. The first way is having the possibility to order spares from another warehouse, instead of the supplier. In this way, the average stock levels can be decreased, because the spares are at SU Oss within a few hours for example.

The second way is having a technical warehouse for a couple of factories combined. In this way, the number of FTEs can be combined and decreased, and total supervision and its advantages can be used. The number of DSS decreases to around zero, and the holding costs are shared.

The first type of factories to share spares with is other Unilever Sourcing Units or Unilever partner. A lot of similar spares where stored in the TW of SU Rotterdam, which have the same demand as in SU Oss, once a year, and these demands could be combined.

The next type is combining powers with the industrial area of Oss or even Den Bosch. Combining powers with several local factories would result in a lot of rules and regulations, but the advantages that are given in the second way are applicable for this situation.

Conclusion, having your own technical warehouse can be something that will disappear in the future as partnerships become more important. Partnering with factories in the same industrial area and combining technical warehouses can be beneficial for SU Oss. However, it requires a lot of communication, rules and regulations.

Combining TD and TW

The classical repairable problem of Sherbrooke (1968) uses a location where the spares are stored, ordered and repaired. This idea can also be applied at SU Oss, by combining the TD and TW, and creating a 'technical heart' of the organization.

Combining maintenance, repairing, mechanics, spare parts, decreases the number of FTE that are needed to control it and can increase the communication between the technical parts. Adding the TD to the TW will also increase the ownership of the mechanics in the TW and this decreases the number of DSS and increase the organization and structure of the TW.

The only problem is, which is also the reason why it is not an alternative in this research, is that it requires an enormous change which will lead to a lot of resistance. In the ideal situation it could lead to a lower number of FTE, but adding a manager Technical Affairs will be expensive and there will also be something like 'first operators' in the technical department.

So this opportunity can be investigated, but as a lot of levels in the company are involved, this cannot be done within six months, which is the time for a normal Master thesis.

All spares in the warehouse

At the moment, several racks and shelves are located next to the technical warehouse, in the 'normal' warehouse. This location is next to the technical warehouse, but it is harder to control this part of the warehouse as administrator. Also, to control and maintain the number of DSS, it is better to have all spares within the walls of the warehouse. The use of a new documentation method, for example barcodes, is easier to implement if the barcode scanner remain in the warehouse all the time. Losing barcode scanners leads to increasing amounts of DSS, which is not preferable.

Therefore, the spares should be maintainable for the warehouse administrators and the electronic documentation devices, so the spares should be placed within the walls of the technical warehouse.

6.3. Discussion

The discussion starts with a reference to the main purpose of the study, followed by a generalised view of the results, possible explanations for the findings, comparison with expected results and it ends with the limitations of this study (Gillett et al., 2009).

- a reference to the main purpose of the study

The goal of this study is: *to give advice on the technical warehouse at Unilever Sourcing Unit Oss, so the amount of spares can be reduced and the service level can increase.*

- a generalised review of the most important findings - summary of results

The results of this research are shown in **Error! Reference source not found.**, where the alternative 'RFID' has the highest output on the eight alternatives, followed by Total Sup and Barcodes. The alternatives are more focussed on the organization and structure of the technical warehouse than on the main items in the goal of this study, because the core problem was not the amount of spares, but DSS and the organization and structure.

- possible explanations for the findings in general

The two most expensive alternatives are the best scoring alternatives, but it is difficult to determine how much money an added 0.05 on the output is worth. The most expensive solution, total supervision, is not the best scoring solution, which is logical in this case. This old idea of organizing a TW is too expensive and working with electronic documentation devices is the future and RFID gives already better results for a lower cost, so therefore the high cost of the 'Total sup' alternative is logical.

The use of Kanban cards does not give the results that are expected beforehand. This is because AHP is a fully compensatory method and because other alternatives score better on the criteria, the use of Kanban cards get low scores. The use of Kanban cards is something that is better applicable for production instead of technical warehouses, where the demand is too low.

- comparison with expected results and other studies

The expected results are achieved, as the concluded ideal situation can be implemented at SU Oss and will result in a better organized and structured warehoused.

- Limitations of the overall study

The limitation of this study that restricts the extent to which the findings can be generalised is the lack of data to calculate the scores for the criteria for other warehouses. The number of critical DSS, the vitality of the spare parts and the time it costs per DSS are not known, and assumptions are made in this report.

Next, the use of AHP has its limitations, as mentioned before. AHP is a fully compensatory method, so an alternative with a very bad score can still be the best after the entire analysis. Despite of the limitations of this method, it remains the ideal method for a comparison of alternatives with a lot of stakeholders with other interests.

The last limitation of the results is the costs of the alternatives. The estimations that are made are based on only one year and therefore the more expensive alternatives score worse. When using for example 5 years and discounted cash flows (DCF), the results would be different. In Appendix 12, a calculation for the use of DCFs and a span of 5 years is done. Because the four alternatives on the efficiency frontier are the same as those on the frontier of Section 4.4, the frontier of Section 4.4 is used for the recommendations.

Concluding, the limitations of this research are because of the lack of data, the used multi criteria decision analysis and the estimations of the costs. Nevertheless, the ideal situation is a situation in which the technical warehouse becomes more structured, better organized, and will result in less DSS.

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Appendix 1: Stakeholder analysis

For stakeholder analyses, there are several possible methods. The two most common methods are the "Power versus Interest grid" (Mendelow, 1981) and "Interest versus Attitude grid". Before the decision for the method is shown, power, interest and attitude are defined.

1. **Power:** Their power or ability to influence in the organisation. This may be their potential to influence derived from their positional or resource power in the organisation, or may be their actual influence derived from their credibility as a leader or expert.
2. **Interest:** Their interest in the project or programme as measured by the extent to which they will be active or passive.
3. **Attitude:** Their attitude to the project or programme as measured by the extent to which they will 'back' (support) or 'block' (resist).

For the technical warehouse, the Power versus interest grid of Mendelow is used, because the most important factors in the stakeholder analysis are the power of the stakeholders and their interest in this problem and the warehouse.

The grid is shown in Figure 9 and within the figure are the corresponding strategies for the different groups.

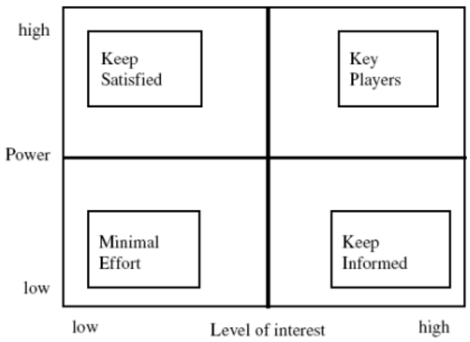

Figure 9: The Power versus Interest grid (source: Mendelow (1981))

In this section, the stakeholders are analyzed one by one and at the end the power versus interest grid with the locations of the stakeholders are shown.

1. **TW administrators**. As the administrators of the problem location, they are very interested in this research and the results. Their power is medium.
2. **Maintenance manager**. As the manager of the problem location, the maintenance manager is very interested in this research and has also high power.
3. **Technical department personnel** (TD). The TD as part of the organization is very interested in this research, but the power of the TD and the personnel is lower.
4. **Work preparer**. They have to order the spares and are judged by their operators on the success of getting the spares, so they are interested in changes in the TW. Their power is medium.
5. **First operators**. Their interest in this research is low, they use the TW but are not judged by the operators and they do not feel responsible for the functioning of the TW. The technical planners

and TD do feel that responsibility, which makes first operators less interested. The power of first operators is medium/low

6. **Toppers**. Their interest is equal to the first operators and their power is lower than that of first operators.
7. **Technical and Implementation manager**. He is the problem owner and therefore very interested in this project and his power, as problem owner and member of the MT, is very high.
8. **Management Team**. The management team has very high power in Sourcing Unit Oss and therefore should also be satisfied in this project. Their direct interest in this research is not very high, because it is a project that influences just one of them directly.
9. **Team leaders of the production lines**. The heads of the different departments, both from CFO and SSF, have high power in the organization, because they will have to use the spare parts and when the parts are not available, results in downtime of their production lines. Regardless of this importance to their production lines, their interest is medium.
10. **Operations Manager**. As manager of the operations department of SU Oss, the operations manager high interest in the technical warehouse, as a low service level would negatively influence his production lines and numbers. The operations manager is part of the MT, and therefore he has high power.

