In(ventory) control of spare parts at the warehouse of the TD of Bolletje Almelo

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Management summary

This research is conducted during six months at the Technical Department (TD) of Bolletje Almelo, as a master thesis for the study Industrial Engineering & Management (IEM) with the specialization Production and Logistics Management (PLM) at the University of Twente. The goal of the TD of Bolletje Almelo is to let all production lines produce as good as possible by conducting an optimal inventory management which minimizes downtime and costs, and maximizes the availability of the machinery. The TD of Bolletje Almelo has its own warehouse to stock spare parts and an IT system called Rimses to register different activities such as usage of spare parts and maintenance tasks. However, at the moment there are multiple problems which cause the lack of adequate inventory management at the warehouse of the TD of Bolletje Almelo, namely wrong and incomplete way of registration of spare parts in Rimses, and no or insufficient historical usage data of spare parts. Due to this it is difficult for the TD to make decisions based on historical data and to correctly estimate the required spare parts. Therefore, our main research question is defined as follows: *"How can adequate inventory management and control policies for the spare parts in the warehouse of the Technical Department of Bolletje Almelo be determined by creating an environment where the spare parts of the Technical Department are managed properly so as to balance the inventory costs and downtime of machinery?"*

The warehouse of the TD is the location for stocking spare parts, which includes simple spare parts like screws, but also complex and expensive spare parts like Programmable Logic Controllers (PLCs), bearings and motors. These spare parts are required for the maintenance of the machinery in the factory. We first considered the current situation, which showed that there is no adequate management and structure of the warehouse, and no adequate use of Rimses. Therefore, we provide an overview of all known problems and causes, which are also tackled in this research:

- Lack of discipline and instruction manuals.
- Not all parts in the warehouse have a barcode.
- No night supervision in the warehouse.
- No history available of consumption of spare parts and services separately.
- Wrong registration of spare parts and services in Rimses.
- Only one KPI used at the warehouse: stay within the budget.
- Incorrect and insufficient use of Rimses.

Secondly, by performing a literature study we investigated the importance of inventory management and control policies in warehouses, Key Performance Indicators (KPIs), the decision whether to stock or not, classification methods and different inventory control policies.

After performing this literature study we selected five Key Performance Indicators (KPIs) for the TD of Bolletje Almelo to create insight in their performance: percentage of stock outs, percentage of emergency purchases, percentage of non moving parts, percentage of target ship dates met, and production line availability. The production line availability is extracted from the Overall Equipment Effectiveness (OEE) tool of the production department. The data for the other KPIs is directly extracted from the Rimses database.

Additionally, we developed a decision making framework for the TD of Bolletje Almelo to justify when and where a specific spare part has to be stocked. The following three choices are compared in this framework: 1) Not stocking the spare part in the warehouse of the TD of Bolletje Almelo, 2) Stocking the spare part in the warehouse of the TD of Bolletje Almelo, 3) Stocking the spare part at the supplier, by using Consignment Inventory. These choices are compared with each other by calculating the total relevant costs for each choice.
Besides that, we selected the ABC analysis as classification method for the spare parts, whereby criticality is used as criterion. We define the degree of criticality by using the following aspects: delivery lead time, possibility of downtime and replaceability of the spare part. We chose an inventory control policy for each class of spare parts, based on the policies of Silver et al. (2017) and Rimses, see Table 0.1.

	Inventory control policy according to Silver et al. (2017)	Corresponding control policy in Rimses
A items	*(s,S)*	*Automatic: via reorder point and maximum stock*
B items	*(s,Q)*	*Automatic: via reorder point and EOQ*
C items	*Manual ~ (s,Q)*	*Manual: via reorder point and EOQ*

Table 0.1 Inventory control policies for ABC classification

To implement the above mentioned inventory control policies several activities are carried out in this research. The following actions are proposed and implemented to improve the management and structure of the warehouse, and the use of Rimses:

- Writing instruction manuals for different processes in Rimses.
- Generating and using pricelists with two of the core suppliers.
- Adequately using the standard Bolletje purchase numbers.
- Changing the current way of reception of spare parts, matching, and invoice registration.
- Specifying the object-ID MATERIAAL in Rimses in different object IDs.
- Generating a closed warehouse environment when the warehouse manager is not present.

By performing a pilot study we implemented the classification method and inventory control policies at multiple spare parts of the warehouse. The (expected) results of this research are as follows:

- Up to date economic values of the stock and historical data of invoices.
- Correctly registration of used spare parts and working hours.
- Complete and up to date quantities and economic values in Rimses of the stock in the warehouse.
- Warehouse manager is able to reorder according to the reorder suggestions from Rimses.
- Ability to determine the reorder point, EOQ and maximum stock based on the historical data from Rimses
- Time savings for the warehouse manager and manager of the TD. The manager of the TD saves approximately eight minutes per invoice, whereby about fifty invoices have to be matched per week.
- Better performance in the warehouse, due to higher reliability of the Rimses system and less chance of stock outs.

Recommendations are listed in Table 0.2 and formulated in the roadmap of Figure 0.1.

	Action	**Actor(s)**
1	Educate and supervise failure mechanics and other employees on correctness and completeness of registration of spare parts usage in Rimses.	TL
2	Classify spare parts according to classification method, select corresponding inventory control policy and set inventory control parameters in Rimses.	WM
3	Counting and registering all spare parts in the warehouse	N-MTS
4	Process inventory control policies in Rimses.	WM
5	Generate and use price lists with all suppliers in Rimses.	WM
6	Display and monitor KPIs at dashboard.	TL and M-TD
7	Reservation of spare parts in Rimses for certain maintenance tasks.	ME and N-MTS
8	Implement as much as possible standardization in the spare parts of different machinery.	TL, ME, M-TD
9	Rearrange the layout of the warehouse.	N-MTS
10	Implement Kanban system for more spare parts in the warehouse.	N-MTS and WM
11	After a year, investigate if criticality is still the best criterion for the ABC analysis, based on the available data in Rimses.	WM and M-TD
12	After a year, review the reorder points, EOQ, maximum stock levels in Rimses	WM
13	After a year, review or eliminate non-moving/slow moving spare parts in Rimses	WM
14	More adequate management and structure of the warehouse, and the use of Rimses	

Table 0.2 Recommended actions and corresponding actor(s)

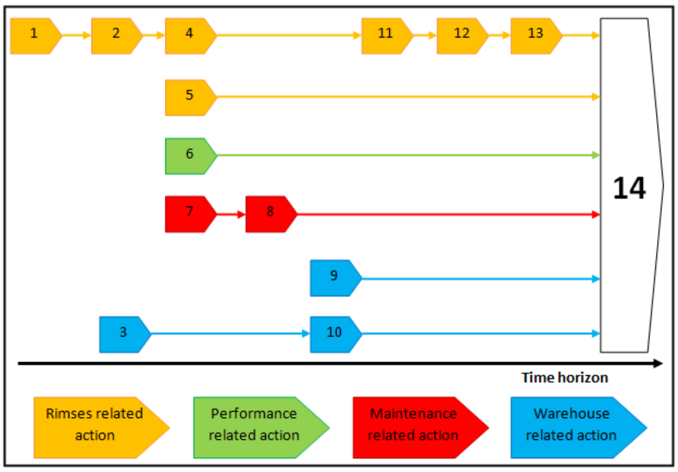

Figure 0.1 Roadmap including sequence of actions

Abbreviations actors:
TL = Team Leader
WM = Warehouse Manager
M-TD = Manager Technical Department
ME = Maintenance Engineer
N-MTS = New Master Thesis Student (to be announced)

Preface

The master thesis is the last step towards completing my master Industrial Engineering and Management (IEM), with the specialization Production and Logistics Management (PLM), at the University of Twente. This report is the result of my master thesis project at the Technical Department (TD) of Bolletje Almelo from February 2017 until July 2017, where I provide a scientific and independent view to improve the management and structure of the warehouse of the TD, and the use of Rimses (software tool used by the TD).

I would not have been able to write this thesis without the support of many people, to whom I am very grateful. First of all, I would like to thank my company supervisor G. Leeftink for the opportunity, the experience, the guidance and support throughout the research. Additionally, I would like to thank my colleagues for all good conversations and the support they provided me. Despite being the only woman at the TD, I really enjoyed working with all of you.

I also thank my supervisors of the University of Twente: Peter Schuur and Ahmad Al Hanbali, for their helpful discussions and valuable feedback to improve my work. Both supervisors provided me extensive support but also enthusiasm, which allowed me to bring my master thesis to a successful end.

Finally, I would like to thank my family and friends for all the love and support they gave me during my studies, which contributed to an unforgettable study time. Special thanks to my parents for their mental and financial support during my complete study time, who helped my get through the ups and downs during my entire studies.

I hope you enjoy your reading!

Almelo, 11th of July 2017

Mayke Schutte

Abbreviations and definitions

CI	*Consignment Inventory*
D3	*The financial accounting system of Bolletje Almelo*
EOQ	*Economic Order Quantity*
FD	*Financial Department*
KPI	*Key Performance Indicator*
L	*Lead Time*
ME	*Maintenance Engineer*
M-TD	*Manager of TD*
N-MTS	*New Master Thesis Student (to be announced)*
PD	*Production Department*
SCC	*Supply Chain Collaboration*
SS	*Safety Stock*
TD	*Technical Department*
TL	*Team Leader*
WIP	*Work-In-Process*
WM	*Warehouse Manager*
WO	*Work Order*
WR	*Work Request*

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1. Introduction

To complete the Master study Industrial Engineering and Management at the University of Twente, students have to perform a graduation project. This thesis describes a graduation project done at the company Bolletje B.V. into creating an environment for adequate inventory management and control policies for the spare parts within the warehouse of the Technical Department (TD) in Almelo.

This chapter introduces the graduation project. Section 1.1 describes relevant background about respectively the company, the factory and the department in which the research is being conducted. Section 1.2 presents the motivation of the research. Section 1.3 describes the problem description. Consequently, Section 1.4 and Section 1.5 respectively contain the research objective and the scope of the project. Section 1.6 outlines the research questions and research approach, and Section 1.7 describes the methodology. Finally, Section 1.8 concludes the chapter with the deliverables of this research.

1.1 Bolletje B.V.

To give a description of the company Bolletje B.V. we discuss some relevant topics in the following sections, namely the background, the factory in Almelo, the Technical Department, and Rimses.

1.1.1 Background

Bolletje is a Dutch industrial bakery headquartered in Almelo. It employs around 400 people over two bakeries: Almelo and Heerde. Bolletje was founded by Gerardus Johannes ter Beek in 1867 as a bakery with shop. In the twenties son Bernard started in the bakery with the specialization in *beschuit*. *Beschuit* is comparable with toasted bread, but more light and dry as bread. In the thirties the five sons and two daughters were included into the company, see Figure 1.1.

Figure 1.1 The family ter Beek (Bolletje B.V.)

Until 1952 Bolletje was not named as Bolletje, but as *Ter Beeks Eierbeschuit*. The products were mainly sold at bakeries, but these bakeries did not like to sell products with the name of another bakery on the package. So Gerard and his brother Jan invented another name when they were walking through the factory. They saw the little balls of dough for making *beschuit* and they decided to change the name of *Ter Beeks Eierbeschuit* to Bolletje. Besides that, an unforgettable and timeless slogan was invented: '*Ik wil Bolletje!'*, which is still in use at the commercials of Bolletje.

After the second world war the third generation of the family Ter Beek became an excellent specialist in *beschuit*. In 1954 they moved to the current plant location at the Turfkade in Almelo. At that moment there were already around twenty companies in the Netherlands which were producing *beschuit*, but after five years Bolletje became market leader.

In the mid sixties the fourth generation Ter Beek figured out that it would be too risky to focus only on *beschuit*, so they came up with a diversifying strategy. To achieve this Bolletje took over several companies in different segments of the market. Their assortment was expanded with several

Figure 1.2 Assortment of Bolletje (Bolletje B.V.)

products, like rye bread (*roggebrood)*, salty snacks (*zoutjes)* and gingerbread (*ontbijtkoek)*. Nowadays, Bolletje produces over 60 different products assorted in five segments: breakfast & lunch, in between (snacks), cookies, salty snacks, and season, see figure 1.2. In 2009 they added the latest new product to their assortment: knäckebröd.

Besides Bolletje's home market in the Netherlands, Bolletje also exports products to countries in Europe and countries with lots of Dutch emigrants, like New-Zealand, Australia, Canada and the United States. (Bolletje B.V.)

1.1.2 The factory in Almelo

The factory in Almelo consists of four different production sections, namely *Oude beschuit*, *Banket*, *Roggebrood*, and *Hal 16*.

The section *Oude beschuit* is the oldest section of the factory, where the first original production machines from 1954 are still in operation. This section consists of three different production lines, where different kinds of *beschuit* are being produced. Here it is interesting to mention "The story of the thirteen *beschuiten"*, see below.

The story of the thirteen *beschuiten*

Several reasons are given for the fact that a package contains thirteen *beschuiten*, but not twelve or fourteen *beschuiten*. The most obvious reason, given by Bolletje, is that this number is actually caused by "ordinary common sense". The width of the oven in which the *beschuiten* are baked is approximately one meter. In this meter exactly thirteen *beschuiten* fit next to each other (horizontal) in a row. In the fifties, the packing machine is adjusted to these thirteen *beschuiten* (Bolletje, n.d.)**.**

Another reason is given by the Nederlands Bakkerij Museum: In the 16th/17th century a ton of *beschuiten* was often too much for only private use. Citizens could buy smaller amounts in the form of one eight or one sixteenth part of a ton. It was also possible to buy a number of *beschuiten*, such as 150, 25 or 13 *beschuiten.* A number of 25 *beschuiten,* ¼ of 100, was called a *verndel*. One could also buy a half *verndel*, but because it is not possible to sell 12 ½ *beschuiten*, it was rounded to 13. This number was also called a baker's dozen (Nederlands Bakkerij Museum, n.d.)**.**

The section *Banket* consists of three different banquet lines, where products like small ginger cookies (*schuddebuikjes, kruidnoten)* and salty sticks are being produced.

The section *Roggebrood* consists of two rye-bread lines. The process of producing rye-bread is not a continuous flow of products like *beschuiten*, but is handled in batches. Batches of rye-bread are mixed, rested and baked in the oven. After the baking process the rye-bread is cooled, sliced and packaged.

The last section, *Hal 16*, consists of three different production lines. This section contains two knäckebröd lines and one new *beschuit* line.

1.1.3 The Technical Department

When a manufacturing process stops for an unplanned event, for example a motor failure, the downtime increases. Downtime time events are unplanned stops that are long enough that there is a reason for each occurrence. For most manufacturers down time is the single largest source of lost production time (Vorne). The goal of the TD of Bolletje Almelo is to minimize downtime in the production process and maximize the availability of the machinery. This means that the TD provides technical support to the production departments, so that they can produce adequately.

A team of approximately 25 people is working at the TD to perform all maintenance related activities, such as:

- Managing the (technical) inventory warehouse;
- Performing repairs, maintenance, modifications and inspections, both corrective and preventive;
- Planning repairs, maintenance, employees;
- Purchasing new machines or production lines.

Figure 1.3 shows the organization chart of the TD of Bolletje Almelo.

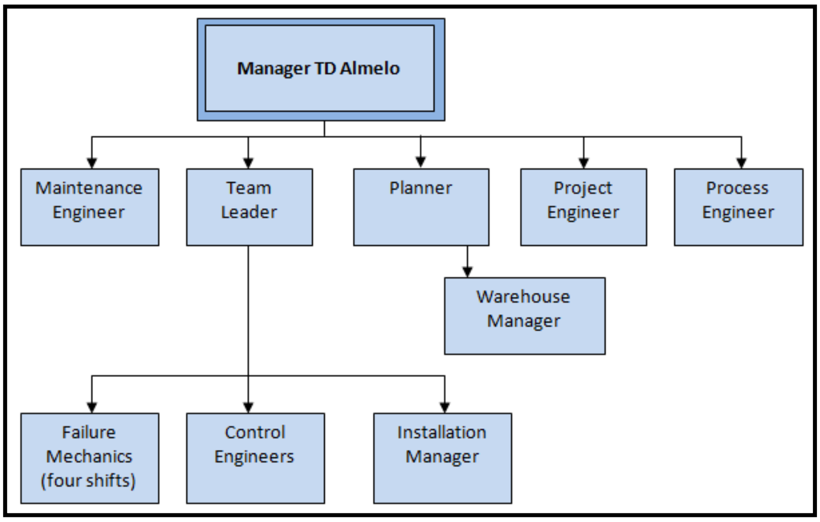

Figure 1.3 Organization chart Technical Department

The TD has its own warehouse, where different spare parts are stored for all technical and maintenance related activities. The warehouse manager has the responsibility of this warehouse, which consists of the following activities:

- Ordering spare parts;
- Registering invoices;
- Managing the inventory and inventory locations;
- Administrative actions.