This results in the following power versus interest grid:

High		8			10	7
			9			2
Power	10					
				4	3	1
Low		5				
		6				
	Low		**Level of Interest**		High	

Table 19: Power versus Interest grid of the stakeholder analysis (source: Mendelow (1991))

Appendix 2: Interview questions and results

The list of interview subjects:

- Differences between the CFO and the SSF
- Experiences with SAP
- Experiences with TW
    - Different locations
    - Paternoster
    - Supervision
- DSS
- Discipline
- Suggestions for the TW
- Experiences with TD
- Experiences with Toppers
- Autonomous maintenance
- TPM / 5S
- ATM
- Different workplaces

Results

1. TW policies are outdated
2. Supervision only during the day
3. One central warehouse, but lots of spares on different locations
4. A lot of old spares which cannot be used anymore, because the corresponding machine is already replaced.
5. It is possible that spares are more than once available in the warehouse
6. Lack of discipline results in DSS
7. High number of responsible actors
8. Toppers not reaching their expected potential
9. Using SAP takes too much time
10. No SAP on all locations of warehouse, which results in paperwork
11. Different AM strategies
12. SSF has more setups than CFO, while both have a lot of setups per week (more than 10 per week)
13. SSF uses Excel for their maintenance management, while CFO uses SAP
14. Transferring SSF to SAP costs a lot of time, which is not available at the moment
15. Number of DSS
16. There is a breakdown culture, putting out small fires (In Dutch: brandjesblussen), and looking at the next day/week is done more often than thinking about next year.
17. A lot of (good) personnel is lost during the reorganization
18. The reorganization cost a lot of knowledge

19. There are a lot of external people on the site, which are more expensive than regular personnel (but easier to fire)
20. Not reaching the PE and OE targets / low ET
21. Too many spares, which in total represent too much
22. Not the correct purchasing policy and control
23. Suggestion: order all the spares per production line
24. ABC ordering for the spares in TW
25. Suggestion: only access to the TW for the TW administrators and TD personnel
26. Suggestion: Control all around the clock, three shifts of TW administrators
27. There is no confidence in the TW at the moment
28. Suggestion: hand scanner connected to SAP to write off spares
29. Suggestion: SAP on all the locations of the warehouse
30. Suggestion: barcodes on all the spares in the warehouse
31. Suggestion: throw all the spares outside and ask the first operators and technical planners to take all the spares they could use for their production line and take those back inside. When this is done, all the old spares stay outside and can be removed afterwards.
32. Suggestion: when a spare is taken out of the warehouse, note the number of spares that is left in the warehouse so the differences can be checked
33. Suggestion: TPM campaign: Whatever you do, write it off!!
34. SAP has no administrator at the moment
35. Suggestion: Make someone responsible for SAP
36. Suggestion: Put the value of the product on the spare, so the care of the product increases when operators / TD personnel see what the spare is worth
37. Suggestion: Add a photo of the spare at SAP, so it is easier for the production line to see if that is the spare they need and therefore reduce walking without knowing if that is the needed spare.
38. Paternoster is a nice storing system for spares, but does not function ideal because of the lack of connection to SAP and automatically writing off taken spares.
39. Risk of transporting a factory to another site if large improvements are investigated
40. Lack of plans for the future
41. Lack of plans of replacing machines in the coming years
42. 60-20-20 rule (CFO, Soup, Sauce) for DSS spares that have to be written off is reasonable, but investigating the DSS could decrease the number of partly bookings to the incorrect production lines
43. SSF and CFO have totally different mentalities
44. QA, responsible for the quality, could combine some of their tasks with the TPM team to reduce time and costs
45. Some of the spares are placed in the warehouse for finished products because of space problems and not delineated

Appendix 3: Literature Review

- Choice of research databases or journals

Because using "people's choice" of search engines for finding articles and randomly searching for articles undermines the credibility of literature reviews and is mostly used for convenience rather than quality, the journals that are used in this research are defined and clearly justified.

The journals that are used have to be peer-reviewed articles that have been through a blind review process, this is the most important indicator of scientific quality (Moody, 2009). To find peer-reviewed articles, the top databases are used, as they use only peer-reviewed articles. The top databases are described by Olson (2005) and ranked in his report (Olson, 2005).

In the list there are a lot of journals that cannot be used for this research, because their interest is different than the interest of this article, therefore the used articles must be related to 'operations research', 'production companies', 'inventory', 'warehousing' and / or 'spare parts'.

Combining those subjects with the SNIP (Source Normalised Impact per Paper) of Scopus (Scopus, 2012) and the impact factor of Thomson Reuters Journal Citation Reports (Thomas Reuters, 2012) used by Elsevier (Elsevier B.V., 2012) the following list of journals is given:

  - International Journal of Production Economics
  - European Journal of Operations Research
  - International Journal of Production Research
  - Production and Inventory Management Journal
  - International Journal of Operations and Production Management
  - OMEGA
  - Harvard Business Review

Because of the first and second place in the article of Olson (2005), the following two journals are also taken into account:

  - Management Science
  - Operations Research

- Choice of search terms

After finding the journals that are used, the search terms must be defined. The following terms are already used for the choice of journals and should be taken into account: 'Operations research', 'production', 'inventory', 'warehousing' or 'spare parts'.

  - Spare parts AND warehousing OR inventory policy OR production
  - Spare parts AND service level OR ownership OR Operations research
  - Service level AND inventory
  - Supervision AND warehouse

- Warehouse AND electronic devices

- Clearly defined selection criteria
    - Include spare parts
    - Exclude production materials and ingredients
    - Exclude the use of other ERP systems

- Clearly defined prioritisation criteria
    - Articles from between the years 2002 and 2012.
    - Articles from the databases mentioned before.

- Evaluation (critical analysis) and synthesis of papers (not just sequential description)

Appendix 4: Different approach per spare type

According to Silver, Pyke and Peterson (1998) the Class B spares should be made by routine (computerized or manual) rules. This should not be the case with Class A items. The potentially high payoff warrants frequent attention to the replenishment decisions of individual spares.

Guidelines for the control of Class A items:

1. Inventory records should be maintained on a perpetual (transaction recording) basis, particularly for the more expensive items. This does not need to be done by a computer, the use of a manual system (for example, VISI-Record or Kanban) is quite attractive.
2. Keep top management informed. Frequent reports should be prepared for at least a portion of the A items.
3. Estimate and influence demand. This can be done in three ways:
    a. Provide manual input to forecasts. (For example, call the customers to get advance warnings of their needs)
    b. Ascertain the predictability of the demand. This is particularly important for expensive, slow-moving items. If there is an adequate warning of the need for replacement part is given, there is no need to carry protection stock. On the other hand, when a random breakdown occurs, some protection stock is preferable. When the unit value of an item is extremely high, it would be wise to use a pool of spare parts shared among several companies within the same industry.
    c. Manipulate the given demand pattern. Seasonal or erratic fluctuations can sometimes be reduced by altering price structures, negotiating with customers, smoothing shipments, and so forth.
4. Estimate and influence supply. Negotiations with suppliers may reduce the average replenishment lead time, its variability, or both.
5. Use conservative initial provisioning. For Class A items that have a very high v value and a relatively low D value the initial provisioning decision becomes particularly crucial. It is a good idea to be conservative in initial provisioning, to reduce the chance of overstocking.
6. Review decision parameters frequently
7. Determine precise values of control quantities
8. Confront shortages as opposed to setting service levels. Because Class A spares are reviewed frequently, it is possible to operate with very little on-hand stock (that is, low safety stock) and make sure the replenishment can be done very fast.

The C category, or so-called *cats and dogs*, usually represents an appreciable percentage of the total number of different spares, but a very small fraction of the total investment in euros (Silver, Pyke, & Peterson, 1998) . There are two choices for selecting a review interval for a C item:

1. Periodic review with a relatively long interval
2. Continuously review but with a mechanism for triggering orders that requires neither a physical stock count nor the manual updating of the stock status.

The different approaches for VED and FSN are similar to ABC. Fast-moving spares need more control and observation than the non-moving spares and using (r,q) or (s,S) can be very beneficial for the fast-movers. (Roy & Guin, 1999)

Vital and essential spares also need most of the observations and attention and their results should be rechecked often. For desirable items should be tried to maintain minimal stock. If spares can be in the warehouse within 2 hours and there is no downtime when they are needed, then there is no need for stock. (Devnani, Gupta, & Nigah, 2010)

Of the three methods, ABC is the most famous, but that does not mean that the other two methods are not needed. A combination of ABC and VED as done by Devnani, Gupta and Nigah (2010) can be very beneficial, because class A products can also be very expensive parts with a very low demand, or there can be Class B or C spares that are vital to the production line and a shortage results in immediate downtime. (Devnani, Gupta, & Nigah, 2010)

Concluding, it is good to divide spares in different categories, but a combination of different methods gives even better results. A combination of VED and FSN for example shows if a spare has a high demand or is vital to the organization, instead of only the importance for the company.

Appendix 5: Inventory control

In this appendix, inventory control literature is discussed that can be used at SU Oss. As mentioned in the conclusion of the problem tree in Chapter 2, inventory control is not the core problem of this report, and this is why it is investigated last. The solutions and alternatives of this research will not involve new inventory control policies, but because some inventory control subjects are important to understand the other alternatives, several subjects are investigated in this section.

Decision making in procurement of inventory management is a problem of coping with large numbers and with a diversity of external and internal factors to the organization. Given that a specific item is to be stocked at a particular location, four basic issues must be resolved:

1. How often the inventory status should be determined
2. When a replenishment order should be placed
3. How large the replenishment order should be
4. How the safety stock level should be determined

First, some definitions are given that are used in the rest of this section.

Definitions

Before inventory control policies are revisited, some definitions are given (Silver et al., 1998) (Hopp & Spearman, 2008) (Muckstadt, 2005) (Sherbrooke, 2004):

- On-hand inventory: number of spares on stock in the warehouse
- Backorders: number of spares that are needed, not on stock, and ordered.
- Replenishment order: purchasing order of spare parts
- Net inventory level: On-hand inventory minus backorder level
- Inventory position: on-hand inventory minus backorder level + replenishment orders
- Cycle stock: inventory held to avoid excessive replenishment costs
- Safety stock: inventory held to avoid stock outs
- Replenishment lead time (L) is defined as the time that elapses from the moment at which it is decided to place an order, until it is physically on the shelf ready to satisfy customer demand.
- T = review period, i.e., the time interval between reviews.

How often the inventory status should be determined

The determination of the number of times the inventory status should be checked can be done on several ways. In this section, they are divided in push vs. pull, and review periods.

Push vs. Pull

The TW of SU Oss uses MRP runs to check which spares should be ordered, which is referred to as a push system according to Hopp & Spearman (2008). The key insight MRP can be stated as follows: dependent demand is different from independent demand. Production to meet dependent demand should be scheduled so as to explicitly recognize its linkage to production to meet independent demand.

The father of JIT, Taiichi Ohno, used the terms *push* and *pull* only in a very general sense: "*Manufacturers and workplaces can no longer base production on desktop planning alone and then distribute, or push, them onto the market. It has become a matter of course for customers, or users, each with a different value system, to stand in the frontline of the marketplace and, so to speak, pull the goods they need, in the amount and at the time they need them"* (Ohno, 1988).

Conclusion, for a spare parts warehouse, a hybrid approach is possible. The trays with expensive and/or slow-moving spare parts are controlled on a pull basis. The fast-moving spares are refilled when they reach its reorder point and the MRP run detects that. For the number of times the inventory status should be determined, the review period s are used and is described in the next section.

Review periods

An inventory control system can be designed so that the inventory position is monitored continuously or periodically. Continuously means that the inventory position is monitored non-stop, while periodically means that the inventory position is checked every review period (T).

At *continuous review,* as soon as the inventory position is sufficiently low, an order is triggered. The triggered order is delivered after a certain lead-time. The lead-time is the time from the ordering decision until the ordered amount is available on shelf. An alternative to continuous review is to consider the inventory position only at certain given points in time. In general, the intervals between these reviews are constant and we talk *about periodic review.*

Continuous review is a faster method, because there are continuously reviews and not only per T. If T is very short, it becomes similar to continuous review (Axsäter, 2006). In Oss, the stock status is reviewed continuously by the stock levels in SAP. The MRP run is done overnight, so the review period is one day.

When should a replenishment order be placed and how large should the order be?

The second and third basic issues of purchasing control are described in one section, because they are dependent. The purchasing policies should look at the following points: reorder times and quantities of spares, the lead time of ordering spares and the minimum / maximum amount of spares that should be in the warehouse. To determine these points, three categories distribution inventory control policies are described (Frazelle, 2002).

Manual inventory control

The most common manual inventory control systems are manual two-bin systems and visual review. The manual two-bin system is similar to the system at home to control the flow of potato chips or milk. The advantage is its simplicity, where the disadvantage is the lack of reliability when discipline is a problem. With visual review, the on-hand inventory in each location is visually inspected and based on the inspector's judgment and/or using visual aids a replenishment order for an item may be placed. Visual review is common in small retail outlets and warehouses that lack the technology required to support automated inventory control policies. Both systems are based on manual control and therefore not applicable for SU Oss.

Basic replenishment schemes

There are four basic replenishment designs in use in literature; continuous review (r, Q) policy, continuous review (s,S) policy, periodic review (R,S) policy, and the (R,s,S) system

The most well-known result in the whole inventory control area may be the classical economic order quantity (EOQ) formula. This simple result has had and still has an enormous number of practical applications. It was first derived by Harris (1913), but Wilson (1934) is also recognized in connection with this model. (Harris, 1913) (Wilson, 1934)

The EOQ formula is shown in Figure 10, where K (ordering cost), D (demand per year), and h (holding cost per year) are used to calculate EOQ, which is the optimal reorder level. The optimal reorder level is used as Q. The EOQ model involves the following costs: ordering, setup, purchasing, holding and stock out costs.

$$EOQ = \sqrt{\frac{2KD}{h}}$$

Figure 10: The EOQ formula (source: Winston (2003), Harris (1913))

- Continuous review (r, Q) policy

When the inventory position declines to or below the reorder point *r,* a batch quantity of size *Q* is ordered. (If the inventory position is sufficiently low it may be necessary to order more than one batch to get above *r,* the considered policy is therefore sometimes also denoted *(r, nQ)* policy

- Continuous review (s,S) policy

In the best (r,q) policy, it is assumed that an order could be placed exactly at the point when the inventory level reached the reorder point r. It is however possible that a demand for more than one unit can arrive between reaching r and the refill. At that moment, the inventory level is below r, and the expected inventory level at the beginning of an inventory cycle is incorrect. To solve that problem, the (s,S) policy is made. To implement an (s,S) policy, an order is placed whenever the inventory level is less than or equal to s. The size of the order is sufficient to raise the inventory level to S (assuming zero lead time) (Winston, 2003).

- Periodic Review (R,S) policy

The difference between the periodic review policies and the continuous review policies is already explained at the review period. Every R units of time, the on-hand inventory level is reviewed and an order is placed to bring the on order inventory level up to S. For example, if a (0.25,100) policy is used, every quarter of the year the on-hand inventory (i) is reviewed and if i is lower than 100 units are on hand, 100-i units are ordered.

- Periodic Review (R,s,S) policy

This is a combination of (s,S) and (R,S) systems, where the idea is to check the inventory position every R units of time. If the inventory position is at or below the reorder point s, an order is done to raise the inventory to S. If the position is above s, nothing is done until at least the next review. The (s,S) case is the special case where R=0 and (R,S) is the special case where s = S-1.