The warehouse manager works with the software tool Rimses, see 1.1.4 for an explanation of this tool.

1.1.4 Rimses

Rimses is a software tool developed by ICT expert Realdolmen. Rimses provides maintenance services and service providers a powerful tool to optimize the organization and the productivity of maintenance operations (Rimses, 2016). For several years Bolletje uses Rimses, but since 2012 Bolletje uses the most up to date version of Rimses for different activities at the Production Department (PD) and TD. Different applications are possible through the use of Rimses, such as:

- Maintenance Management: preventive maintenance, total productive maintenance, inspection rounds, work flow management, work order management and capacity planning. (Rimses).
- Purchase and Inventory Management: purchase management, contract management, inventory management, warehouse management, overview purchase and stock management (Rimses).
- Service Management: service management, service contracts and sales management. (Rimses).

At the moment only a few of the functions of Rimses are used by Bolletje, like some maintenance management functions. However, Rimses could be used for more applications such as inventory management and warehouse management, so that inventory and maintenance are linked with each other.

1.2 Research motivation

The overall goal of Bolletje in the coming years is to make sure that every production line can produce a high quality product, at a constant level without any major interruptions.

The goal of the TD is to let all production lines produce as good as possible by conducting an optimal inventory management which minimizes downtime and costs, and maximizes the availability of the machinery.

For Bolletje the availability of their production machinery has a high priority. Downtime of their machinery could have disastrous consequences such as lost revenue due to production stagnation. To minimize the downtime, maintenance must be performed and this means having the right spare parts available in stock at the TD when they are demanded for conducting maintenance. However, in the current situation it frequently occurs that some spare parts are not on stock, whereas they are needed regular. This research is being conducted to determine which spare parts have to be stocked in the warehouse of the TD, and afterwards the stock levels and the reorder points of these spare parts are determined.

1.3 Problem description

As described in Section 1.1.2 Bolletje Almelo has different production lines, which all need different spare parts. Therefore the warehouse of the TD has also a lot of different spare parts in stock. New technologies, new innovations and new machinery also cause an increase in variety of the assortment of the warehouse. The following sections describe the problems of the warehouse of the TD of Bolletje Almelo, which is divided into the management of spare parts, and the registration of data in Rimses.

1.3.1 Management of spare parts

The spare parts inventory management represents a very complex problem due to difficulties concerning for example the large amount of the spare parts involved. However, as long as the service level of the warehouse is close to 95%, it is not a big problem to have a large number of spare parts in stock. According to the manager of the TD they do not reach this service level, because it is too often the case that some of the spare parts are not available when needed and/or the quantity of these parts is insufficient.

The supervision and control of the warehouse and its spare parts is done by the warehouse manager, who is present during workings days from 8.00 am to 4.00 pm. So during night there is no supervision in the warehouse. Normally, the spare parts which are needed by the mechanics are registered through a work order in Rimses, or they are registered by the warehouse manager in Rimses. However, during night it could be the case that the mechanics need some spare parts from the warehouse, but they forget to register these spare parts in Rimses or they write the used spare parts on a paper, so that the warehouse manager has to register them in Rimses the next day.

1.3.2 Registration of data in Rimses

Next to waiting for spare parts which are not available, there are differences in the number of spare parts in the warehouse and the number of spare parts that is registered in the IT system Rimses.
As mentioned earlier, the warehouse manager of the TD has the responsibility to order spare parts, manage the inventory and register the invoices. A spare part which is ordered by the warehouse manager, is physically stocked in the warehouse after delivering at the TD of Bolletje. However, in the Rimses system the spare part is not directly registered as incoming order and stocked part. The reason for this is because of lack of awareness of a function in Rimses: invoice registration. The price that has to be filled in during the ordering process in Rimses has to match with the actual invoice when receiving the parts. However, at the moment the warehouse manager waits with registering and stocking the incoming spare part in Rimses until the invoice arrives, which could take a day but also a couple of weeks. The desired situation is registering and stocking incoming orders directly, both physically and in Rimses.

Next to that, the designation of the spare parts in Rimses is not as it should be, because a lot of parts are designated as *materiaal*. Several years ago the Financial Department (FD) of Bolletje has decided to designate costs in four different groups: *materieel* (rent of machinery), *dienst* (hiring service mechanics), *materiaal* (other) and *contract* (contracts Bolletje). Nowadays a lot of spare parts, but also working hours of external service mechanics are designated as *materiaal*, consequently there is no history available on the usage of many spare parts and services. The desired situation is registering the physical spare parts and working hours separately in Rimses, which gives the possibility for the future to analyze the usage of all different spare parts. Thereafter the stock levels and reorder points are optimized, based on this actual usage data.

In general, the stock levels in Rimses are not up to date. Since 2012 Bolletje uses the newest version of Rimses, but all data from before 2012 is lost and only available in the previously used versions of Rimses. In 2012 they have done a inventory correction, but afterwards the stock levels are not updated again. So at the moment there are no actual stock levels, minimum stock levels and reorder points.

Finally, according to the manager of the TD and warehouse manager there is not sufficient collaboration between the warehouse of the TD and suppliers of spare parts. Schipper Techniek is one of the big suppliers of the TD and is located close to the plant location of Bolletje Almelo. At the moment the inventory levels of Bolletje and Schipper Techniek are not matched to each other. Therefore some of the spare parts are available in large quantities in the warehouse of the TD of Bolletje, whereas Schipper Techniek also has a big inventory of these spare parts. The desired situation is to match the inventory levels of Bolletje and other (major) suppliers with each other.

Concluding we can say that the main problems for the lack of good inventory management at the warehouse of the TD at Bolletje Almelo are the wrong and incomplete way of registration of spare parts in Rimses, the fact that no or insufficient historical usage data of spare parts is available and the weak collaboration with suppliers. Due to this it is difficult for the warehouse manager to make decisions based on historical data and make correct estimations of required parts.

1.4 Research objective

Based on the problem description in Section 1.3, the objective of this research is defined as follows:

***Research goal:** gain insight in how to determine adequate inventory management and control policies of the spare parts at the warehouse of the TD, including minimum stock levels and reorder points, so as to balance the inventory costs and downtime of machinery.*

1.5 Scope of research

The time frame of this research is six months and therefore this research is scoped in different ways.

Firstly, this research is carried out at the TD of Bolletje Almelo, because the TD is the initiator. Therefore the view of the TD is used as guideline, so answering the main research question contributes to improvement of the performance of the TD.

Besides that, the warehouse of the TD Almelo is only used as a source of information, and the warehouse of the TD Heerde is not taken into account.

Data about usage and purchases given by the software Rimses is analyzed to provide information about the demand of the different spare parts.

Finally, in literature there are two well-known types of maintenance: corrective maintenance and preventive maintenance. With both planned and unplanned demand, from corrective and preventive maintenance, it is possible to allocate special stocks of a part for preventive maintenance and another for corrective maintenance. The TD of Bolletje is responsible for the corrective and preventive maintenance of the complete machinery at the factory in Almelo. In the past the TD mainly performed corrective maintenance, but since several months the TD of Bolletje moves towards a preventive maintenance environment. This means that the available data about spare parts usage until now is mainly based on corrective maintenance. The coming year (February 2017 – February 2018) is needed to store data about the spare part usage of corrective and preventive maintenance. See Section 2.2 for more information about the maintenance procedure at Bolletje Almelo. Therefore this research focuses on keeping one pool of inventory for planned (preventive) and unplanned (corrective) maintenance demands.

1.6 Research questions/approach

To realize the objective of this research, as stated in Section 1.4, the main research question is formulated as follows:

***Main research question*: How can adequate inventory management and control policies for the spare parts in the warehouse of the Technical Department of Bolletje Almelo be determined by creating an environment where the spare parts of the Technical Department are managed properly so as to balance the inventory costs and downtime of machinery?**

Six research questions, including some sub-questions, are formulated to answer the abovementioned main research question. These research questions represent the main chapters of this report.

***Question 1:* What is the current way of working within the warehouse of the Technical Department of Bolletje Almelo?**

- *What is the current design of the warehouse?*
- *What is the current maintenance strategy?*
- *What is the current way of working when looking at the warehouse operations?*
- *Which data is available from the current inventory management, such as usage and classification of spare parts?*
- *What are the current Key Performance Indicators at the warehouse?*
- *What is the current performance at the warehouse?*
- *What are the bottlenecks in the current warehouse?*

Firstly, it is necessary to do a zero-measurement. Chapter 2 describes the current situation within the warehouse of the TD with all background information. This analysis takes place by means of interviews and conversations with relevant employees of Bolletje, and data gathering in Rimses and other relevant documents from Bolletje.

***Question 2:* What methods are available in literature for managing spare parts in the warehouse of production companies?**

- *What is the importance of spare parts management and control policies?*
- *What Key Performance Indicators are found in literature to measure the performance of a warehouse?*
- *How to determine whether to stock (critical) spare parts or not?*
- *What classification methods are available in literature besides the ABC classification?*
- *What inventory control policies are available in literature?*

After analyzing and describing the current situation, in Chapter 3 a literature research is done to find theories about successful methods and plans for managing spare parts in warehouses. This literature research includes topics such as inventory control, Economic Order Quantity (EOQ), reorder points and safety stock.

<u>Question 3:</u> How to organize the (new) inventory control policies at the warehouse of the Technical Department of Bolletje Almelo?

- *What Key Performance Indicators give a representative review of the performance of the warehouse of the TD of Bolletje Almelo?*
- *What requirements are stated for the (new) inventory control policies for the warehouse of the TD of Bolletje Almelo?*
- *Which approach do we use to determine which (critical) spare parts to stock and which ones not at the warehouse of the TD of Bolletje Almelo?*
- *What classification method do we select to classify the spare parts from the warehouse of the TD of Bolletje Almelo?*
- *How do we develop the (new) inventory control policies, based on the selected KPIs, classification method and requirements?*

By having interviews and conversations with the manager of the TD and the warehouse manager the KPIs from Chapter 3 are discussed and afterwards suitable KPIs for the warehouse of the TD of Bolletje Almelo are selected in Chapter 4. Besides that, the requirements for the (new) inventory control policies are discussed with the manager of the TD and the warehouse manager, so that the control policies from Chapter 3 are compared with these requirements. Based on the literature from Chapter 3, a classification method to classify the spare parts in the warehouse is chosen. Finally, in this chapter inventory control policies are developed for the warehouse of the TD of Bolletje Almelo, based on the KPIs, classification method and requirements.

<u>Question 4:</u> How to implement these (new) inventory control policies at the warehouse of the Technical Department of Bolletje?

- *What activities should be carried out to reach a successful implementation of the (new) inventory control policies?*
- *How to execute these implementation activities at the warehouse of the TD of Bolletje of Almelo?*

In Chapter 5 an implementation plan arises after answering the research questions from the previous chapters. The activities of this implementation plan are based on the requirements, selected classification method and selected inventory control policies from Chapter 4. By having several meetings with the Financial Department, warehouse manager and manager of the TD we agree on the changes and consequences related to the implementation plan. So after these meetings and some tests we already start with the implementation phase of these activities.

<u>Question 5:</u> Based on a pilot study, what are the expected results of the chosen method and inventory control policies for the warehouse of the Technical Department of Bolletje Almelo?

- *How to execute the pilot study at the warehouse of the TD of Bolletje Almelo?*
- *What are the results of this pilot study?*
- *What are the expected results when implementing the classification method and (new) inventory control policies at the whole warehouse of the TD of Bolletje Almelo?*

In Chapter 5 we have carried out several implementation activities to reach a successful implementation of the chosen classification method and inventory control policies. Consequently, in Chapter 6 we execute a pilot study at the warehouse of the TD of Bolletje Almelo, in order to test the chosen classification method and inventory control policies. This pilot study is executed in collaboration with the warehouse manager and some failure mechanics of Bolletje. Afterwards we analyze some of the results of this pilot study and we map the expected results when implementing it at the whole warehouse of the TD of Bolletje Almelo.

<u>Question 6:</u> What are the conclusions and recommendations for the warehouse of the Technical Department of Bolletje Almelo?

- *What can be concluded by answering the main research question of this research?*
- *What are recommendations for the TD of Bolletje Almelo, based on this research*?

Finally, in Chapter 7 the main research question is answered based on the results of the other questions. This chapter also includes some recommendations for the TD of Bolletje. These recommendations also include a roadmap which defines how the TD of Bolletje Almelo has to continue in the future, because not all issues are addressed in this research, due to time limit.

1.7 Deliverables

- Development of inventory management and control policies for the warehouse of the TD of Bolletje Almelo, which are implemented in Rimses.
- Implementation plan
- Instruction manual for the warehouse operations and a pedestrian approach for Rimses
- Correctly working warehouse operations system
- Correctly working Rimses system, by using the right functions
- Roadmap which describes how the TD of Bolletje has to continue in the future.

2. Current situation

This chapter describes the current situation of the warehouse of the TD of Bolletje Almelo, by answering the first research question: "What is the current way of working within the warehouse of the Technical Department of Bolletje Almelo?".

We first describe the current arrangement of the warehouse of the TD in Section 2.1. Section 2.2 explains how maintenance is performed at Bolletje in Almelo. In Section 2.3 there is a description about the different activities in the warehouse, such as picking and ordering. Section 2.4 and Section 2.5 represent respectively the available data and Key Performance Indicators. The current performance is described in Section 2.6. Section 2.7 shows the problem tree, including all bottlenecks of the warehouse of the TD. Finally, Section 2.8 gives a summary of this chapter.

2.1 Design of the warehouse

The warehouse of the TD is the location for stocking spare parts, such as screws, bearings and motors. The warehouse is controlled by one warehouse manager, who is present every working day from 8.00 am to 4.00 pm and responsible for storing, ordering and receiving spare parts. Mechanics and production personnel from Bolletje can take spare parts from this warehouse. At this moment around 5,600 unique spare parts are available in the warehouse, with a total of approximately 53,000 spare parts. Each spare part has its own barcode, which is attached to the shelf or storage rack where the part lies. In this way the users and the warehouse manager can easily scan the barcode of a specific spare part. However, at the moment approximately five percent of the spare parts does not have a barcode.

The warehouse consists of different areas, namely a ground floor within the warehouse (area 1), a upper floor within the warehouse (area 2) and a storage area within one of the old production halls (area 3). Appendix 1 and Appendix 2 show the map of the ground and upper floor of the warehouse, for each of the areas. Area 1 and 2 include the smaller spare parts, such as lamps and bearings. Area 3 (storage racks 50 – 58) includes especially the bigger spare parts which are too big to store within the warehouse, such as motors, cables, pipes, and other mechanical or electrical components.

Storage racks 1 and 2 from area 1 are assigned to one specific but essential supplier, namely It's Me, so these storage racks only include spare parts from It's Me.

According to the manager of the TD and the warehouse manager there is insufficient collaboration between the warehouse of the TD and suppliers of spare parts. Schipper Techniek is one of the big suppliers of the TD of Bolletje Almelo and is located close to the plant location of Bolletje Almelo. Nowadays, both Bolletje Almelo and Schipper Techniek have their own inventory, but without cooperation in their inventory levels. This causes large quantities of spare parts inventory at both companies, which is unnecessary. It is also possible to match their inventory levels, allowing lower inventories and lower inventory costs for Bolletje.

2.2 Maintenance

The TD of Bolletje Almelo has the responsibility to perform corrective and preventive maintenance for the complete machinery at the factory in Almelo. Corrective maintenance is unplanned maintenance in which parts that have failed unexpectedly are replaced, whereas preventive maintenance is planned maintenance in which parts are replaced in order to prevent future failures. Corrective maintenance cannot be planned in advance and thus, in order to prevent excessive downtime due to unplanned failures, safety stock must be held to meet these demands. Preventive maintenance is planned in advance and thus the spare parts which are required can be ordered to arrive just-in-time (Basten & Ryan, 2015). While it is possible to manage the spare parts inventory for these two demands separately, this research focuses to jointly control this inventory, because until now there is no separate data available from both corrective and preventive maintenance, as already mentioned in scope in Section 1.5.

Until the summer of 2016, most of the man hours of the failure mechanics from the TD were used for urgent failure solving. The only preventive maintenance that was being performed were so called maintenance weeks. For every production line one week per year was planned for periodic maintenance, where some standard maintenance activities were being performed.