Advanced control policies

There are three main advanced control policies, which are defined as the joint replenishment program, the distribution requirements planning, and continuous replenishment program (Frazelle, 2002). All systems are based on decentralized systems, so not applicable for SU Oss.

How to determine the safety stock level

Next to the replenishment schemes and the reorder points and values, it is very important to determine the safety stock level of the spares. If demand is constant and the lead time is zero, then safety stock is not necessary, but that does not apply for SU Oss. In different methods, one of the recurring costs is the cost of shortages and backorders (Silver et al., 1998) (Axsäter, 2006). At SU Oss, the cost of a shortage is difficult to determine, because the client is Unilever itself and not all spares are vital for the production lines and result in downtime.

Conclusion of inventory control for Unilever SU Oss

The use of proper inventory control policies influences the stock levels of the SKUs. Safety stocks are needed to ensure a good fill rate and decrease the chance for downtime because a lack of spare parts. Having a good replenishment scheme, having good reorder points and levels, is beneficial for Unilever SU Oss, but is something that has to be implemented after the first organization and structure steps.

Having the optimal r and q for example can be beneficial for the stock levels, but with low discipline and high numbers of DSS this does not result in optimal results.

Appendix 6: Comparable companies

Unilever Sourcing Unit Oss is, as mentioned in the first and second chapter of this report, a factory where savoury food products are made. Industry classification is quite hard for SU Oss, because they have different types of products. The sausages belong to category C1010, which stands for "Processing and preserving of meat" according to ISIC (International Standard Industrial Classification of All Economic Activities) Rev.4 (United Nations Statistics Division, 2012). Soups and sauces are harder to classify, but also belong to category C10 "Manufacture of food products".

Sausages, soups and sauces are indeed food products, but when comparing SU Oss to other companies other product types could also be investigated. The products of SU Oss are fast moving consumer goods, while the production line of sausages could be compared with a production line of televisions or chemical products. Televisions and chemical products are totally different products, but they could have the same production line.

Comparing foods with chemicals can be done based on the three major production parts; making the product, filling the product and packaging the product. The mixing and blending of Oss can be compared with the production of the chemicals, and both could use the same bottle to be filled and have similar lines for packaging.

Next, SU Oss must be compared with a company who also has a lot of turnovers. The production line of soup has 20 to 50 turnovers and therefore setups per week, which costs a lot of time. Comparing SU Oss with another company with a lot of turnovers can be beneficial.

Last, the production line must be non-critical. If the production line has downtime or the products have problems, at SU Oss there is no big problem as there would be when they would make airplanes. Breakdowns and downtime at an airplane could endanger human lives, when cannot be said directly from breakdowns at the production lines at SU Oss.

Summarizing the points before, the companies to compare SU Oss to must be one (or more) of the following:

- Processing and preserving of meat
- Fast moving consumer goods
- Production line with a lot of turnovers
- Non critical production line

The following companies are visited:

- Unilever SU Rotterdam
- Heineken Den Bosch
- Johma Losser

Appendix 7: Interview questions for visiting other warehouses (Dutch)

Algemene vragen (voor beschrijven van de situatie)

- Hoeveel spares liggen er op voorraad?
- Hoeveel verschillende spares liggen er op voorraad?
- Op hoeveel locaties liggen er spares op voorraad?
- Strategische voorraad en hoe bepaald.

Centrale of decentrale voorraad

- Is er gekozen voor decentrale of centrale voorraad en waarom?
- Zijn er verschillende productielijnen die een eigen voorraad zouden kunnen hebben?
- Liggen er onderdelen bij de productielijnen?

ERP systeem

- Hoe wordt de voorraad beheerd, elektronisch of op papier?
- Indien elektronisch, wordt hier een ERP systeem of Excel voor gebruikt?
    - Indien ERP, welke mogelijkheden heeft het systeem voor voorraadbeheer?
    - Indien Excel, hoe wordt dit gedaan?
    - In beide gevallen; Hoe wordt dit beheerd?
- Indien papier, waarom is hier voor gekozen?
- Wordt er gebruik gemaakt van scanners, RFID, of Barcode lezers?

Afboeken

- Hoe worden de spares afgeboekt?
- Door wie?
- Hoeveel mensen kunnen er afboeken?

Misgrijpen

- Wordt de voorraad (regelmatig) geteld?
    - Zo ja, hoe vaak en door wie allemaal?
      Methode ABC ranking?
      Tellen automatisch door systeem aangegeven
    - Zo nee, waarom niet?
        - In hoeverre is de voorraad accuraat?
- Is er sprake van misgrijpen?
    - Hoe worden deze voorkomen?
    - Is er een beloning/straf systeem voor misgrijpen?

Beheer

- Hoe wordt de voorraad beheerd?
    - Door hoeveel mensen?
    - Hoeveel uur per dag?
- Hoeveel mensen kunnen het magazijn in?
- Hoe ziet de organisatiestructuur er uit?
- Hoe wordt het financieel beheerd? Incentives, vooraf betalen, verschilboekingen.

Technische dienst

- Kunnen de (storings)monteurs ook in het magazijn?

- Worden er (veel) spares gerepareerd en wat is het beleid hiervoor?
- Is de technische dienst eigenaar van het magazijn en/of wat is de betrokkenheid?
- Zijn er dagdienstmonteurs, storingsmonteurs, area-monteurs of andere soorten monteurs?

Bestellen
- Wordt er gebruik gemaakt van automatisch of handmatig bestellen? (en waarom)
- Worden bestelhoeveelheden en bestelmomenten vastgesteld door gegevens, literatuur of ervaring?
- Is er sprake van een minimale voorraadbeleid of risicovermijdend door alles (meerdere malen) op voorraad te hebben?
- Wie bepaalt welke onderdelen een spare krijgen, productie, TD of samen?
- Gebeurt dit op basis van gevoel of met onderbouwing?

Oude parts en nieuwe machines
- Wat is het beleid t.a.v. spares bij het aanschaffen van een nieuwe machine?
    - Wordt er gekeken naar de spares die al aanwezig zijn?
    - Worden machines besteld die al aanwezig zijn of altijd de nieuwst mogelijke ?
- Wat wordt er gedaan met een oude machine en haar parts/spares?
- Wordt er bijgehouden welke spares er al jaren niet meer gebruikt zijn?
- Wordt de kwaliteit van oude spares in de gaten gehouden?
- Hoe wordt om gegaan met spares die niet meer ondersteund worden?
- Hoe wordt om gegaan met spares die een upgrade krijgen en daardoor andere montage maten.

Locaties in het magazijn
- Hoe lang doet men erover om een spare te vinden in het magazijn?
- Hoe worden spares en de locaties aangegeven?
- Staat alles per machine, per afdeling of anders (en waarom)?
- Liggen de spares gesorteerd via ABC methode, op leeftijd of anders (en waarom)?

Onderhoud
- Wordt er gebruik gemaakt van breakdown, preventief of een andere vorm van onderhoud (en waarom)?
- Is er een goede koppeling tussen onderhoud en het magazijn?
- Wat gebeurt er met de onderdelen die van de lijn komen door onderhoud, intern gerepareerd, extern gerepareerd of weggegooid (en waarom)?

Testen van ideeën uit de literatuur
- Wordt er gebruik gemaakt van ABC ranking?
- Is er een system of item approach?
- Multi-echelon optimization
- Centraal of decentrale voorraden

Technical & Implementation Manager:
- Hoe is het magazijn voor onderdelen georganiseerd aantal mensen, (in house of geoutsourced), openingstijden, waarde onderdelen t.o.v. de assetbase wat houdt men op voorraad en wat niet en tot op welk niveau, hoe komt men tot de keuze welke onderdelen op voorraad moeten liggen.

Appendix 8: Choice of MCDA

Guitouni and Martel (1998) made a comprehensive list of some known multi criterion aggregation procedures (MCAP) in there study (Guitouni & Martel, 1998). These methods can be assigned to one of the three following categories: (i) the single synthesizing criterion approach without incomparability, (ii) the outranking synthesizing approach and (iii) the interactive local judgements with trial-and-error approach (Roy B. , Methodologie Multicritere d'Aide a la Decision, 1985). These categories are called by Vincke (1989) (i) the multi attribute utility theory methods, (ii) the outranking methods and (iii) the interactive methods (Vincke, 1989). Many other specifications and categorisations exist, so combining the two categories and adding the "simple" methods, gives the following four types of MCDA: 1) Elementary methods, 2) single synthesizing criterion, 3) outranking methods, and 4) mixed methods. Before the categories are investigated, the term compensatory is explained.

Compensatory

Next to the different categories, we can state that any MCDA method can be either:

1. *Compensatory*: in this case, one admits that an absolute compensation between the different evaluations can exist. Hence, a good performance on one criterion can easily counterbalance a poor one on another. There exist many methods that can fall into this category like the weighted sum.

2. *Non-compensatory*: no compensation is accepted between the different dimensions. The decision method may state that the dimensions are important enough to refuse any kind of compensation or tradeoffs. The lexicographic method is considered as a non-compensatory method.

3. *Partially compensatory*: in this case, some kind of compensation is accepted between the different dimensions or criteria. Most of the MCDA methods fall within this category. The major problem is to evaluate the degree of compensation for each one.

Categories

- Elementary methods

The elementary methods are the simple methods of MCDA. An example of an elementary method is taking the weighted sum of all the scores. If all criteria can be made into indexed number, a comparison can be made, but this method are used for SU Oss.

For SU Oss, it is important to score the alternatives on both their costs as well as their outputs, so they cannot directly be combined to one type of score.

- Single synthesizing criterion

Single synthesizing criterion methods have some of the most famous MCDA methods, which are fully compensatory methods: SMART (Simple multi-attribute rating technique), AHP (Analytic Hierarchy Process) and MAUT (Multi-attribute utility theory). These methods are used in the choice for a MCDA. SMART is discussed in Appendix 14, AHP in Appendix 15, and MAUT in Appendix 16.

- Outranking methods

At Electre, the concept of outranking relationship is used. The procedure seeks to reduce the size of non dominated set of alternatives. The idea is that an alternative can be eliminated if it is dominated by other alternatives to a specific degree. This method is used in the choice for a MCDA and is discussed in Appendix 17.

- Mixed methods

The use of mixed methods like qualiflex and fuzzy conjunctive/disjunctive method are not used in the choice for a MCDA as the previous two categories give enough possible results and the methods have been used a lot less in literature and practice.

Different types of MCDA / MCAP

The four MCDA categories are summarized in Table 20 (Guitoni and Martel, 1997). Guitoni and Martel (1997) used the term MCAP, which stands for multiple criteria analysis procedures, and is a synonym of MCDA.

MCAP	
Elementary methods	**Outranking methods**
Weighted sum	Electre I
Lexicographic method	Electre II
Conjunctive method	Electre III
Disjunctive method	Electre IV
Maximin method	Electre IS
	Electre TRI
Single synthesizing criterion	Promethee I
TOPSIS	Promethee II
MAVT	Melchior
UTA	Oreste
SMART	Regime
MAUT	NAIADE
AHP	
EVAMIX	Mixed methods
Fuzzy weighted sum	Qualiflex
Fuzzy maximin	Fuzzy conjunctive/ disjunctive method
	Martel and Zaras method

Table 20: Different types of MCAP (source: Guitouni and Martel, 1997)

Choice of MCDA

Of all the methods, the four methods mentioned in this section are SMART, AHP, MAUT, and Electre.

The first question that needs to be answered is why the particularly method should be used.

- Why Electre? → Outranking method
- Why MAUT? → Risk involved → attitude toward risk is essential
- Why SMART → Fully compensatory with efficient frontier, and a relatively easy method
- Why AHP → Fully compensatory, alternatives preferences with regard to a certain criterion

The first two methods that are excluded from this research are Electre and MAUT. Using an outranking method and its thresholds has its advantages, but a fully compensatory method is preferred in this research. The implementation cost is the most important criteria which has a requirement or threshold, that there is not infinite money available for implementation, but this can also be handled in the fully compensatory methods.

The problems with MAUT are in practice that a lot of hypothetical lotteries and one-off decisions are used. Using multiple criteria, in this research 9 criteria are used, is difficult for MAUT and the overview of the results would be harder to understand for the stakeholders.

AHP and SMART are the two fully compensatory methods which are used the most in literature and are the easiest to use. The two methods and their characteristics are summarized in Table 21.

SMART	AHP
• SMART is fully compensatory • Value tree • Uniform 0 – 100 scale • Direct rating, value functions • Weights are related to range of scores (swing weights) • Efficient frontier may be used if it is hard to compare costs and benefits directly	• AHP is fully compensatory • Attribute weights and preferences of alternatives w.r.t. a certain attribute are derived in the same way • Pair wise comparisons • Verbal statements • Consistency checks

Table 21: Summary of the characteristics of SMART and AHP (source: Edwards (1997) and Saaty (1980))

For the analysis in this research, AHP is used, because of the preferences between the alternatives on several criteria. The most important stakeholders are asked for their preferences on certain aspects, and the scores for the AHP analysis is made from those interviews.

Appendix 9: AHP

Analytic Hierarchy Process (AHP) (Saaty, 1980) is a fully compensatory method. The main goal of AHP is to find out which alternative scores the best on several criteria, where these criteria all have weights and the criteria are scored on relative importance per alternative. In this appendix, AHP is explained by using the steps of the AHP process, using examples to clarify.

1. Decision maker(s)

The first steps of the AHP method are one or more decision maker(s). The decision makers need to have preferences regarding the alternative on several criteria. In this research, the ten stakeholders are all used.

2. Alternatives (added to value tree)

The second steps are the alternatives. The alternatives that are used in this research are the same type as the criteria used in AHP. In this research there are six alternatives which have to be analysed.

3. Attributes

To find the ideal situation, several attributes are used. The attributes AHP uses are the criteria of this research, which are the decision making values. The score on all criteria combined results in the final score, so all criteria or attributes are relevant.

4. Measure performance of alternatives on attributes

Measuring the performance of the alternatives on the criteria can be done on several ways. In this research, the input variables are all based on the amount of Euros the alternative will cost based on that criterion. So for example, the criteria "implementation cost" looks at the costs that are needed for the implementation, which is the purchase of barcodes and scanners for the barcodes alternative.

The decision makers compare the alternatives on the criteria and tell if alternative A is preferred over alternative B. This can be done by giving it different scores, between equally important and very strongly important. For example, if coffee machine A makes very good coffee, and coffee machine B makes not so good coffee, coffee machine A is preferred very strongly over coffee machine B on the criterion taste of the coffee.

5. Weight of attributes

The weight of attributes calculates the weight a criterion gets for the analyses. A more important criterion will receive an higher weight than a less important one. The calculation is equal to the calculation for the scores of the criteria, so the explanation is done here.

Calculation of the weights and scores

As mentioned at the fourth step, the comparison between two criteria has to be recalculated to values. The preferences of the stakeholders are used and for the coffee machines example, machine A is preferred very strongly over coffee machine B on the criterion taste of coffee. This importance is given by a_{ij}, where i = alternative A, j = alternative B, and the scale is from 1 – 9, as shown in Table 22. So on taste of coffee a_{ij} = 7.