During the past few months, but also during the coming months, the TD of Bolletje Almelo tries to move towards a more preventive maintenance environment. Firstly, the mechanics from Bolletje are registering their activities through a special smartphone and corresponding application. This is among others implemented to register the usage of spare parts, so that after a few months a history of spare parts usage is available. This history is used to plan preventive maintenance in the future and order spare parts, because then the TD knows the frequency of failures and the demand of specific spare parts. Besides that, they implemented the Monday morning maintenance, which means that every week on Monday morning one production line is planned for preventive maintenance. This preventive maintenance consists of cleaning, lubrication and inspection of the production lines.

2.3 Activities in the warehouse

Various activities are performed in the warehouse of the TD of Bolletje Almelo, which are described in the following sections. The following activities are covered: picking and consuming spare parts; ordering spare parts; receiving spare parts, and registering spare parts and invoices.

2.3.1 Picking and consuming spare parts

At the moment there are two different ways in which spare parts are picked up from the warehouse, namely digital through a smartphone and on paper. To create more understanding of how this works, there is first an explanation about the registration of maintenance activities.

At Bolletje there is a distinction between the registration of maintenance activities in Rimses, namely registration of urgent failures (Prio 1) and non-urgent maintenance activities (Prio 3). A Prio 1 is directly registered in the form of a work order (WO), because it is urgent and crucial that it is solved as soon as possible, so no planning is required. A Prio 3 is registered in the form of a work request (WR). This WR is planned by the planner of the TD and when this WR is ready to perform it turns into a WO.

Since February 2017 the mechanics from Bolletje are using a special smartphone with 2D scanner, see Figure 2.1, which is used in combination with an application developed by IT system Rimses. At this moment only the failure mechanics of Bolletje are using this smartphone and application. When an operator in the factory encounters a machine failure or something else in the factory which is not working as it should

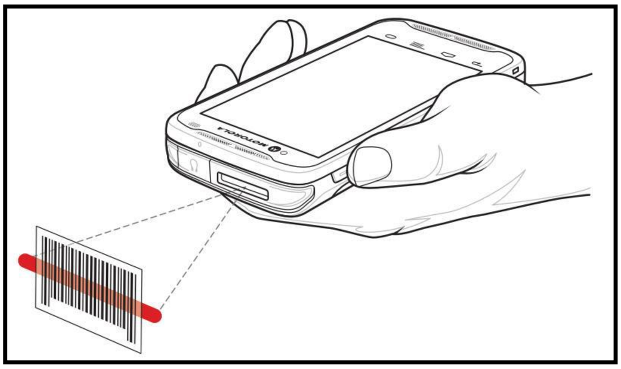

Figure 2.1 Smartphone with 2D scanner used by the TD

be (a Prio 1), a failure mechanic from the TD of Bolletje is called. Then the failure mechanic can start a WO by clicking 'Start Prio 1' in the application of his smartphone and register time, corresponding machine (by using the 2D scanner), work description, type of work, symptom, cause and action in the specific WO. When a failure mechanic has to execute a Prio 3, the planner creates a WO which shows up in the application on the smartphone of the mechanic. The failure mechanic only has to click on a WO which he wants to execute and again he can register all relevant data. When this failure mechanic needs spare parts from the warehouse for a specific WO (both for Prio's 1 and Prio's 3), he can go to the warehouse, scan the barcode of that part which is attached to the shelf or storage rack where the part lies in the warehouse and take the part. All information registered and scanned by the smartphone is automatically stored in Rimses, so that used spare parts are correctly registered in Rimses and thereafter these spare parts can be analyzed. Finally, this leads to the situation that the warehouse manager gets reorder suggestions from Rimses, so that required spare parts are almost always available on time and there are less stock outs.

Besides that there is another way to pick and register spare parts. Mechanics from external companies and production personnel do not have the aforementioned smartphone and application, so they have to register the required spare parts on paper. They can go to the warehouse when they need spare parts for a specific work order or machine, but the registration of these spare parts works differently. At the desk of the warehouse there is a registration paper for spare parts. On this paper the person who is picking up a spare parts has to fill in the WO (written as *Werkorder* on the Dutch paper*)*, the barcode of the specific part (*Objectcode)*, number of parts (*Aantal)*, his or her name (*Naam monteur)*, and finally if the picked part is the last one in the warehouse (*Laatste)*, see Figure 2.2.

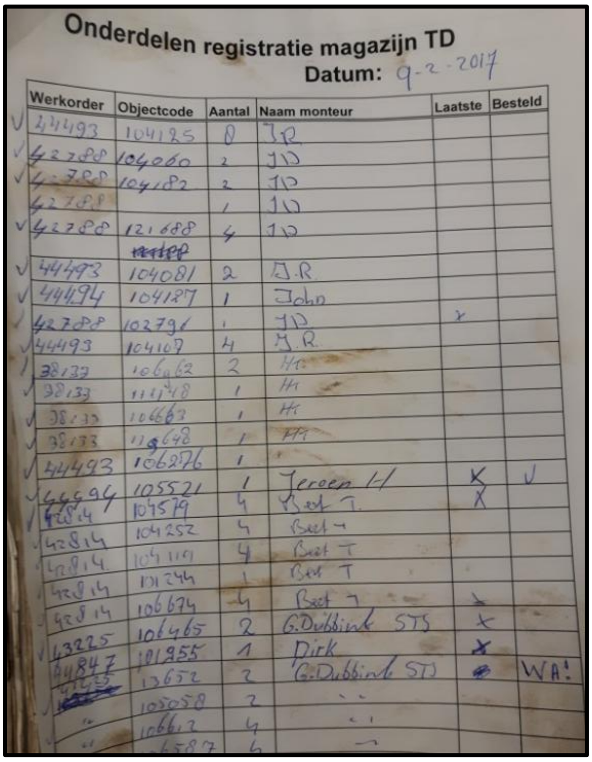

Figure 2.2 Registration of spare parts on paper

Every day all used spare parts written on the paper are registered by the warehouse manager in Rimses, which is an extra step compared to the registration of parts through the smartphone and application.

2.3.2 Ordering spare parts

As mentioned earlier, the warehouse manager of the TD is among others responsible for ordering and receiving parts. The warehouse manager orders parts if they are not available in the warehouse but needed for a rush order, or he orders according some parameters for restocking (called *herbevoorradingsparameters* in Rimses). The parameters used in Rimses are: reorder policy (*Bestelpolitiek*), method of restocking (*Herbevoorradingswijze)*, EOQ, reorder point (*Bestelpunt)*, maximum stock (*Max. voorraad)*, multitude (*Veelvoud)*, minimum order (*Min. bestellen)* and monthly usage (*Maandverbruik)*, see Figure 2.3.

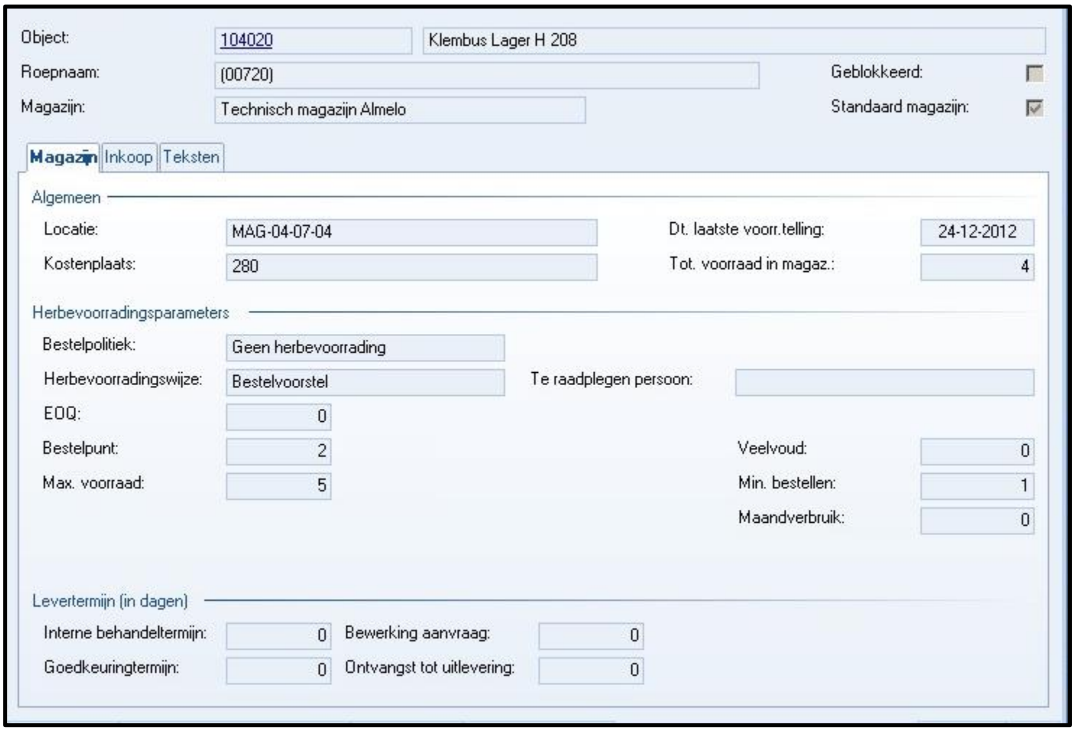

Figure 2.3 Restocking parameters in Rimses

Using the reorder policy enables the warehouse manager to determine how the parts should be restocked. For restocking of parts there are five different reorder policies in Rimses, divided into automatic and manual restocking:

- No restocking.
- Automatic – via reorder point and EOQ: restocking the EOQ, if the inventory position is below the reorder point. The warehouse manager gets an automatic reorder suggestion from Rimses.
- Automatic – via reorder point and maximum stock (as defined in Rimses): restocking the difference between the current available inventory position and the maximum stock (as defined in Rimses), if the inventory position is below the reorder point. The warehouse manager gets an automatic reorder suggestion from Rimses.
- Manual – physical stock, reorder point and EOQ: based on the inventory position, restocking the EOQ if the inventory position is below the reorder point. The warehouse manager has to order manually.
- Manual – physical stock, reorder point and maximum stock (as defined in Rimses): based on the inventory position, restocking the difference between the current inventory position and the maximum stock (as defined in Rimses), if the inventory position is below the reorder point. The warehouse manager has to order manually.

The formula used in Rimses for automatic calculating the EOQ is as follows:

$$\sqrt{\frac{2 * average\ consumption * fixed\ cost\ per\ order}{holding\ cost\ per\ unit}}$$

If the stock of a specific part is below the reorder point, Rimses automatically generates a reorder suggestion, afterwards the warehouse manager can decide if he wants to reorder or not (Rimses, 2015).

At this moment for most of the spare parts the reorder policy and other parameters for restocking are defined in Rimses. However, the values of these restocking parameters are not up to date, because there are differences in the stock which is registered in Rimes and the physically stock in the warehouse. Besides that, the warehouse manager does not use the so called reorder suggestions, because in the current situation he reorders required spare parts manually instead of via the reorder suggestions from Rimses.

Besides that, for the supplier It's Me, an essential supplier of the TD of Bolletje, the ordering process is different, because they use the two-bin Kanban system. Kanban is the Japanese word for a card or signboard. According to Association of Southeast Asian Nations (ASEAN) (2014) the definition of Kanban is: "a signal that gives an instruction to get, move, produce, order, or take some other activity with production materials". So Kanban tells when to order, what to order, how much to order, and where to order it from. As already mentioned in Section 2.1, It's Me has its own storage racks in the warehouse of the TD. Each part from It's Me has two boxes filled with parts behind each other in the storage rack of the warehouse. Required parts are picked from the front box and if this front box is empty, it is moved to a separate storage rack which contains three different shelves: empty boxes, spare parts in order and spare parts that need to be ordered. Once a week the warehouse manager updates this separate storage rack and by scanning the empty boxes he orders new spare parts, so that all empty boxes are filled again. In the meantime the second box, which was behind the empty box, is placed forward, making it still possible to pick the relevant part from the warehouse. The order list is automatically send to It's Me, but the warehouse manager has to register the ordered parts manually through a so called inventory correction in Rimses. For It's Me it is an easy and efficient way for reordering parts, however it makes it difficult for Bolletje because It's Me is the only supplier who is working in this way and the warehouse manager has to do some extra steps during the ordering process.

The last step in the ordering process is estimating the costs of the order, based on experience of the warehouse manager, previous orders and other information. In Rimses there is a possibility to work with price lists, a link between suppliers and parts. A price list includes among others the purchase prices of parts, eventually split into discount prices, and the expiration date of these prices. For one part there may be different price lists from different suppliers, which enables the customer to choose the best price. Though, the warehouse of the TD of Bolletje is yet not using these price lists.

2.3.3 Receiving spare parts, and registering spare parts and invoices

After ordering and receiving the spare parts from the supplier the warehouse manager physically stores the received parts in the warehouse. However, at this moment it is not possible for the warehouse manager to put a received part on stock in Rimses if the invoice has not been received yet. Because of lack of awareness he is not using an essential function in Rimses: invoice registration. This function enables a purchaser to check and register incoming invoices from suppliers. After receiving the invoice the purchaser checks if the invoice corresponds with the parts he or she ordered. If there are any deviations in the invoice, such as extra transport costs, these costs are entered in Rimses. By entering these deviated costs in Rimses, the invoice is also ready for accounting (Rimses, 2015).

So the registration of spare parts and invoices is at the moment a cumbersome process. Appendix 3 and 4 show the flow of these processes. If the invoice is delivered together with the ordered parts there is no problem, but often it takes several days, weeks or months before receiving the invoice which causes differences between the number of parts and the stock value in the warehouse and in Rimses. To get more understanding of the above mentioned fact there is an example of this case, see Example 1 below.

Besides the lack of awareness of the invoice registration, the warehouse manager is not working with price lists, as already described in Section 2.3.2, which makes it difficult for him to fill in the costs during the ordering process. The lack of using price lists and the invoice registration function causes that the incoming parts are only registered and stored in Rimses when the invoice has arrived, so that the costs in Rimses are correctly entered.

Example 1

1) *The Warehouse Manager (WM) orders ten screws at Wednesday 1 March, because they are out of stock, both physically in the warehouse and in Rimses.*
- *The WM estimates that the total ordering costs are € 12.50. He has to estimate these costs, based on experience and historical data.*

2) *The ten parts are delivered on Monday 6 March. These ten parts are physically stocked in the warehouse. However until the invoice arrives, the stock level in Rimses is zero, because the WM cannot register the parts in Rimses. This is because the invoice has not arrived yet and until that moment the WM is not sure about the final ordering costs.*

3) *In the meantime, at Friday 17 March, one of the mechanics from Bolletje needs four screws, so this mechanic picks the four screws from the warehouse and then the actual stock level is six. The mechanic cannot register these four screws within a WO, because Rimses shows a stock level of zero, and a negative stock is not possible. Therefore the WM writes this usage on a separate paper, including the user, number of the WO, quantity, and the object code of the part.*

4) *After a long time, the invoice arrives at Wednesday 5 April. Now the WM can put the ten ordered screws on stock in Rimses by registering the invoice. The invoice has total ordering costs of € 15 so the WM changes the estimated ordering costs from € 12.50 to € 15. So this results in a difference in stock: a stock level of ten screws in Rimses, but a stock level of six screws in the warehouse.*

5) *In the case the WM still has and remembers his written paper, he can solve this difference by belatedly registering the four screws (which are already used by one of the mechanics) within the right WO.*

Table 2.1 shows a summary of the above described steps.

	Date	Stock level in warehouse	Stock level in Rimses	Value of stock in warehouse (based on order costs)	Value of stock in Rimses (based on order costs)
1	Wednesday 1 March	0	0	€ 0	€ 0
2	Monday 6 March	10	0	Estimated on € 12.50	€ 0
3	Friday 17 March	6	0	Estimated on € 7.50 (= 6 * € 1.25)	€ 0
4	Wednesday 5 April	6	10	€ 9 (= 6 * € 1.50)	€ 15 (= 10 * € 1.50)
5	In case of revision	6	6	€ 9 (= 6 * € 1.50)	€ 9 (= 6 * € 1.50)

Table 2.1 Data summary from Example 1

So through the current way of registration of spare parts there is never a real-time quantity and value of the stock in the warehouse and in Rimses.

2.4 Available data

Rimses is the software tool used by the TD of Bolletje Almelo for purchasing, maintenance and inventory management.. When looking to the data of inventory management in Rimses, this data is not up to data and complete. The first reason is because the stock levels are not updated again after the update of Rimses and inventory correction in 2012. For some of the spare parts the actual stock levels, minimum stock levels and reorder points are corrected by the warehouse manager in the meantime, but the majority of the parts needs revision.