Value of a_{ij}	Interpretation
1	Objectives *i* and *j* are of equal importance
3	Objective *i* is weakly more important than objective *j*
5	Experience and judgment indicate that objective *i* is strongly more important than objective *j*
7	Objective *i* is very strongly or demonstrably more important than objective *j*
9	Objective *i* is absolutely more important than objective *j*
2, 4, 6, 8	Intermediate values

Table 22: Relative importance interpretation values (source: Saaty (1980))

The set of all importance scores is shown in a matrix, called A. The matrix is a reciprocal, consistent matrix and after half of the matrix is filled in, the other half can set $a_{ji} = 1/a_{ij}$.

$$A = \begin{bmatrix} a_{11} & . & . & . & a_{1n} \\ . & . & a_{ij} & . & . \\ . & . & . & . & . \\ . & . & . & . & . \\ a_{n1} & . & . & . & a_{nn} \end{bmatrix}$$

a. Sum of weights/ priorities equals 1

The next step is making the sum of the weights equals 1. The formula used for this is: $\sum_{i=1}^{n} a_{ij}$ = 1, with n is the number of rows of matrix A. The table should be recalculated to make this sum 1. After that the weights are calculated, by using the formula: $\sum_{j=1}^{n} a_{ij}$ / n. Now that the two formulas as used, the weights of all n (number of rows) attributes are calculated by adding the horizontal rows.

b. Consistency check

After finding the weights, a consistency check is done to find out if the scores are consistent. If the scores are not consistent, they cannot be used for the rest of the analysis.

- Determine eigenvalue λ_{max} , which is the sum of the weights of the attributes multiplied by the sum of the normalized score. In 5c, an explanation is done, which shows how the eigenvalue is calculated.
- Next, the consistency index (CI) has to be calculated and compared with the random index (RI)
  - CI = $(\lambda_{max} – n)/(n – 1)$
  - Compare CI with the random index (RI), which is shown in Table 23.
  - Degree of consistency is satisfactory in case the consistency ratio CR = CI/RI < 0.10

n	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
RI	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

Table 23: Random index values (n = 2,...,10) for AHP (source: Winston, 2004)

c. Example

A decision has to be made for the purchase of a new coffee machine. There are three possible new coffee machines, X, Y, and Z. One of the criteria is taste of coffee others are costs and looks of the machine. The decision maker decided that costs is moderately preferred to taste of coffee and very strongly preferred to looks of the machine. In turn, taste is strongly to very strongly preferred to looks.

This results in the following table A:

	Taste	Costs	Looks
Taste	1	1/3	**6**
Costs	**3**	**1**	**7**
Looks	1/6	1/7	1

Sum of the weights equals 1, so the columns should sum to 1:

	Taste	Costs	Looks
Taste	6/25	7/31	6/14
Costs	18/25	21/31	7/14
Looks	1/25	3/31	1/14

The weight of taste is therefore= (6/25+7/31+614)/3 = 0,298. Costs and looks get therefore 0,632 and 0,069 respectively. The sum of the normalized scores of taste is 4,166 (1+3+ 1/6), and costs and looks score 1,48 and 14 respectively.

The largest eigenvalue λ_{max} is therefore (0,298 * 4,166) + (0,632 * 1,483) + (0,069 * 14) = 3,145.

Consistency check gives ((3,145-3)/2)/0,58 = 0,072. Because this is lower than 0,1, the results are consistent.

6. Ranking

In the ranking stage of AHP, the alternatives are ranked based on their scores, and the provisional decision can be made based on this ranking. The weights of the criteria are multiplied by the scores of the alternatives and those scores are summed per alternative. At the end, six total scores will show, and the highest score is ranked number 1. This decision can be checked by doing a sensitivity analysis, which checks if the results change if several weights change.

Appendix 10: Weights of the criteria

As mentioned in Section 4.3, the weights of the criteria are calculated by using four steps:

1. Stakeholder analysis
2. Interest
3. Scores
4. Weights of the criteria

Stakeholder Analysis

The first step is using the stakeholder analysis, as shown in Section 2.2.3, which is shown in Figure 11, where the ten stakeholders are shown as numbers. In Table 24, the numbers and names of the stakeholders are shown.

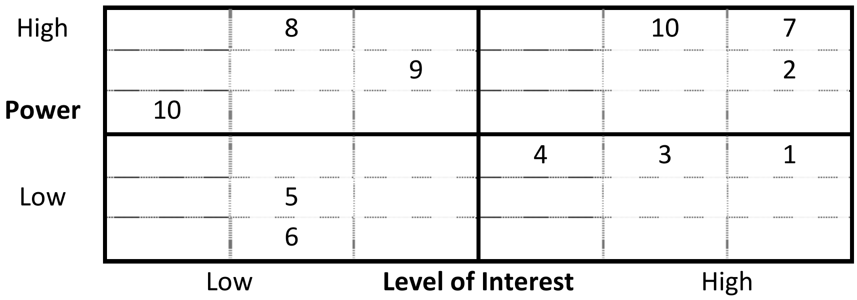

Figure 11: Stakeholder analysis (source: Unilever SU Oss)

Interest

The next step is using the level of interest of the stakeholders to calculate the weights of the stakeholders for determining the weights of the criteria for the AHP analysis. The interest numbers are the location in the stakeholder analysis of Figure 11, where 1 is the lowest level of interest and 6 is the score for the highest level of interest.

Stakeholder	Interest	Weight
1: TW administrators	6	0,146
2: Maintenance Manager	6	0,146
3: TD personnel	5	0,122
4: Work preparor	4	0,097
5: First operator	2	0,049
6: Toppers	2	0,049
7: T&I Manager	6	0,146
8: Management Team	2	0,049
9: Production leaders	3	0,073
10: Operations Manager	5	0,122
Total	**41**	**1**

Table 24: Stakeholders, their interests, and the weights for calculation the weights of the criteria for the AHP analysis (source: Unilever SU Oss)

Finally, the total of the interest numbers are calculated, which is 41. The weight of a specific stakeholder is the percentage of the total interest, so interest score divided by 41. At the end of this step, the ten weights of the stakeholders are used for the next steps.

Scores

In this step, the ten stakeholder groups are asked for their preferences and opinion on the eight criteria. For this, the stakeholders were asked to gives scores between 1 (not very important for the TW) and 5 (very important for the TW), so their most and least important criteria can be compared with the other stakeholders. In Table 25, the scores of the stakeholders are shown, with also the weights of the stakeholders, as mentioned in the previous step, and at the end the total scores.

Criterion	**Weight**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Total**
Number of SKU in the TW	0,146	1	4	4	3	2	2	5	4	3	3	3,22
Innovativeness	0,146	2	3	1	2	2	2	3	1	1	1	1,93
Cleanliness of the TW	0,122	5	4	3	3	2	2	3	5	2	2	3,24
Daily and yearly counting	0,097	1	3	3	4	4	4	4	2	4	4	3,20
Number of people responsible	0,049	3	4	1	2	2	1	3	1	2	2	2,37
Compatibility with SAP	0,049	4	4	4	3	3	2	3	3	3	3	3,37
Spare part procedure	0,146	4	5	4	3	4	4	4	3	3	4	3,93
SKU categories	0,049	2	2	3	2	2	3	3	3	2	2	2,37

Table 25: Scores of the stakeholders on the eight criteria and the total scores of those criteria (source: Unilver SU Oss)

Weights of the criteria

The last step is the calculation of the weights of the criteria by using the total scores of Table 25. The score of the spare part procedure (SPP) is the highest score, and gets the score 1 with itself in the AHP table. SPP is weakly more important than Number of SKU in the TW, Cleanliness of the TW, Daily and yearly counting, and compatibility with SAP, so gets the score 3. SPP is strongly more important than Number of people responsible and SKU categories, so gets the score 5. Finally, SPP is very strongly more important than Innovativeness, so gets the score 7. In Table 26, these and the other scores are given.

Weight	SPP	# SKUs	Cleanliness	# Responsibles	SKU cat.	SAP compat.	Counting	Innova-tiveness
SPP	1	3	3	5	5	3	3	7
# SKUs	1/3	1	1	3	3	1	1	5
Cleanliness	1/3	1	1	3	3	1	1	5
# Responsibles	1/5	1/3	1/3	1	1	1/3	1/3	3
SKU cat.	1/5	1/3	1/3	1	1	1/3	1/3	3
SAP compat.	1/3	1	1	3	3	1	1	5
Counting	1/3	1	1	3	3	1	1	5
Innovativeness	1/7	1/5	1/5	1/3	1/3	1/5	1/5	1

Table 26: Relative importance interpretation scores of the eight criteria (source: Unilever SU Oss)

Appendix 11: Calculations at the analysis

In this appendix, the calculation of the weights and the criteria of the analysis of Chapter 4 are done. The calculations start with the weight of the criteria and then the ten criteria. The criteria and their relative importance interpretation values are calculated in three steps:

Step 1: finding a factor to compare (plusses, Euros, or minutes)

Step 2: Relative importance interpretation values

Step 3: Determine results on the criterion of the alternatives

Step 4: Consistency check

The method that is used in this calculation is AHP, which is shown in Appendix 15.