Another reason is the designation of spare parts and services. As already mentioned earlier, the costs at the TD are divided into four different groups: *materieel, dienst, materiaal* and *contract.* An example of *materieel* is renting a cherry picker (hydraulic crane) from an external company. An example of *dienst* is hiring an external mechanic. An example of *contract* is an activity performed by an organization with which Bolletje has a contract, such as an annual check of the fire detectors. The remaining spare parts and services, also working hours, are designated as *materiaal*. These objects are designated as *materiaal* for several reasons. Sometimes there is a WO which includes some spare parts, but also working hours, and then it is difficult to split these two different costs, so then they are together designated as *materiaal*. Another reason is the laziness of the people who have to register the object in Rimses, because according to them it is easier to register the specific object as *materiaal* then making a new *Object-ID.* Finally this causes that there is no history available of the usage of different spare parts, see Figure 2.4. All spare parts shown in this figure with Object-ID *materiaal* cannot be used to analyze the usage of spare parts. Figure 2.5 gives an example of an object registered as *materiaal.* This object comes from supplier Boplan Nederland BV and the costs are € 1,329.20. Because of the designation of *materiaal*, it is not clear if this object includes used spare parts and/or work hours, so therefore an analysis of the usage and costs is impossible.

Datum	Leverancier	Leveranciernaam	Object-ID	Objectnaam	Hoeveelheid	Eenheid	Waarde (EUR)	Kostenplaats beweging	Kostenplaats object	WO-nr.
15-2-2017	00994	Voskamp Bouw en In	MATERIAAL	MATERIAAL	1	ST	8,19	280	750.WPL	
15-2-2017	08030	Pacoma Europe (Siat	121691	Borgring, Anello a Scatto S	11	ST	10,384	403.INP		42759
15-2-2017	51301	Leering Hengelo BV	MATERIAAL	MATERIAAL	1	ST	18,22	280	750.WPL	
15-2-2017	23120	Ingersoll Rand Interna	CONTRACT	TD Onderhoudscontracten	1	ST	4220,34	280.PLI	280	44521
15-2-2017	51174	Lodige Benelux	CONTRACT	TD Onderhoudscontracten	1	ST	1402	750	280	
15-2-2017	00866	HRT Service & Tech	DIENST	TD Uitbesteed werk	1	ST	1539	280	280	
15-2-2017	73497	Schipper Technische	107117	Naaldlager NKI 43/30	6	ST	144,72	403.021	280	42788
15-2-2017	50926	Lowik Installatietechni	MATERIAAL	MATERIAAL	1	ST	243,2	750.402	750.WPL	43959
15-2-2017	94722	Eriks Servicecenter Al	121668	RVS Meetlat met plakstrip	25	ST	44,4375	H16		44371
15-2-2017	24278	Itsme	121608	Siemens, 6ES7511-1AK01-	1	ST	524,56	B121TD007		
15-2-2017	07829	Boplan Nederland BV	MATERIAAL	MATERIAAL	1	ST	1329,2	400	750.WPL	34987
13-2-2017	24278	Itsme	121460	LENS ROOD Moeller M22-	14	ST	10,0912	280		
10-2-2017	09645	Busch BV	MATERIAAL	MATERIAAL	1	ST	6444	409.353	750.WPL	44502

Figure 2.4 Designation of spare parts in Rimses

Boplan Nederland BV	MATERIAAL	MATERIAAL	1	ST	1329,2

Figure 2.5 Example of an object registered as materiaal in Rimses

To get useful data in the future from the usage of the different spare parts, all physical spare parts and working hours should be registered separately in Rimses. As a result, one can, for example after a year, reviewing and updating the stock levels and reorder points, based on the usage of the past year. Besides that, Bolletje gets insight in the different costs per machine, because then there is made a distinction between spare parts costs and man hour costs.

Thirdly, there is a possibility in Rimses to use a ABCDE classification for spare parts. This ABCDE classification in Rimses is comparable with the standard ABC classification, but then with five different classes instead of three different classes. Though, at the moment Bolletje is not using this function, because it is entered as a default setting for all parts in Rimses, namely all parts are registered as class E. By using this classification in Rimses, the inventory management of the spare parts is more adequate in the future.

The ABC classification is an interesting method to classify the spare parts in the warehouse of the TD of Bolletje Almelo, because this classification method is already available at Bolletje through using Rimses correctly. In Chapter 3 some other alternative classification methods are investigated and explained. This is done to compare them with the ABC classification method and to select the best classification method of spare parts for Bolletje in Chapter 4.

2.5 Key Performance Indicators

Rimses Analyzer is one of the additional modules which could be a added to the standard Rimses tool. Rimses Analyzer retrieves all relevant data about installations, machines, work orders, maintenance services, purchase processes and stock from the Rimses database, loads the information in a data warehouse and creates a number of cubes (maintenance, stock, purchase, sales). By using another tool such as Microsoft Excel, SQL Server Reporting Services or QlikView, a company is able to analyze the information and create reports (Rimses). Figure 2.6 shows the technical concept of Rimses Analyzer and how it works.

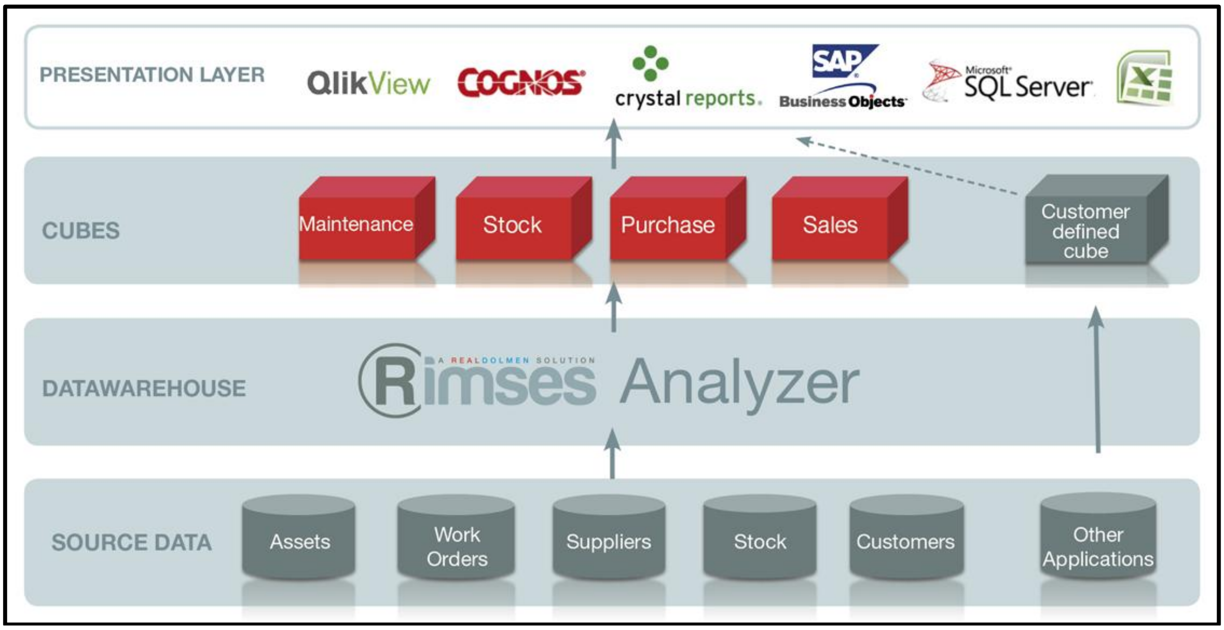

Figure 2.6 Rimses Analyzer technical concept (Rimses)

The following sets of KPIs could be used through Rimses Analyzer:

- Maintenance: Mean Time To Repair, planned versus unplanned work, failure rate, top 10 failures;
- Purchase: average delivery time, delivery reliability, delivery percentage;
- Warehouse: stock value, stock rotation, number of movement via MRP (Rimses).

The TD of Bolletje Almelo already possesses the Rimses Analyzer module for several years, but unfortunately they are not using this functional tool. Besides that, the TD does not make use of any other sort of resource to create insight how they are actually performing. The TD tries to keep the production lines up and running, with one restriction, namely stay within the budget. Concluding we can say that there is only one KPI, namely stay within the budget. In Chapter 3 a literature study is done about among others KPIs for a warehouse. In Chapter 4 the KPIs which are suitable for the warehouse of the TD of Bolletje Almelo are selected through a meeting with the TD manager and warehouse manager.

2.6 Current performance

Normally it is possible to measure the performance of a company, department, activity or machine with several KPIs, which are suitable for the given situation. However, the warehouse of the TD does only have one KPI, which makes it difficult to say something about the current performance. Rimses contains a lot of useful information which could be used to manually analyze the current performance of the warehouse of the TD of Bolletje Almelo. At the moment there is only a limited amount of data available from Rimses, namely data concerning the number of out of stocks, and the number and value of spare parts, as described in the following sections.

2.6.1 Number of stock outs

From Rimses some useful data is obtained about the warehouse history. Analyzing this data gives information about the orders, usage and stock corrections. For the year 2016 a manually analysis in Excel is done to say something about the number of stock outs. A stock out means that a spare part is required by a failure mechanic or someone else, but not directly available from the warehouse. Therefore the warehouse manager first has to order the required part, before the part is available for usage. According to Dewald (2011) the percentage of stock outs is calculated as follows:

$$\frac{Number\ of\ occurences}{Total\ spare\ parts\ picked} * 100\%$$

As already mentioned in Section 2.4 a lot of costs at the TD are not designated correctly, because they are designated as *materiaal* whereas they could be spare parts, but also services. For this reason the number of stock outs from Rimses is not correct, because the number of stock outs excluding all parts designated as *materiaal* is a lower bound of stock outs. On the other hand, the number of stock outs including all parts designated as *materiaal* is an upper bound of stock outs, because it includes spare parts but also services such as repair of roofs. For this research the assumption is that the number of stock outs excluding *materiaal* is the correct one, because for these stock outs it is sure that they are materials and not services. Table 2.2 shows the total number of usage, number of stock outs and percentage of stock outs, for the year 2016. Figure 2.7 shows the number of stock outs per month in the year 2016.

	Excluding *materiaal* (lower bound)
Total number of usage	1,545
Number of stock outs	282
% of stock outs	18.25 %

Table 2.2 Number of stock outs in 2016

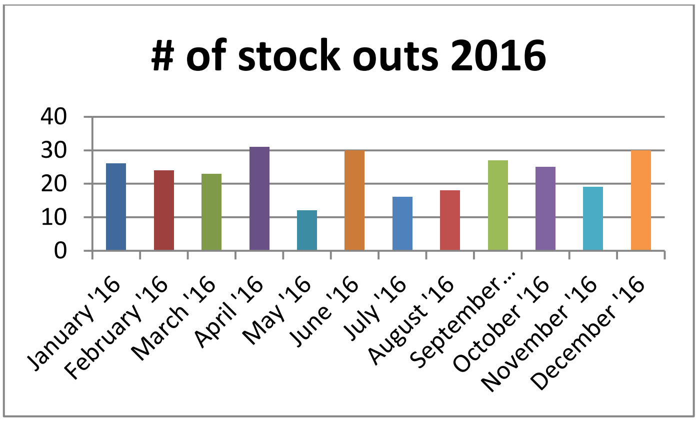

Figure 2.7 Graph of stock outs per month in 2016

2.6.2 Number and value of spare parts in Rimses

According to the warehouse manager it is possible to calculate the amount of spare parts and the value of these parts from Rimses. At the end of the year the warehouse manager has to deliver a overview with the total number and value of the spare parts for accounting. Then he sends a document with an overview from Rimses, but he already knows that it is not a complete overview, because both the amount and value of spare parts from Rimses are not similar with the physical amount and value of spare parts in the warehouse.

From Rimses we can say something about the number of unique spare parts registered, the number of unique spare parts with registered stock, the total amount of registered stock, and the total value of all spare parts, see Table 2.3. The second column shows this information retrieved from Rimses (before counting the physical warehouse). After this research we recommend to execute the counting of all spare parts at the warehouse of the TD of Bolletje Almelo. This physical counting should be done later, because it is first necessary to carry out some changes in the warehouse. After the physical counting the differences between the warehouse and Rimses are visible, which says something about the current reliability of the warehouse

	Rimses (before counting the warehouse)
Number of unique spare parts registered	19,950
Number of unique spare parts registered with registered stock	5,621
Total amount of registered spare parts with stock	53,007
Total value of spare parts	€ 470,300

Table 2.3 Overview amount of spare parts and value in Rimses

2.7 Problem tree

The problems mentioned in the previous sections in this chapter are used for the problem tree given in Figure 2.8. This tree is used to get insight in the interdependence of the problems and causes, and to give a clear view of the whole situation at the warehouse of the TD of Bolletje Almelo.

The problem tree shows that at the moment the management and structure of the warehouse and the use of Rimses are not adequate. This research will create insight how to determine adequate inventory management and control policies of the spare parts at the warehouse of the TD.

The focus of this research is on the green coloured boxes of Figure 2.8, so these problems are tackled in this research.

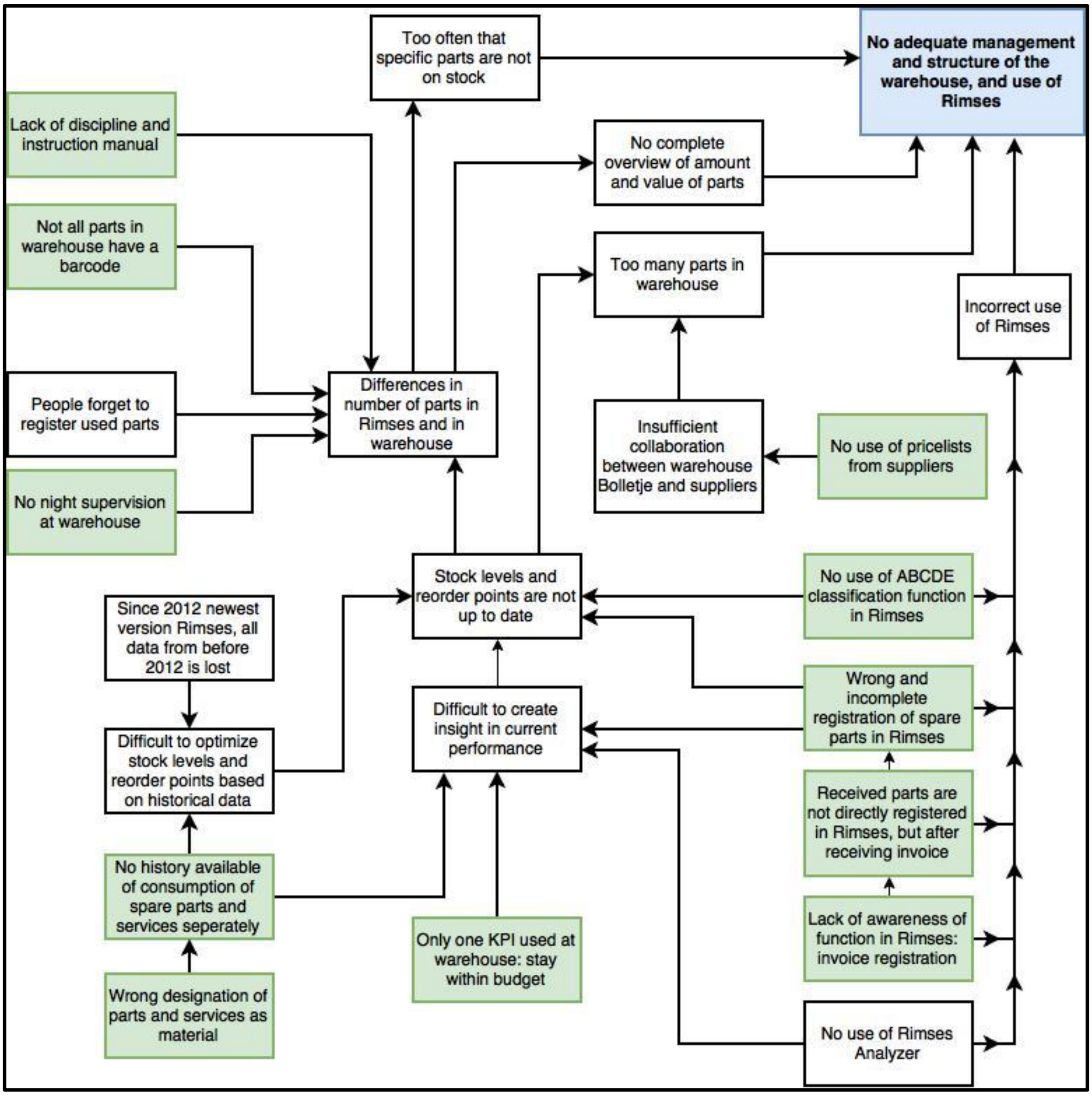

Figure 2.8 Problem tree

2.8 Conclusion

Here we can say something about the current situation of the warehouse of the TD of Bolletje Almelo, by answering the first research question: "*What is the current way of working within the warehouse of the Technical Department of Bolletje Almelo?*".

The warehouse of the TD of Bolletje Almelo is the location for stocking spare parts. The warehouse manager is responsible for the different activities in the warehouse, such as ordering, receiving and registering spare parts. The failure mechanics and production personnel of Bolletje and external mechanics are able to pick and consume the different spare parts from the warehouse, by using a special smartphone and application or by registering the consumed spare parts through a paper. Rimses is the software tool which is used by the TD of Bolletje Almelo. Rimses is used for different applications at the TD, such as inventory management and maintenance management.

From the problem tree of Figure 2.8 we can conclude that in the current situation there is insufficient control and structure in the warehouse of the TD and the software tool Rimses is not used correctly. Too often it is the case that specific parts are not on stock in the warehouse, because of differences in the number of parts in Rimses and in the warehouse, outdated reorder points and stock levels, and insufficient insight in the current performance of the warehouse. To give a fact: for the year 2016 we saw a percentage of 18.25 percent of stock outs.

Besides that, Rimses is not used correctly at the moment, caused by the fact that several functions in Rimses are either not used correctly, or not used at all, as described in the problem tree of Figure 2.8.

So the core problem of the warehouse of the TD of Bolletje Almelo is no adequate management and structure of the warehouse, and no adequate use of Rimses (see Figure 2.8). Therefore it is important to create more insight in the performance of the warehouse and to get (more) control in both the warehouse and Rimses.

In the next chapter, Chapter 3, a literature study about managing spare parts is done. This literature study includes the following topics: the importance of spare parts management and control policies; Key Performance Indicators; classifications methods; and inventory control policies.

Consequently, Chapter 4 and 5 focus on the selection of Key Performance Indicators, the selection of a classification method, the development of the (new) inventory control policies, and an implementation plan for the TD of Bolletje Almelo.

3. Relevant literature for managing spare parts

This chapter answers the second research question: "What methods are available in literature for managing spare parts in the warehouse of production companies?".

Section 3.1 describes the importance of inventory management and control policies in warehouses. Section 3.2 contains a review regarding KPIs, which are required to measure the performance of a warehouse. Section 3.3 is about the decision whether to stock a spare part or not. Consequently, Section 3.4 handles classification methods for spare parts, to compare them with the ABC classification. Section 3.5 describes the different inventory control policies which are available in literature. Finally, Section 3.6 summarizes this chapter.

3.1 Importance of spare parts management and control policies

According to Gopalakrishnan & Banerji (2013) a spare part is defined as a part identical to the part of a machine which need replacement due to wear and tear during the operating life of the equipment. Spare parts play an essential role in maintaining, ensuring and reinforcing the reliability of any equipment. Spare parts are divided into different categories: 1) materials such as: pipes, tubes, springs, electrical cables; 2) sub-assemblies of essential parts of the machines like engines, motors, compressors; and 3) complete units which are to be fitted with a machine like water circulating pumps, controls, gears (Gopalakrishnan & Banerji, 2013).

Most companies have the tendency to manage the purchasing, storage and supply of spare parts and materials as a separate department to the management of the maintenance department. The management of spare parts is a company level system, supplying the maintenance system with one of its crucial resources. Spare parts are one of the essential resources necessary to carry out maintenance. According to Kelly (2006) the basic function of the warehouse of spare parts is defined as follows: to act as a buffer (or reservoir) between the uncertainties of the supply from manufacturers and the inherent variability of the maintenance demand.

3.1.1 Spare parts management in a warehouse

The rational objective of running a warehouse of spare parts and controlling its inventory is to minimize the sum of the direct costs (receiving and holding parts) and the indirect costs (loss of production or repair time due to waiting for parts). Another objective is to minimize the downtime of the machinery in the plant. Therefore it is important to find a good balance between the costs and downtime (Kelly, 2006). A model that describes the operations of the warehouse system is shown in Figure 3.1. An explanation of this model is shown on the page next to this figure.

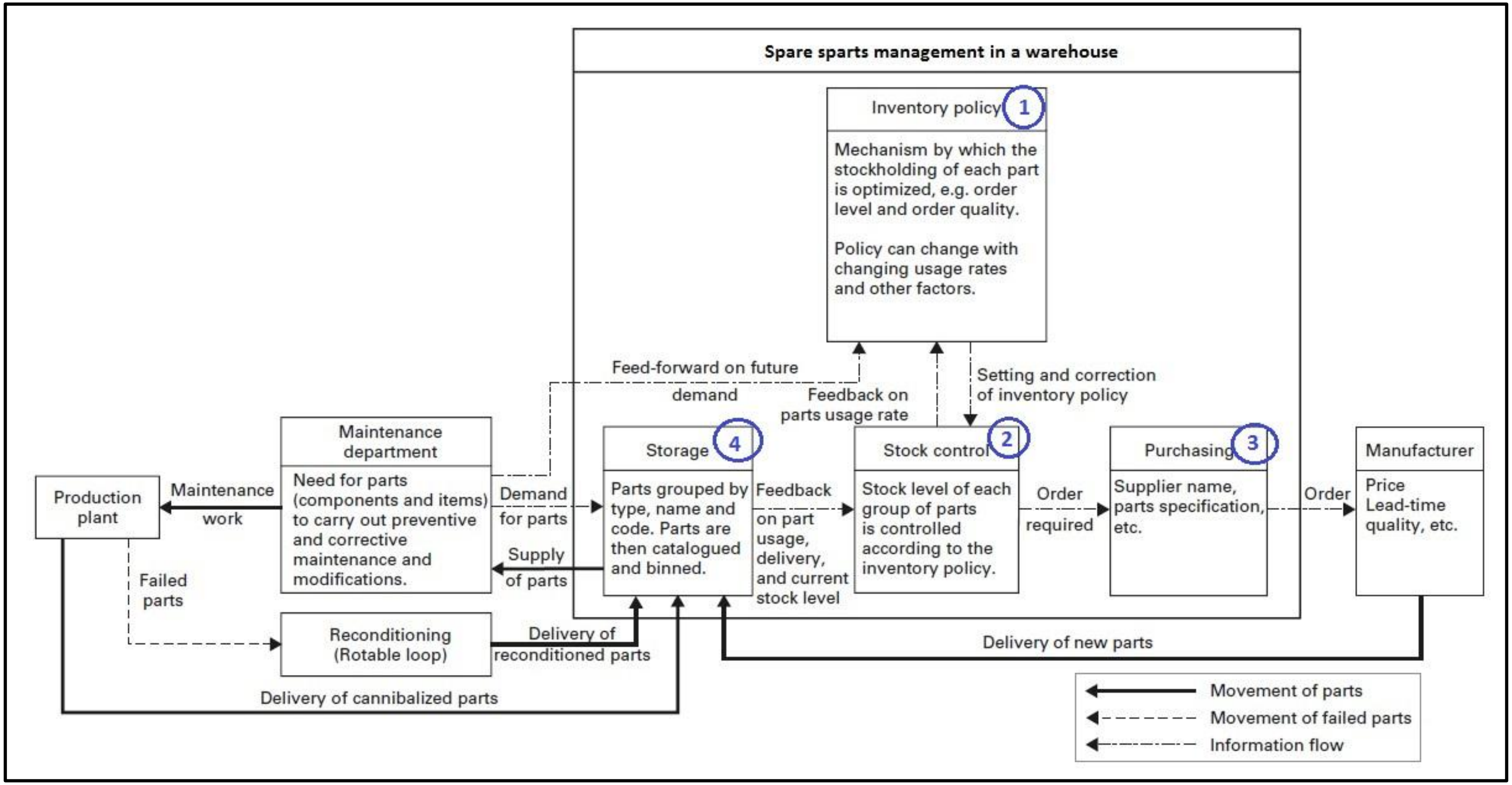

Figure 3.1 Spare parts management in a warehouse (Kelly, 2006)

1) Each spare part requires an inventory policy, a set of rules for deciding how the number of parts held in the warehouse is to be controlled, see Figure 3.1. One inventory policy would be for example to determine a maximum number of parts to hold and a minimum level at which the part should be reordered, also called the reorder point. Section 3.5 describes some other inventory policies suitable for different types of spare part usage.
2) Stock control monitors the usage and delivery of each spare part in collaboration with the designated inventory policy and feedback from part usage, delivery and current stock level, see Figure 3.1. This means that the inventory policy is used to decide when the part should be reordered.
3) Thereafter purchasing can place an order with a manufacturer, see Figure 3.1. To have complete information it is essential that all ingoing and outgoing parts to and from the warehouse are correctly registered into stock control.
4) The warehouse also plays a big role in the storage and control of new and reconditioned spare parts. An additional source of spare parts can come from cannibalizing old and unwanted parts.

3.1.2 Approaches for spare parts optimization

According to Sherbrooke (2004) there are two different approaches for spare parts optimization, namely the system approach and the item approach.

Traditional inventory theory uses the item approach, where the spares for an item are determined by simple formulas that balance the costs of holding inventory, ordering and stock out. The item approach projects the number of spare units needed for an item without considering the other items on the system. The consideration of only one item at a time may lead to a very low system availability or a funding requirement for all parts that exceeds the overall budget. So the disadvantage of the item approach is that the availability and total investment in the system of items are uncontrolled outputs of the item decisions (Sherbrooke, 2004).

The availability and investment targets should be inputs to the decision-making process. The system approach provides the manager an availability-cost curve of efficient system alternatives, as shown in Figure 3.2. Any points below the availability-cost curve are called inefficient, because for these points it is possible to find solutions on the curve with more availability or less cost. Points above the availability-cost curve are unobtainable. The manager chooses the point on the curve that meets the availability requirements within budget limitations. The slope of the availability-cost curve at any point shows the marginal cost of obtaining higher or lower availability. Each point on the optimal system cost-effectiveness curve corresponds to a set of stock policies – a stock level for every item (Sherbrooke, 2004).

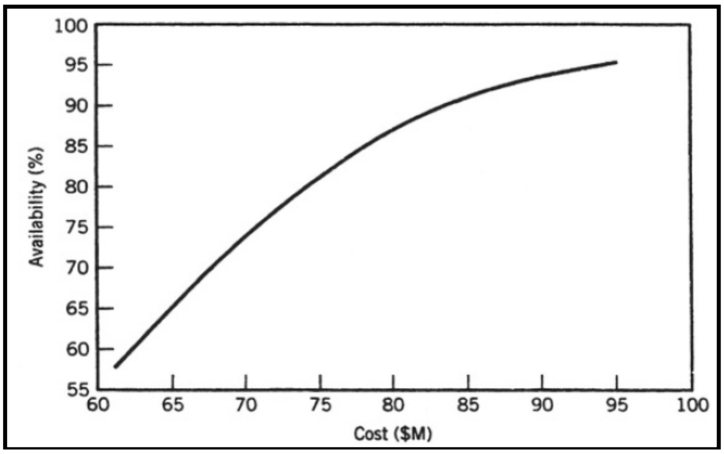

Figure 3.2 An availability-cost curve of efficient system alternatives (Sherbrooke, 2004)

For both the item approach and the system approach every point on the system availability-cost curve is computed from an item approach solution for a particular set of parameters: inventory holding cost, order cost, and stock out cost. So, to generate the system curve, it is necessary to solve a series of item approach problems (Sherbrooke, 2004).

At the moment the warehouse of the TD of Bolletje Almelo uses the item approach, because they determine the spares for an item especially based on ordering costs, stock out costs and holding inventory costs, so without considering the other items on the system. In this way there is often a mismatch between item-level decisions and system resources, such as money, or system performance requirements. For this reason, we recommend to use a more balanced approach in the future, where the item and system approach are combined. In this way the service level agreements are made on a machine level, so there is no availability agreement for each of the separate spare parts, but rather an agreement on the availability level of the entire machine. Finally this leads to an more efficient and economical inventory approach (Sherbrooke, 2004).

Achievements regarding spare parts inventory optimization mainly focus on four aspects (Lin & Ghodrati, 2011):

1) Spare parts classification optimization;
2) Spare part forecasting optimization;
3) Spare part inventory strategy optimization;
4) Spare part inventory management information system development.

In addition, to measure the effectiveness of such optimizations, it is essential to focus on the spare parts inventory value improvement with some special Key Performance Indicators (KPIs). Section 3.2 describes the definition of KPIs and suitable KPIs for spare parts inventory management.

3.1.3 Types of (spare parts) inventories

Spare parts inventories differ from other manufacturing inventories in several ways, because spare parts are not intermediate or final products to be sold to a customer. First, the functions are different. The function of spare parts inventories is to assist a maintenance staff in keeping equipment in operating condition. Work-In-Process (WIP) inventories exist in order to disembarrass irregularities in the production flow. Finished product inventories exist to provide a source of products for delivery to customers and are designed to protect against irregularities in lead time demand, differences in quality levels and other well known production characteristics. Second, the policies that lead spare parts inventories are different. WIP and finished product inventories could be increased or decreased by changing production rates and schedules, improving quality or reducing lead times. Spare parts inventory levels are largely dependent of how equipment is used and how it is maintained. Maintenance which requires a specific spare parts can sometimes be postponed or avoided, and the choice of a maintenance action can have an immediate impact upon the relevant spare parts inventories (Kennedy et al., 2002).

Spare parts inventories are divided into two different categories, namely corrective spare parts inventory and preventive spare parts inventory. As already mentioned in Section 1.5 these two types of inventory are the result of corrective and preventive maintenance. The scope of this research is to focus on keeping one pool of inventory for preventive and corrective maintenance, because of the available data about spare parts usage. For this reason, there is no distinction in this research between corrective spare parts inventory and preventive spare parts inventory.

3.2 Key Performance Indicators (KPIs)

This section describes the definition and function of KPIs, and gives an overview of suitable KPIs for spare parts management.

3.2.1 Definition of KPIs

Performance measurement is an essential principle of management, because it identifies current performance gaps between current and desired performances and provides an indication of progress towards closing these performance gaps. Carefully selecting KPIs is required to identify where to take action to improve performance (Weber & Thomas, 2005). Many companies are working with the wrong measures, many of which are incorrectly termed KPIs. Very few organizations really monitor their true KPIs. Therefore it is essential to know what a KPI actually is (Parmenter, 2007).

According to Parmenter (2007) the definition of KPIs is: a set of measures focusing on those aspects of organizational performance that are the most critical for the current and future success of the organization. Using these financial and non-financial measures allows organizations to reveal how successful they were in accomplishing long lasting goals. Continual measuring is crucial in this process to achieve continual improvement of organizations performances, so KPIs should be monitored 24/7, daily, or perhaps weekly for some (Velimirovic et al., 2011).

Besides the control function KPIs also have the two next functions (Velimirovic et al., 2011):

- Developing and guiding function: KPIs are a base for formulating and implementing the strategy of the organization.
- Motivation function: KPIs induce management to fulfil goals and motivate all stakeholders to realize those goals.

The selection of appropriate indicators that are used for measurement and appraisal of performances is a very important activity.

3.2.2 Suitable KPIs for spare parts inventory management

Different KPIs are formulated for spare parts inventory management. Dewald (2011) has proposed a quantitative measurements matrix chart with 24 KPIs for spare parts inventory management being discussed. His study lists useful KPIs with the formula, but also includes a ranking of the importance of each KPI in four categories: critical needs (C), high importance (H), moderate needs (M) and low importance (L) (Lin & Ghodrati, 2011), (Dewald, 2011), see Figure 3.3.