Weights of the criteria

Step 1:

Criterion	**Weight**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Total**
Number of SKU in the TW	0,146	1	4	4	3	2	2	5	4	3	3	3,22
Innovativeness	0,146	2	3	1	2	2	2	3	1	1	1	1,93
Cleanliness of the TW	0,122	5	4	3	3	2	2	3	5	2	2	3,24
Daily and yearly counting	0,097	1	3	3	4	4	4	4	2	4	4	3,20
Number of people responsible	0,049	3	4	1	2	2	1	3	1	2	2	2,37
Compatibility with SAP	0,049	4	4	4	3	3	2	3	3	3	3	3,37
SPP	0,146	4	5	4	3	4	4	4	3	3	4	3,93
SKU categories	0,049	2	2	3	2	2	3	3	3	2	2	2,37

Step 2:

Weight	SPP	# SKUs	Cleanliness	# Responsibles	SKU cat.	SAP compat.	Counting	Innovativeness
SPP	1	3	3	5	5	3	3	7
# SKUs	1/3	1	1	3	3	1	1	5
Cleanliness	1/3	1	1	3	3	1	1	5
# Responsibles	1/5	1/3	1/3	1	1	1/3	1/3	3
SKU cat.	1/5	1/3	1/3	1	1	1/3	1/3	3
SAP compat.	1/3	1	1	3	3	1	1	5
Counting	1/3	1	1	3	3	1	1	5
Innovativeness	1/7	1/5	1/5	1/3	1/3	1/5	1/5	1

Step 3:

Weight	SPP	# SKUs	Cleanliness	# Responsibles	SKU cat.	SAP compat.	Counting	Innovativeness
SPP	0.35	0.38	0.38	0.26	0.26	0.38	0.38	0.21
# SKUs	0.12	0.13	0.13	0.16	0.16	0.13	0.13	0.15
Cleanliness	0.12	0.13	0.13	0.16	0.16	0.13	0.13	0.15
# Responsibles	0.07	0.04	0.04	0.05	0.05	0.04	0.04	0.09
SKU cat.	0.07	0.04	0.04	0.05	0.05	0.04	0.04	0.09
SAP compat.	0.12	0.13	0.13	0.16	0.16	0.13	0.13	0.15
Counting	0.12	0.13	0.13	0.16	0.16	0.13	0.13	0.15
Innovativeness	0.05	0.03	0.03	0.02	0.02	0.03	0.03	0.03

Step 4:

Consistency check

Before the weights can be used, a consistency check is made. In the explanation of AHP in Appendix 11, the total procedure is given, but the three main steps are described here briefly.

1. Approximation for w_{max} : the values of

Criteria	SPP	# SKUs	Cleanliness	# Responsibles	SKU cat.	SAP compat.	Counting	Innova-tiveness
Weight	0.32	0.14	0.14	0.05	0.05	0.14	0.14	0.03

2. Table 12 are the approximations
3. Approximation for Δ_{max} : 8.18
4. Consistency ratio
    a. Consistency Index: $(\Delta_{max} - n)/(n-1) = 0.03$
    b. Random index: 1.41
    c. Consistency ratio: 0.03 / 1.41 = 0.02
    d. 0.02 is lower than 0.1, so the weights are consistent

Calculation of the relative importance interpretation values of the eight criteria which influence the chance of DSS on the six alternatives.

Not all the four steps of the calculation of the relative importance interpretation values of the eight criteria are given. The second step, the results, and the consistency check are given. Step 1 is already given in Section 4.3.

1. **Spare part procedure (SPP)**

	Current Plus	Total sup	Consignment	Barcodes	RFID	Kanban	Result
Current Plus	1	1/3	1	1/5	1/7	1/3	**0.05**
Total sup	3	1	3	1/3	1/5	1	**0.11**
Consignment	1	1/3	1	1/5	1/7	1/5	**0.05**
Barcodes	5	3	5	1	1/3	3	**0.24**
RFID	7	5	7	3	1	5	**0.45**
Kanban	3	1	3	1/3	1/5	1	**0.11**

Consistency check

- Δ_{max} = 6.08
  - CI = 0.02
  - RI = 1.24 (n=6)
  - CR = 0.01 < 0.10, so consistent.

2. **Number of SKU in the TW**

	Current Plus	Total sup	Consignment	Barcodes	RFID	Kanban	Result
Current Plus	1	3	3	1	1	1	**0.21**
Total sup	1/3	1	1	1/3	1/3	1/3	**0.07**
Consignment	1/3	1	1	1/3	1/3	1/3	**0.07**
Barcodes	1	3	3	1	1	1	**0.21**
RFID	1	3	3	1	1	1	**0.21**
Kanban	1	3	3	1	1	1	**0.21**

Consistency check

- Δ_{max} = 6.00
  - CI = 0.00
  - RI = 1.24 (n=6)
  - CR = 0.00 < 0.10, so consistent.

3. Cleanliness of the TW

	Current Plus	Total sup	Consignment	Barcodes	RFID	Kanban	Result
Current Plus	1	1/3	3	1	1	1	**0.14**
Total sup	3	1	5	3	3	3	**0.38**
Consignment	1/3	1/5	1	1/3	1/3	1/3	**0.05**
Barcodes	1	1/3	3	1	1	1	**0.14**
RFID	1	1/3	3	1	1	1	**0.14**
Kanban	1	1/3	3	1	1	1	**0.14**

Consistency check

- $\Delta_{max} = 6.05$
    - CI = 0.0097
    - RI = 1.24 (n=6)
    - CR = 0.01 < 0.10, so consistent.

4. Number of people Responsible

	Current Plus	Total sup	Consignment	Barcodes	RFID	Kanban	Result
Current Plus	1	1/5	1	1	1	1	**0.10**
Total sup	5	1	5	5	5	5	**0.50**
Consignment	1	1/5	1	1	1	1	**0.10**
Barcodes	1	1/5	1	1	1	1	**0.10**
RFID	1	1/5	1	1	1	1	**0.10**
Kanban	1	1/5	1	1	1	1	**0.10**

Consistency check

- $\Delta_{max} = 6.00$
    - CI = 0.00
    - RI = 1.24 (n=6)
    - CR = 0.00 < 0.10, so consistent.

5. SKU categories

	Current Plus	Total sup	Consignment	Barcodes	RFID	Kanban	Result
Current Plus	1	1	3	1/3	1/3	1/3	**0.10**
Total sup	1	1	3	1/3	1/3	1/3	**0.10**
Consignment	1/3	1/3	1	1/5	1/5	1/5	**0.04**
Barcodes	3	3	5	1	1	1	**0.26**
RFID	3	3	5	1	1	1	**0.26**
Kanban	3	3	5	1	1	1	**0.26**

Consistency check

- Δ_{max} = 6.07
  - CI = 0.0146
  - RI = 1.24 (n=6)
  - CR = 0.01 < 0.10, so consistent.

6. Compatibility with SAP

	Current Plus	Total sup	Consignment	Barcodes	RFID	Kanban	Result
Current Plus	1	1/5	3	1/3	1/5	1	**0.07**
Total sup	5	1	7	3	1	5	**0.33**
Consignment	1/3	1/7	1	1/5	1/7	1/3	**0.03**
Barcodes	3	1/3	5	1	1/3	3	**0.16**
RFID	5	1	7	3	1	5	**0.33**
Kanban	1	1/5	3	1/3	1/5	1	**0.07**

Consistency check

- Δ_{max} = 6.23
  - CI = 0.0462
  - RI = 1.24 (n=6)
  - CR = 0.04 < 0.10, so consistent.