Description	Acceptable Range	Formula	When Due	CHML
Inventory Turnover	Greater than 12.0	Cost of Goods Sold / Average Inventory	Weekly/ Monthly	C
Inventory Accuracy	Greater than 95%	Actual Count / Computer on Hand Balance	Weekly	C
Total Inventory Valuation	Actual Dollars	Graph Inventory Valuation	Weekly	C
Total Dollars Used	Actual Dollars	Graph Dollars Used	Weekly	C
Stock Outs	Less than 1%	# of Occurrences / Total Pieces Picked	Daily/ Weekly	C
Emergency Purchases	Less than 2%	Emergency Dollars / Total Purchases	Monthly	C
Days Inventory On Hand	Less than 30 days on hand	Inventory Valuation / Average Daily Dollars Used	Monthly	C
Quality Defects Received vs. Overall Receipts	50 PPM or less external defects	# of Parts Defective / Total Parts Received = X / 1,000,000	Monthly	C
Required Delivery Dates Met	98%	Receipt Date / PO Date	Monthly	C
Warehouse Space Utilization	85% or less	Cubic Feet Used / Cubic Feet Available	Monthly	H
Slow Moving Parts	Less than 5% of total SKU	Parts Identified as Slow Moving / Total # of Parts in Inventory	Monthly	H
Equipment Bills of Materials	100% critical equipment; 95% and greater for all	Equipment Parts Entered / Total Equipment Parts	Monthly	H
Service Level	Greater than 95%	Parts Filled / Parts Ordered	Weekly/ Monthly	H
Receipt Lines Received Daily	Actual number	Graph--Trending	Daily/ Weekly	M
Target Ship Dates Met	95%	# Shipments on Time / Total # Shipments	Monthly	M
Backorders and Vendor Performance	98%	Items Delivered / Items Ordered	Monthly	M
Daily Order Picking Productivity	Actual lines picked daily (per employee)	Graph	Daily/ Weekly	M
Productivity of Receiving Personnel	Actual lines picked daily	Graph	Daily/ Weekly	M
Warehouse Capacity Measurement	Measured capacity	Total Floor Space Available In Cu Ft (Aggregate Of All Warehouses) *Should Be Posted*	Monthly	L
Price Variance	+ or - 2%	Price on Invoice / Price on Purchase Order	Monthly	L
Warranty Claims	Less than 2% of total inventory $	Dollars of Warranty Costs / Total Dollars of Inventory Value	Monthly	L
Freight Claims	Less than 2% of all freight dollars	Dollars in Freight Claims / Freight Dollars Expensed	Monthly	L
Kit Delivery Dates Met	Greater than 98%	Kits Filled / Kits Due	Daily/ Weekly	H
Delivery Route Effectiveness	Greater than 98%	# Delivered on Time / # of Stops Scheduled	Daily/ Weekly	H

Figure 3.3 Quantitative measurements matrix with 24 KPIs for spare parts inventory management (Dewald, 2011)

Lin & Ghodrati (2011) also described some other KPIs, which are suitable for spare parts management:

- Cost of keeping stock;
- Operational downtime due to stock outs;
- Rate of circulation;
- Number of returned spare parts to stores.

In the next chapter, in Section 4.1, we will discuss and select the KPIs which give a representative review of the performance of the warehouse of the TD of Bolletje Almelo.

3.3 Whether to stock or not

As shown in Figure 3.4, for unplanned breakdowns the overall downtime is made of many components that can heavily endanger the productivity of a production line. If the spare part is not stocked, there could be an administrative delay, in contacting and negotiating with the supplier. Besides that, there is a logistic delivery time, which can amount up to several weeks or months. However, stocking spare parts for a certain availability can lead to high inventory holding costs, in case of expensive and rarely used spare parts (Cavalieri et al., 2008).

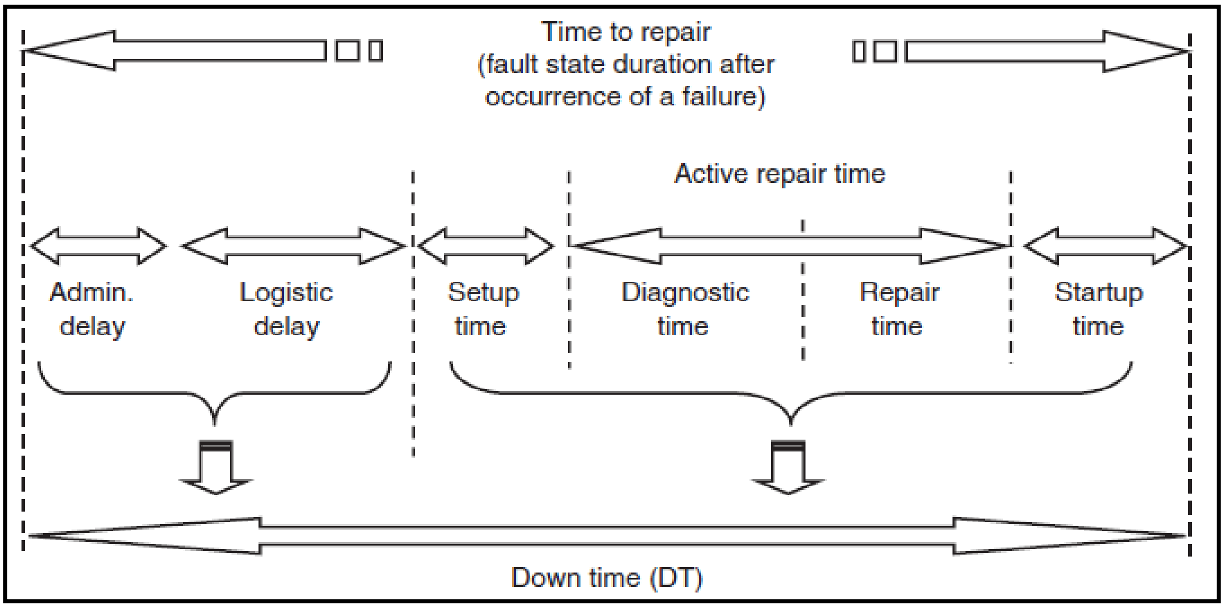

Figure 3.4 Typical time components of the down time of a piece of equipment (Cavalieri et al., 2008)

So spare parts are a serious issue for companies: from stocking parts for equipment that never fails (an unnecessary cost), to failing to stock the right part when key equipment fails. Neither extreme is a good option, so then the question is which spare parts to stock and which ones not. As Figure 3.5 illustrates, the decision whether to stock a spare part or not is based on purchasing and inventory costs, but also takes into account those hidden costs which arise from the unavailability of a spare part (Cavalieri et al., 2008).

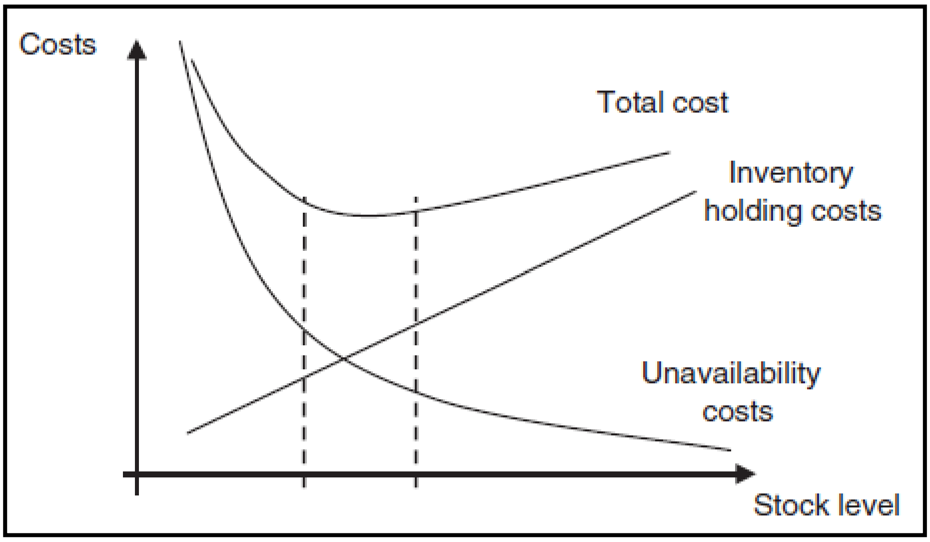

Figure 3.5 Finding the right level of stock as a compromise between inventory holding costs and unavailability costs (Cavalieri et al., 2008)

The total relevant costs for stocking an item are calculated as follows:

$$Total\ relevant\ costs = inventory\ holding\ costs + downtime\ costs + purchase\ costs$$

- The inventory costs consist of the cost of energy, material handling, warehouse space, insurance, obsolescence, depreciation, IT system, etc.
- The downtime costs consist of the abovementioned elements: costs of administrative delay, logistic delay, setup time, diagnostic time, repair time and start up time.
- The purchase costs consist of the unit cost per item.

From the problem tree we saw that the TD of Bolletje Almelo often experiences failed spare parts which are very critical for the production line, because missing these spare parts causes downtime of the production line which is not desired. On the other hand, the warehouse of the TD of Bolletje Almelo includes a lot of expensive spare parts which have a low demand but are critical. This means that Bolletje has both high inventory costs and high downtime (unavailability) costs. At the moment there is also insufficient collaboration between the warehouse of the TD of Bolletje Almelo and their suppliers. Supply chain collaboration is a method to solve this insufficient collaboration between different companies.

3.3.1 Supply chain collaboration (SCC)

Besides stocking spare parts in your own warehouse, it is also possible to work together with suppliers to stock spare parts. This is an example of so called supply chain collaboration which is defined as: “when two or more independent companies work jointly to plan and execute supply chain operations with greater success than when acting in isolation” (Sridharan, 2002).

Sridharan (2002) describes different forms of supply chain collaboration, including definitions of (Supply Chain Visions, 2010):

- Collaborative Planning, Forecasting and Replenishment (CPFR): “A concept that aims to enhance supply chain integration by supporting and assisting joint practices. CPFR seeks cooperative management of inventory through joint visibility and replenishment of products throughout the supply chain. Information shared between suppliers and retailers aids in planning and satisfying customer demands through a supportive system of shared information. This allows for continuous updating of inventory and upcoming requirements, essentially making the end-to-end supply chain process more efficient. Efficiency is also created through the decrease expenditures for merchandising, inventory, logistics, and transportation across all trading partners” (Supply Chain Visions, 2010).
- Quick Response (QR): “A strategy widely adopted by general merchandise and soft lines retailers and manufacturers to reduce retail out-of-stocks, forced markdowns and operating expenses. These goals are accomplished through shipping accuracy and reduced response time. QR is a partnership strategy in which suppliers and retailers work together to respond more rapidly to the consumer by sharing point-of-sale scan data, enabling both to forecast replenishment needs” (Supply Chain Visions, 2010).
- Continuous Replenishment (CR): “The practice of partnering between distribution channel members that changes the traditional replenishment process from distributor-generated purchase orders, based on economic order quantities, to the replenishment of products based on actual and forecasted product demand” (Supply Chain Visions, 2010).
- Vendor Managed Inventory (VMI): “The practice of retailers allowing their suppliers to take responsibility for determining supply order size and timing, usually based on receipt of retail POS and inventory data from the retailer. The goal is to increase retail inventory turns and reduce stock outs. It may or may not involve consignment of inventory (supplier ownership of the inventory located at the customer location)” (Supply Chain Visions, 2010).

- Consignment Inventory (CI): "1) Goods or product that are paid for when they are sold by the reseller, not at the time they are shipped to the reseller. 2) Goods or products which are owned by the vendor until they are sold to the consumer" (Supply Chain Visions, 2010).
- Supplier Owned Inventory (SOI): "A variant of vendor-managed inventory and consignment inventory. In this case, the supplier not only manages the inventory, but also owns the stock close to or at the customer location until the point of consumption or usage by the customer" (Supply Chain Visions, 2010).

In Section 4.3 we develop a decision-making framework whether the TD of Bolletje Almelo has to stock a spare part, and if so whether to stock this spare part at their own warehouse or at the warehouse of the supplier, based on supply chain collaboration.

3.4 Classification methods

In this section different classification methods to classify spare parts are described, which are discussed in the following order:

- Original ABC analysis;
- Multi-criteria ABC analysis;
  - Joint criteria matrix;
  - Analytic Hierarchy Process (AHP);
- FSN analysis;
- VED analysis.

3.4.1 Original ABC analysis

The ABC analysis is a well-established classification technique based on the Pareto principle for determining which items should get priority in the management of a company's inventory. Inventories are categorized into three classes: A, B and C. The original ABC analysis uses only one criterion to separate spare parts from each other. The criterion set out to conduct an ABC analysis could be annual dollar usage, annual demand, unit price or criticality. According to Axsäter (2015) this classification is often done by dollar volume. Usually a relative small percentage of items account for a large share of the total volume. Typically 20 percent of the items can account for about 80 percent of the dollar volume, and the remaining 80 percent of the items only account for 20 percent of the volume.

Class A items consists of items with very high dollar volume. Typically the A class contains around 20 percent of the items, they account for about 80 percent of the total annual turnover and they should receive the most personalized attention from management.

About 30 percent of the items with intermediate dollar volumes are classified as class B items, which account for about 15 percent of the total annual turnover. Class B items are of secondary importance and they should get a moderate but significant amount of management attention.

Finally the remaining 50 percent of the items with low dollar volumes are classified to as the C class items. The class C items account for approximately 5 percent of the total annual turnover. They are the least important items, so decision systems must be kept as simple as possible (Axsäter, 2015), (Silver et al., 2017). The above mentioned percentages used for the class A, B and C items could be chosen different in each situation. Figure 3.6 shows an example of an ABC analysis, based on total annual turnover and the above mentioned percentages.

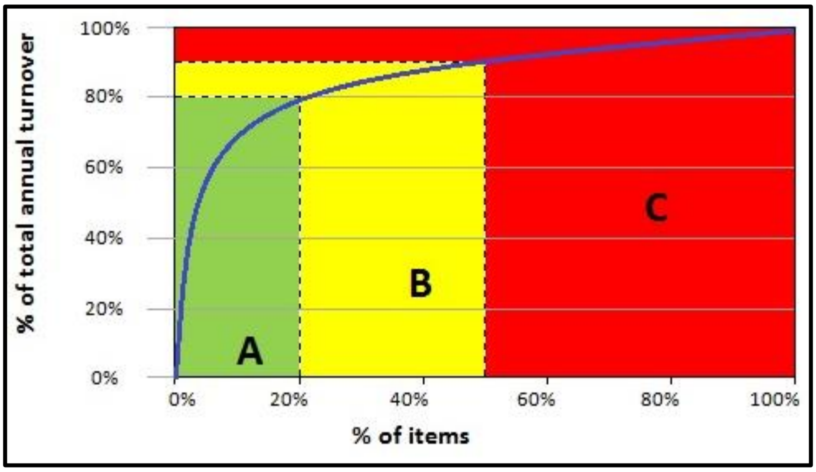

Figure 3.6 Example of an ABC analysis

Multi-criteria ABC analysis

The ABC analysis is famous for its ease of use, but it has also been criticized for its exclusive focus on dollar usage. Other criteria such as lead-time, commonality, obsolescence, durability, inventory cost, order size requirements, criticality of the article, and the number of orders also represent important considerations for management (Yu, 2010). Classification of items using the value and demand criteria exclusively can sometimes create problems for an organization. Depending upon the nature and type of the firm, the number of criteria that should be used to manage the inventory may vary. However, then firms are faced with the problem of how to classify, analyze, and rank inventory items when more than one criterion is used. Different techniques are used to combine the different criteria, where the joint criteria matrix and Analytic Hierarchy Process (AHP) are the most used approaches. Let us discuss these two approaches in the following two sections.

Joint criteria matrix

Flores & Whybark (1986) proposed the use of a joint criteria matrix when considering two criteria for classification. This matrix consists of nine cells: AA, AB, AC, BA, BB, BC, CA, CB, and CC, see Figure 3.7. However, the consequence is that a two criteria joint matrix may require nine different policies to deal with inventory items in the nine cells. It is possible to establish nine different policies, but it would be a difficult process to implement and manage successfully. Therefore a reclassification of the items into three groups could be done to establish only three instead of nine different policies, but the appropriate number of categories must be defined by the user. The next page shows an example of a joint criteria matrix including a reclassification, see Example 2. In this example we defined three categories in the reclassification phase, but in other situations more or fewer categories may be appropriate (Flores & Whybark, Multiple criteria ABC analysis, 1986).

		Variable 1		
		A	**B**	**C**
Variable 2	**A**	AA	BA	CA
	B	AB	BB	CB
	C	AC	BC	CC

Figure 3.7 Joint criteria matrix

Example 2

Modified example from (Flores & Whybark, Multiple criteria ABC analysis, 1986)

Figure 3.8 shows a joint criteria matrix, based on the data from Table 3.1. Dollar usage and criticality are used as criteria in this joint criteria matrix. The matrix shows each part number in the cell corresponding to its classification on both criteria.

Figure 3.8 Joint criteria matrix based on data from Table 3.1

Part No.	Criticality	Dollar Usage
1	A	B
2	C	C
3	C	A
4	B	B
5	A	A
6	C	B
7	B	C
8	A	B
9	A	C
10	B	C

Dollar usage		Criticality		
		A	B	C
	A	5	8	3
	B	1	4	6
	C	9	7, 10	2

Table 3.1 Data set based on criticality and dollar usage

The objective is to reclassify the items into three categories, corresponding to AA, BB and CC. This means that all off-diagonal items (AB, AC, BA, BC, CA, CB) should be reclassified. In practice, managerial judgement is used to achieve the reclassification on an item by item basis. An example of a mechanical procedure could be to reclassify AB and BA as AA, AC and CA as BB, and BC and CB as CC. Applying this mechanical procedure to the matrix of Figure 3.8 results in reclassifying parts 1 and 8 to AA; parts 3 and 9 to BB; and parts 6, 7 and 10 to CC, as shown by the arrows in Figure 3.9.

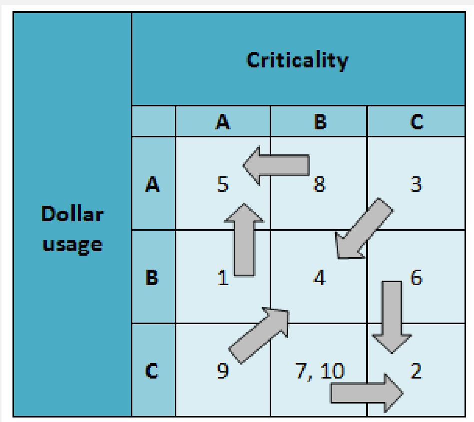

Figure 3.9 Reclassification of joint criteria matrix

Analytic Hierarchy Process (AHP)

The Analytic Hierarchy Process (AHP) is based on the experience gained by its developer T.L. Saaty. Flores et al. (1992) explain AHP in the following three steps:

1) First, the decision maker identifies all criteria of importance to the specific decision. As the human mind can analyze only a limited number of criteria simultaneously, Saaty has suggested restricting the number of criteria to be considered at one time to seven.

2) Thereafter, these criteria are arranged in a hierarchy of one or more levels.

3) Then a series of pair wise comparisons are done at each node of the hierarchy, where the decision maker(s) subjective judgement is converted into a set of weights of relative importance. The resulting set of weights can then be combined to provide a formula reflecting the combination of all hierarchical elements.

4) Finally, there is a check on the relative consistency of the subjective evaluations.

Below an example of the Analytic Hierarchy Process is shown to get more insight in this classification method, see Example 3.

Example 3

Modified example from (Flores, Olson, & Dorai, 1992)

1) The organization identifies in the first step the following criteria of importance: *average unit cost, annual dollar usage*, *criticality*, and *lead time.*

2) The four criteria are then combined and reduced to a single variable named *utility*. The definition of the variables continues at lower levels. For example criticality consists of *impact*, *scarcity* and *substitutes*. See Figure 3.10 for the hierarchy with criteria.

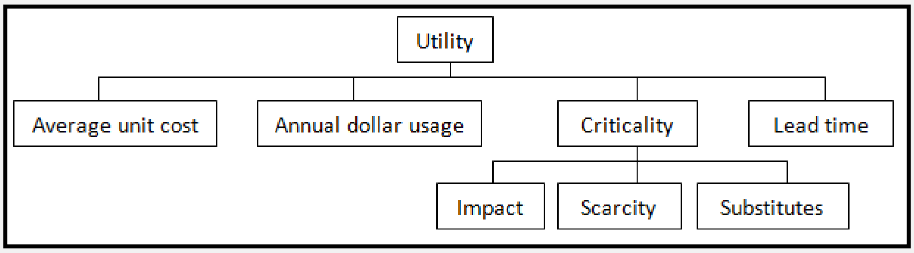

Figure 3.10 Hierarchy with criteria

3) Then pair wise comparisons are required wherever sub elements are found in the hierarchy, in this case *utility* and *criticality* both have sub elements. (Saaty, 2008) has developed a scale to describe the relative importance of each pair, see Table 3.2. Importance 2, 4, 6 and 8 are used as intermediate values on this scale.

Scale	Relative importance	Explanation
1	Equal importance	Both factors contribute equally
3	Weak preference	Base factor is slightly more important than second factor
5	Essential preference	Base factor strongly preferred
7	Demonstrable preference	Definite preference for base factor
9	Absolute preference	Base factor preferred at highest possible level

Table 3.2 Scale of importance (Saaty, 2008)

Table 3.3 shows the pair wise comparison which is done for the first sub element, *utility*. From this table one can see that *average unit cost* is considered equivalent in importance to *annual dollar usage* and much less important than *criticality*.

Example 3 – continued

	Average unit cost	Annual dollar usage	Criticality	Lead time
Average unit cost	1	1	1/8	1/4
Annual dollar usage		1	1/3	1/6
Criticality			1	1
Lead time				1

Table 3.3 Pair wise comparison for *criticality*

The weights 1/8, 1/4 and 1/6 in Table 3.3 are used as intermediate values, so 1/8 is the intermediate value between the scale of 7 and 9, see Table 3.2.

The implicit weights for this pair wise comparison matrix can be derived by a variety of software products. In this example the results of these weights are:

$$0.0782\ \boldsymbol{average\ unit\ cost} + 0.09161\ \boldsymbol{annual\ dollar\ usage} + 0.41969\ \boldsymbol{criticality} + 0.40999\ \boldsymbol{lead\ time}$$ **(Inconsistency Index = 0.04)**

These weights indicate that for this decision maker *average unit cost* contributes about 8 percent, *annual dollar usage* about 9 percent, *criticality* about 42 percent, and *lead time* about 41 percent to *utility.*

4) Another feature of AHP is the existence of the check on the relative consistency of the subjective evaluations. We expect that subjective assessments are not totally consistent, so the inconsistency index provides a measure of relative inequality. This index value is zero if perfectly consistent evaluations were made, so a low index is desired. Table 3.4 shows values for totally random indices as a function of the number of factors compared. An inconsistency index greater than 10 percent of random indicates more inconsistency than is desired, which means that de decision maker(s) should reassess the subjective comparisons.

Number of factors	2	3	4	5	6	7
Random index	0.00	0.58	0.90	1.12	1.24	1.32
Maximum (10% of index)	0.00	0.06	0.09	0.11	0.12	0.13

Table 3.4 Values for totally random indices as a function of the number of factors compared

In this example, with four factors, the index of 0.044 is below the maximum of 0.09, so adequate consistency is assumed.

The same process is applied to the sub elements of *hierarchy*. Finally, one formula is generated, including all criteria from the hierarchy:

$$0.0782\ \boldsymbol{average\ unit\ cost} + 0.09161\ \boldsymbol{annual\ dollar\ usage} + 0.28095\ \boldsymbol{impact} + 0.10183\ \boldsymbol{scarcity} + 0.03691\ \boldsymbol{substitutes} + 0.40999\ \boldsymbol{lead\ time}$$

Now this formula is ready for use to evaluate inventory items, reflecting all six criteria considered. The total weighted scores for all items are calculated and listed in descending order. The last step is reclassify the items to the correct class (A, B or C), by defining the ABC categories.

AHP generates a consistent measure that is used for reclassification of items in a simple ABC structure. When multiple criteria are combined into a single ranking, the assignment of items of classes is more uniform and it improves the quality and completeness of the inventory analysis. A disadvantage of AHP is that more managerial time is needed to develop more information for each item, especially in the case when reviewing and classifying more than thousands of items is required (Flores et al., 1992). Another issue is the subjectivity involved in the analysis.

3.4.2 FSN analysis

The FSN analysis is used to find out the fast moving, slow moving, and non moving items in a warehouse. The FSN analysis categorizes the items based on the basis of the rate of movement of items in a warehouse or on the basis of usage pattern of items. In this analysis parts are categorized into three different groups (Stoll et al., 2015):

- Fast-moving items (F): high demand and usage rate, for example more than once for a specific time period.
- Slow moving items (S): slight demand and usage rate, for example once in a specific time period.
- Non moving items (N): no demand at all in a specific time period.

The steps followed in the FSN analysis according to Vaisakh et al. (2013) are:

1) Calculation of average stay and usage rate of the item in a warehouse.
2) FSN classification of items based on average stay in the inventory OR
FSN classification of items based on usage rate.

3.4.3 VED analysis

The VED analysis classifies spare parts based on the critical nature or relative importance, into three categories:

- Vital (V): non-availability of vital spare parts, even for short periods, leads to stoppage of production. The stock outs costs associated with such parts are very high, and therefore the service levels are very high for this class of parts. So every effort should be made to ensure the availability of these parts.
- Essential (E): medium sized losses and reduced performance are expected due to non-availability of these spare parts. The service level of essential spare parts is lower than of the vital parts.
- Desirable (D): desirable spare parts are easily available in the market. They do not hold up production and may be substituted as well. So these parts are needed, but their stock out for a short period may not lead to stoppage of production (Bose, 2006).

The VED analysis helps in focussing the attention of the management on the vital spare parts and ensuring their availability by frequent reviewing and reporting (Vaisakh et al., 2013). The VED analysis is easy to implement as the classification is based on experts' opinions, but therefore also some subjectivity is involved in this analysis.

In the next chapter, in Section 0, we discuss the above mentioned classification methods. Subsequently we specify our choice out of the classification methods above, to classify the spare parts of the warehouse of the TD of Bolletje Almelo.

3.5 Inventory control policies

The overall purpose of an inventory control system is to determine when and how much to order (Axsäter, 2015). This decision should be based on the stock situation, but also on the anticipated demand and different cost factors. The stock situation includes not only the physical stock on hand, but includes also the outstanding orders that have not yet arrived, and backorders, which are units that have been demanded but not yet delivered. Therefore the stock situation is defined as the following equation (Axsäter, 2015):

$$Inventory\ position = stock\ on\ hand + outstanding\ orders - backorders - reservations.$$

In the following sections we describe different inventory control policies, which are divided into continuous and periodic review policies. Besides that, we define how to calculate the Economic Order Quantity (EOQ), lead time, reorder point and safety stock.

3.5.1 Continuous or periodic review

An inventory control system is designed so that the inventory position is monitored continuously or periodically.

Continuous review means that as soon as the inventory position is sufficiently low, an order is triggered. This triggered order is delivered after a certain lead time (L). The lead time is the time from the ordering decision until the ordered amount is available on shelf.

Periodic review means to consider the inventory position only at certain given points in time. In general, the intervals between these reviews are constant. The review period (R) is defined as the time interval between reviews (Silver et al., 2017).

According to Silver et al. (2017) there are four main types of inventory control policies for single-echelon systems, divided into policies for continuous and periodic review:

- Continuous Review: Order-point, Order-Quantity *(s,Q)* policy;
- Continuous Review: Order-Point, Order-Up-To-Level *(s,S)* policy;
- Periodic Review: Order-Up-To-Level *(R,S)* policy;
- Periodic Review: *(R,s,S)* policy.

Schultz (1990) adds another continuous review policy to these policies, which is typically used for slow movers:

- Continuous Review: *(S-1,S)* policy.

These five different control policies are described in the following sections.

<u>Continuous Review: Order-point, Order-Quantity *(s,Q)* policy</u>

A fixed quantity batch *Q* is ordered whenever the inventory position drops to the reorder point *s* or lower. If the inventory position is sufficiently low it may be necessary to order more than one fixed quantity batch *Q* to get above *s.* The (*s,Q*) policy is often called a two-bin system. As long as units remain in the first bin, demand is satisfied from it. The amount in the second bin corresponds to the order point. So when the first bin is empty, the second bin is opened and a replenishment is triggered. When the replenishment arrives, the second bin is refilled and the remainder is put into the first bin. However, when more than one replenishment order is outstanding, which means that there is no stock on hand, no more orders are triggered since no bins are available (Silver et al., 2017).

Continuous Review: Order-Point, Order-Up-To-Level *(s,S)* policy

This policy again assumes continuous review and like the (*s,Q*) policy, a replenishment is made whenever the inventory position drops to the reorder point *s* or lower. However, the (*s,S*) policy uses a variable replenishment quantity, ordering enough items to raise the inventory position to the order-up-to-level *S.* This policy is frequently referred to a min-max system because the inventory position, except for a possible temporary fall below the reorder point, is always between a minimum value of *s* and a maximum value of *S.*

The difference between *(s,Q)* and *(s,S)* policies is shown in Figure 3.11. The *(s,Q)* policy shows that a batch quantity is ordered when the inventory position is below the reorder point *s=5.* The *(s,S)* policy shows that a variable quantity is ordered to raise the inventory position to the order-up-to-level *S=20* (Silver et al., 2017).

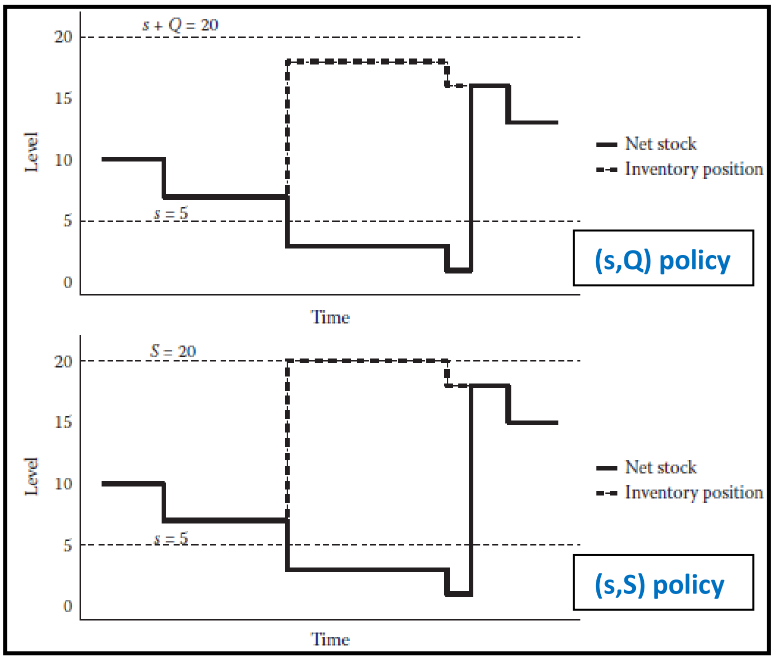

Figure 3.11 Difference between *(s,Q)* and *(s,S)* policies (Silver, Pyke, & Thomas, 2017)

Continuous Review: *(S-1,S)* policy

The one-for-one *(S-1,S)* policy (sometimes referred to as a sell-one/buy-one policy when demands are unit sized), is a special case of the above mentioned *(s,S)* inventory control policy. The maximum stock level of the *(S-1,S)* policy may be up to *S* and whenever there is demand for one unit, a replenishment of one unit is ordered. So each demand for a unit will immediately trigger an order, where the replenishment order is equal to the size of the demand. This policy is often advocated for controlling the stock of slow-moving items (Schultz, 1990).

Periodic Review: Order-Up-To-Level *(R,S)* policy

This policy is also known as a replenishment cycle policy. The procedure is that every *R* units of time enough items are ordered to raise the inventory position to the level *S*. Figure 3.12 shows an example of a *(R,S)* policy. In this example orders are placed every ten periods, with a lead time of two periods (Silver et al., 2017).

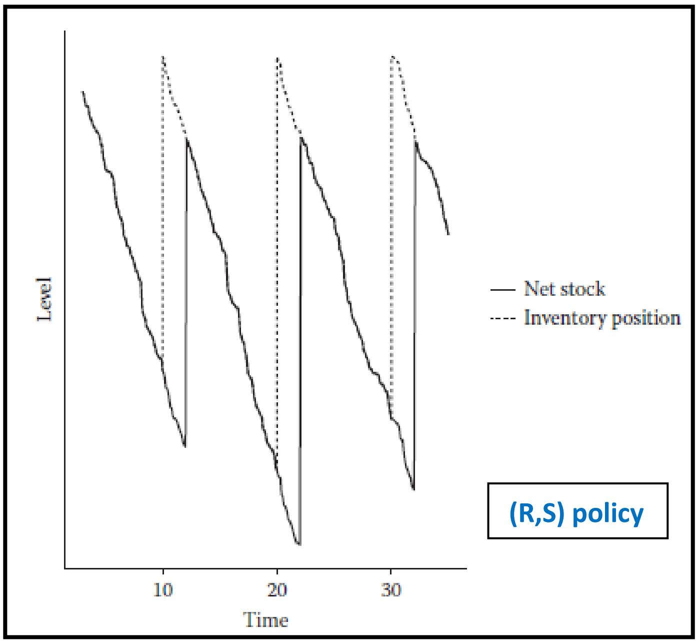

Figure 3.12 *(R,S)* policy (Silver, Pyke, & Thomas, 2017)

Periodic Review: *(R,s,S)* policy

The (*R,s,S*) policy is a combination of the (*s,S*) and *(R,s)* policy, where every *R* units of time the inventory position is checked. If the inventory position is at or below the reorder point *s*, an order is required to raise the inventory position to *S.* If the position is above *s,* nothing is done until at least the next review moment.