7. Daily counting

	Current Plus	Total sup	Consignment	Barcodes	RFID	Kanban	Result
Current Plus	1	1/3	1	1/3	1/3	1/3	**0.07**
Total sup	3	1	3	1	1	1	**0.21**
Consignment	1	1/3	1	1/3	1/3	1/3	**0.07**
Barcodes	3	1	3	1	1	1	**0.21**
RFID	3	1	3	1	1	1	**0.21**
Kanban	3	1	3	1	1	1	**0.21**

Consistency check

- Δ_{max} = 6.00
    - CI = 0.00
    - RI = 1.24 (n=6)
    - CR = 0.00 < 0.10, so consistent.

8. Innovativeness

	Current Plus	Total sup	Consignment	Barcodes	RFID	Kanban	Result
Current Plus	1	3	1/3	1/3	1/5	1/3	**0.07**
Total sup	1/3	1	1/5	1/5	1/7	1/5	**0.04**
Consignment	3	5	1	1	1/3	1	**0.16**
Barcodes	3	5	1	1	1/3	1	**0.16**
RFID	5	7	3	3	1	3	**0.40**
Kanban	3	5	1	1	1/3	1	**0.16**

Consistency check

- Δ_{max} = 6.16
    - CI = 0.0326
    - RI = 1.24 (n=6)
    - CR = 0.03 < 0.10, so consistent.

Appendix 12: Using five years to calculate the results

As mentioned in the discussion in Chapter 5, the input variables for the six alternatives are re-calculated for using a five year scale. For this, discounted cash flows (DCFs) are used, which shows the costs of an investment for the following years. In this case, five years are used, because it shows the differences with the current results.

In Table 27, the fixed costs and the annual costs are given. The fixed costs are equal to the fixed costs from the analysis of Chapter 4. The annual costs are calculated by using the DCFs of the five years and the discounted present value (DPV) of the alternatives.

The DPV is calculated by using the following formula:

$$DPV = \frac{CF_1}{(1+r)^1} + \frac{CF_2}{(1+r)^2} + \dots + \frac{CF_n}{(1+r)^n}$$

CF are the costs of the alternative and r is the risk free factor that for example a bank should give. For r, 5% is used, and CF are the annual costs as shown in Table 27 under annual and 0. Zero is used, as the cost of the first year have no risk free possibilities.

		Current Plus	Total sup	Consignment	Barcodes	RFID	Kanban
Fixed cost:		5,000	5,000	5,000	25,000	105,000	22,500
Annual:	0	1,115,000	1,404,000	1,215,000	1,130,000	1,130,000	1,130,000
	1	1,061,905	1,337,143	1,157,143	1,076,190	1,076,190	1,076,190
	2	1,011,338	1,273,469	1,102,041	1,024,943	1,024,943	1,024,943
	3	963,179	1,212,828	1,049,563	976,136	976,136	976,136
	4	917,313	1,155,074	999,584	929,654	929,654	929,654
		Current Plus	**Total sup**	**Consignment**	**Barcodes**	**RFID**	**Kanban**
DPV		5,068,735	6,382,515	5,523,330	5,136,924	5,136,924	5,136,924
input		**5,073,735**	**6,387,515**	**5,528,330**	**5,161,924**	**5,241,924**	**5,159,424**
output		**0.094**	**0.204**	**0.058**	**0.199**	**0.299**	**0.146**

Table 27: Input and output results if the input is calculated from DPV and fixed costs (source: Unilever SU Oss)

Combining the new input variables with the output variables of the six alternatives, results in a new graph. In Figure 12, the alternatives are shown on the same way as in Figure 8, with also an efficiency frontier. The four alternatives that are on the efficiency frontier in Chapter 4 are equal to the four alternatives on the frontier in this new situation and therefore they are used in the recommendations.

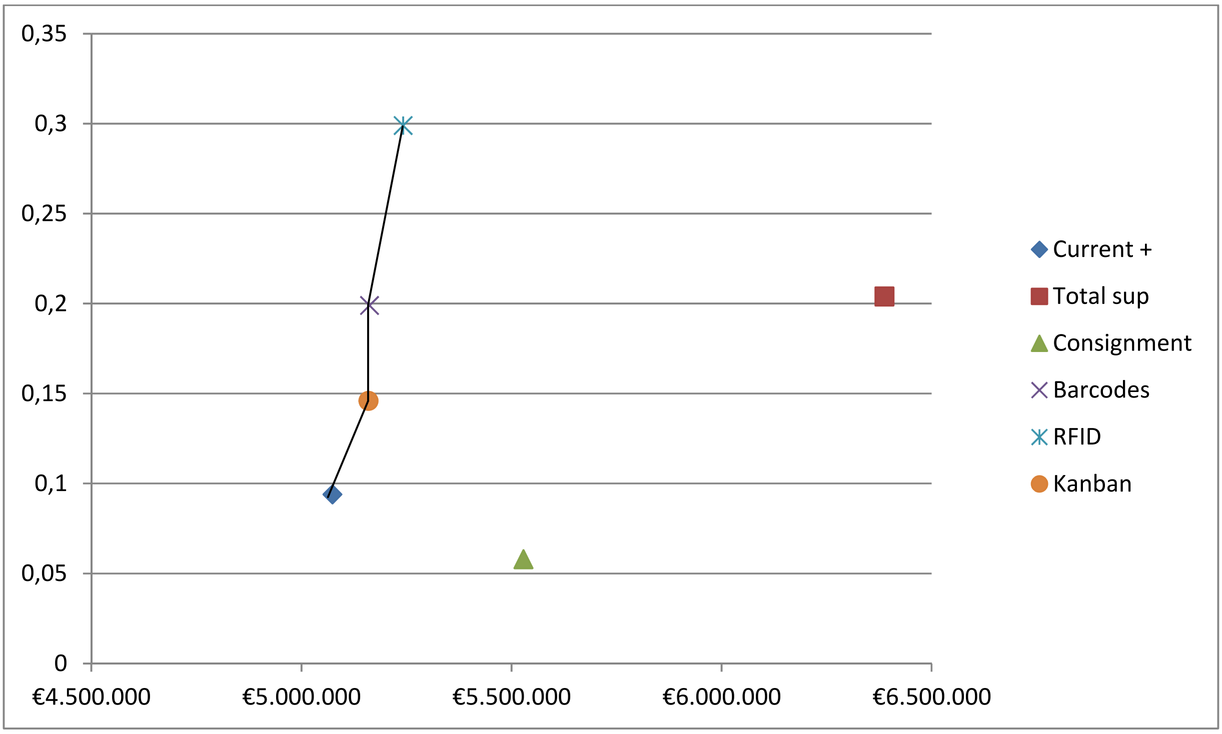

Figure 12: Input vs. output of the alternatives using a five year plan with an efficiency frontier (source: Unilever SU Oss)

Appendix 13: Time schedule for the implementation plan

In this appendix, the time schedule for the implementation plan is given. This time schedule is made to show which of the steps can be done simultaneously. The time numbers which are used are estimations and the total time span of 1 year is used.

Week 0

- Make the project team (end week 2)
- Clear job descriptions per person in the team

Week 2

- Start cleaning (end week 6)
- Ordering (end week 6)
- Counting (end week 6)
- Buy barcode scanners and integrate the software with the current SAP software (end week 14)
- Add barcodes on all containers (end week 6)

Week 6

- KPIs (end week 8)
- Information (end week 12)

Week 8

- Determine the number of clients (end week 10)
- Determine responsibilities of those clients for the TW (end week 12)

Week 12

- Training and education for using barcodes for the responsible clients (end week 14)

Week 14

- Start using barcodes (no end)
- Investigate SKU categories locations (end week 20)

Week 20

- Count the spares (end week 22)
- Start cycle counting
- Determine safety stocks based on information of week 2 to week 20 and historical data (en week 24)

Week 22

- Warehouse based on SKU categories (end week 32)
- ND and Z6

Week 32

- First control of reorder points etcetera
- Total check if there are new parts.

Week 40

- ‘New’ TW up and running, less DSS and an organized and structured warehouse!