When using the ABC classification for items, Table 3.5 gives a simple rule of thumb for choosing the form of the policy. For C items, firms generally use a more manual and simple approach, which could be equivalent to (*s,Q*) or (*R,S*) policies (Silver et al., 2017). The most common manual inventory control policies are manual two bin systems and visual review.

	Continuous review	Periodic review
A items	*(s,S)* *(S-1,S)*	*(R,s,S)*
B items	*(s,Q)*	*(R,S)*
C items	*Manual ~ simple (s,Q)*	*Manual ~ simple (R,S)*

Table 3.5 Inventory control policies for ABC classification (Silver et al., 2017)

In the next chapter, in Section 4.5, we discuss the abovementioned inventory control policies. Consequently, in the same section, the (new) inventory control policies for the warehouse of the TD of Bolletje Almelo are selected.

3.5.2 Economic Order Quantity (EOQ)

The Economic Order Quantity formula is one of the most well-known approaches in inventory control management. Harris first derived this formula, but Wilson is also recognized in connection with this formula. The simplest version is based on the following assumptions (Axsäter, 2015):

- Demand is constant and continuous.
- Ordering and holding costs are constant over time.
- The batch quantity does not need to be integer.
- The whole batch quantity is delivered at the same time.
- No shortages are allowed.

The EOQ formula is defined as the following equation, where A (ordering cost), D (demand per time unit), and h (holding cost per unit and time unit) are used to calculate the EOQ:

$$\boldsymbol{EOQ} = \sqrt{\frac{2 * A * D}{h}}.$$

This formula is used to find the optimal order quantity that minimizes the holding costs and ordering costs.

3.5.3 Calculating the lead time, reorder point and safety stock for CONTINUOUS review policy

According to Silver et al., (2017) a stock out can only occur during periods when the inventory on hand is low. The decision about when an order should be placed will always be based on the minimum inventory level before the order arrives. Therefore an order should be placed early enough so that the expected number of units which is demanded during the lead time is sufficient to have the lowest number of stock outs as possible. Lead time is defined by Silver et al., (2017) as the time that expires from the moment at which is decided to place an order, until it is stored physically on the shelf and ready to satisfy customers' demand.

When the demand and lead time of an item are known, it is possible to calculate the exact time an order needs to be placed. In this way there will not be any excess stock or unsatisfied demand. This is called defining the reorder point, which reflects the level of inventory that triggers the placement of an order for additional units (Chen, 1998). However in practice there might be some variation in the lead time and demand. Therefore it is useful to have some buffer: the safety stock. This safety stock protects the company from stock outs or backorders (Waters, 2011).

Summarized the following three factors are needed to determine the reorder point: demand per time unit (D), lead time (L) and safety stock (SS). Figure 3.13 shows the connection between the reorder point and the lead time and order quantity as a function of time, for a continuous review policy.

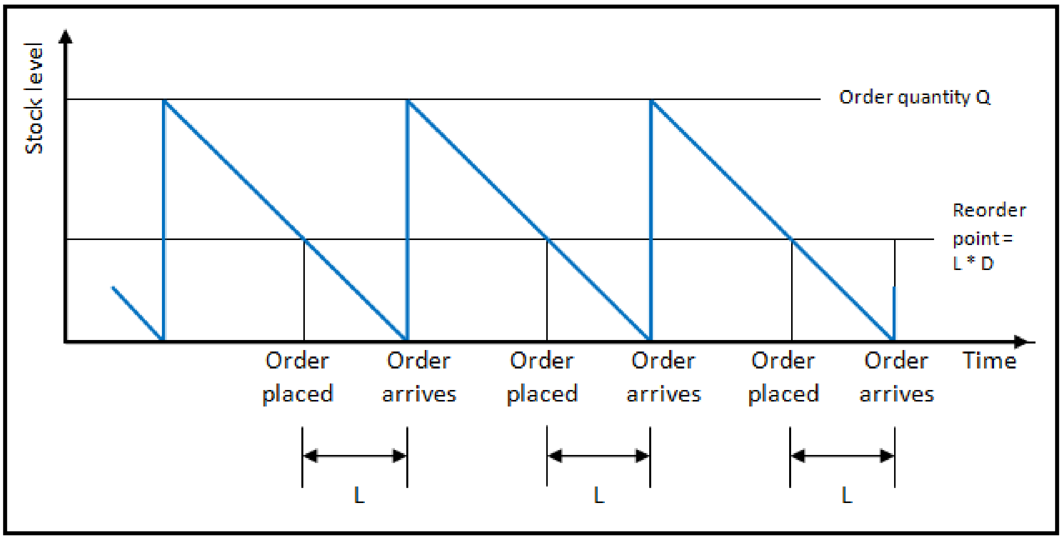

Figure 3.13 Reorder point, lead time and order quantity for continuous review period (modified from (Waters, 2011))

If the demand is constant and the lead time is known, then the formula for the reorder point, without safety stock, is as follows (Waters, 2011):

$$\boldsymbol{Reorder\ point = lead\ time * demand\ per\ time\ unit}$$
$$\boldsymbol{= L * D.}$$

When a safety stock is kept in inventory, then the reorder point is calculated as follows (Waters, 2011):

$$\boldsymbol{Reorder\ point = (lead\ time * demand\ per\ time\ unit) + \ safety\ stock}$$
$$\boldsymbol{= (L * D) + SS.}$$

The most accurate and effective method for calculating the safety stock is a statistical approach, which uses the following formula (Radasanu, 2016):

$$\boldsymbol{Safety\ stock =}$$
$$\boldsymbol{service\ factor * \sqrt{(lead\ time * (st.dev.(demand))^2) + \ (demand * st.dev.(lead\ time))^2}}$$
$$\boldsymbol{= Z * \sqrt{(L * (st.dev.(D))^2) + (D * st.dev.(L))^2}}$$

Where the service factor Z is calculated by using the following Excel formula (Radasanu, 2016):

$$\boldsymbol{Z = Normsinv(service\ level)}$$

The normal distribution often provides a good empirical fit to the observed data (mean demand during lead time and standard deviation during lead time). Nevertheless, particularly for expensive, slow moving spare parts it may be appropriate to use an alternative distribution such as the exponential, Gamma, Poison, or negative binomial (Silver et al., 2017).

Silver et al. (2017) recommend to use the following rule of thumb:

If the ratio $\frac{\sigma_L}{\hat{x}_L}$ is greater than 0.5, consider a distribution other than the normal.

The Gamma distribution has considerable intuitive appeal for representing the distribution of lead time demand. In particular, if the distribution is skewed to the right, or if the above mentioned ratio is greater than 0.5, use of the Gamma distribution should be considered (Silver et al., 2017). In Chapter 6 we execute a pilot study, where we use the above mentioned formulas and chose the correct distribution for the service factor Z.

Important note!
The abovementioned formulas for calculating the reorder point and safety stock are applicable to the continuous review policy. For a periodic review policy the above mentioned formulas are the same, except for the variable L. The periodic review policy uses L+R instead of only L.

Depending on the development of the (new) inventory control policies in Section 4.5, the above mentioned formulas for either the continuous or the periodic review policy are used in the remainder of this research.

3.6 Conclusion

In this chapter we found an answer to the second research question: "*What methods are available in literature for managing spare parts in the warehouse of production companies?"*.

It is important to find a good balance between the costs and downtime, related to the spare parts of the warehouse. To achieve this, adequate spare parts management and control policies are needed.

First, it is essential to focus on some Key Performance Indicators (KPIs) for spare parts inventory management, such as total inventory valuation, stock outs, rate of circulation and downtime.

Besides that, classification methods for spare parts are useful to categorize the different spare parts on one or more variables. The classification methods found in literature are the original ABC analysis, joint criteria matrix, Analytic Hierarchy Process (AHP), FSN analysis and VED analysis.

Finally, there are different inventory control policies which are used to get more control in a warehouse of spare parts, where a distinction is made between continuous and period review. The five policies described by Silver et al., (2017) and Schultz (1990) are:

- Continuous Review: Order-point, Order-Quantity *(s,Q)* policy;
- Continuous Review: Order-Point, Order-Up-To-Level *(s,S)* policy;
- Continuous Review: *(S-1,S)* policy;
- Periodic Review: Order-Up-To-Level *(R,S)* policy;
- Periodic Review: *(R,s,S)* policy.

The well-known Economic Order Quantity (EOQ) is used to find the order quantity that minimizes the total holding costs and ordering costs.

In the next chapter, Chapter 4, we select the relevant KPIs for the warehouse of the TD of Bolletje Almelo, one of the above mentioned classification methods, and the (new) inventory control policies.

4. (New) Inventory control policies for the spare parts of the TD

This chapter answers the third research: "How to organize the (new) inventory control policies at the warehouse of the Technical Department of Bolletje Almelo?".

Section 4.1 describes the Key Performance Indicators which give a representative review of the performance of the warehouse of the TD of Bolletje Almelo, by having interviews and conversations with the manager of the TD and the warehouse manager. Section 4.2 states the requirements for adequate spare parts inventory management, which are given by the manager of the TD and the warehouse manager. In Section 4.3, we expand the approach from Section 3.3 to decide whether to stock a spare part or not in the case of Bolletje Almelo. In Section 4.4 we compare and select one of the classification methods found in the literature study in Chapter 3. In Section 4.5, we develop the (new) inventory control policies for the warehouse of the TD of Bolletje Almelo, based on the KPIs, requirements and classification method from respectively Section 4.1, 4.2 and 4.4. Finally, Section 4.6 summarizes this chapter.

4.1 Selection of Key Performance Indicators

The KPIs found in the literature study in Section 3.2 are used for the meeting held with the manager of the TD and the warehouse manager. The goal of this meeting was to select a number of KPIs to achieve effective performance management. However, in real world, it is rather complicated to determine the right number of KPIs, due to limits of humans capacity for processing information, such as handling and managing KPIs. The paper "The magical number seven, plus or minus two" has inspired different theories, so Miller (1955) suggest numbers between five (seven minus two) and nine (seven plus two). Whereas Muchiri (2010) suggest to use at least six to a maximum of 31 KPIs.

It is the first time KPIs are being used at the TD of Bolletje Almelo, so therefore we choose for a maximum of five KPIs, partly based on the above mentioned numbers. This limited number of five KPIs ensures a good absorption in the organization of Bolletje with a possibility for extension in the future.

The following KPIs are selected during the meeting with the manager of the TD and the warehouse manager:

- Percentage of stock outs;
- Percentage of emergency purchases;
- Percentage of non moving parts;
- Percentage of target ship dates met;
- Production line availability.

These KPIs are based on the opinion of the author of this thesis, and the experiences and opinions of both the manager of the TD and the warehouse manager.

4.1.1 KPI 1: Percentage of stock outs

From an earlier meeting with the manager of the TD we already know that it is too often the case that some of the spare parts are not available from the warehouse when needed and/or the quantity of these parts is insufficient, see Section 1.3. This case is also called a stock out: when there is demand for an inventory item, but there is no stock.

The percentage of stock outs is already calculated for the current situation, see Section 2.6. When implementing stock outs as a KPI, the TD of Bolletje Almelo is able to monthly calculate this percentage of stock outs. Then this KPI is a useful indicator of incorrect inventory settings. If there are a lot of stock outs, this indicator tells that the inventory settings have to be reviewed. An important note here is that there is a difference between stock outs of different inventory types. Not all items are equal, so it may be okay that non critical spare parts have occasional stock outs, while stock outs are not desired for critical spare parts. A critical spare parts is defined as a spare part which has long delivery time (more than two days) and without this spare part there is downtime of the production line. Non critical spare parts are immediately available from the supplier and without this spare part there is no downtime of the production line.

According to Dewald (2011) the percentage of stock outs is calculated as follows:

$$\frac{Number\ of\ stock\ outs}{Total\ spare\ parts\ picked} * 100\% .$$

4.1.2 KPI 2: Percentage of emergency purchases

The second KPI is based on the goal of the TD, which is also described in Section 1.2:

> *The goal of the TD is to let all production lines produce as good as possible by conducting an optimal inventory management which minimizes downtime and costs, and maximizes the availability of the machinery.*

The KPI percentage of emergency purchases is distracted from the part *minimize downtime and maximize the availability of the machinery.* For Bolletje the availability of their production machinery has a high priority, because downtime of their machinery and production stagnation is definitely not desirable.

Here we define an emergency purchase as: an immediately needed purchase of a spare part because the failure and lack of this spare part causes downtime of a production line. The specific spare part is not (yet) registered in Rimses.

According to Dewald (2011) the percentage of emergency purchases is calculated as follows:

$$\frac{Number\ of\ emergency\ purchases}{Total\ number\ of\ \ purchases} * 100\%.$$

Monthly calculating this KPI gives the TD of Bolletje Almelo more insight in the number and effect of emergency purchases. Then, it could be useful for some spare parts to store one or more spare parts in the warehouse, to avoid downtime of a production line in the future.

4.1.3 KPI 3: Percentage of non moving parts

The percentage of non moving parts is the third interesting KPI for the warehouse of the TD of Bolletje Almelo. In the problem tree of Section 2.7, we already mentioned: there are too many different parts in the warehouse, because of insufficient collaboration between Bolletje and suppliers, and because the stock levels and reorder points are not up to date.

We define non moving parts as spare parts that have had no customer demand over a given time period. For Bolletje we distinguish between the spare parts in the different areas of the warehouse, because they differ in customer demand. For the spare parts in area 1 and 2 (see Appendix 1 and 2), which are the smaller parts such as lamps and bearings, we define a spare part as non moving when it did not had any customer demand over one year. For the spare parts in area 3 (see Appendix 1 and 2), which are the bigger spare parts such as motors and electrical components, we define a spare parts as non moving when it did not had any customer demand over five year.

Non moving parts takes up valuable warehouse space and ties up capital, so it is useful to get (more) insight in the amount of non moving parts.

According to Dewald (2011) the percentage of non moving parts is calculated as follows:

$$\frac{Parts\ identified\ as\ non\ moving}{Total\ number\ of\ parts\ in\ inventory} * 100\%.$$

Yearly calculating this KPI enables the TD of Bolletje Almelo to continuously update the stocks in their warehouse. Optionally, it is possible to sell back these non moving parts to suppliers of Bolletje, who are still using or purchasing these parts.

4.1.4 KPI 4: Percentage of target ship dates met

The fourth KPI is the percentage of target ship dates met, also called the percentage on time delivery. This KPI is especially useful to investigate the supplier's performance. From the meeting it becomes clear that this is an interesting and useful indicator, because during a contract negotiation with a specific supplier it is useful to have facts and numbers of that specific supplier, such as the percentage of on time deliveries.

According to Dewald (2011) the percentage of target ship dates met for a specific supplier is calculated as follows:

$$\frac{Number\ of\ shipments\ on\ time}{Total\ number\ of\ shipments} * 100\%.$$

When the warehouse manager places an order at a specific supplier, he also gives the desired delivery date. This delivery date indicates when the delivery can take place at the latest, because Bolletje needs the spare parts within this order as soon as possible. If the supplier delivers the order before or on this day, we define the order as an on time shipment. If the suppliers delivers the order later than the delivery date, they fail and the order is not delivered on time.

Monthly calculating this KPI enables the TD of Bolletje to have a well established position during contract negotiations with suppliers.

4.1.5 KPI 5: Production line unavailability (downtime)

The fifth and last KPI is also based on the goal of the TD as described in Section 1.2:

> *The goal of the TD is to let all production lines produce as good as possible by conducting an optimal inventory management which minimizes downtime and costs, and maximizes the availability of the machinery.*

At the moment Bolletje uses the Overall Equipment Effectiveness (OEE) tool as a measure of total equipment performance. This tool analyzes the availability, performance, and the quality rate of the output. The OEE tool is designed to identify losses that reduce the equipment effectiveness. These losses are activities that absorb resources but do not create value. In Figure 4.1 the OEE calculation is shown.

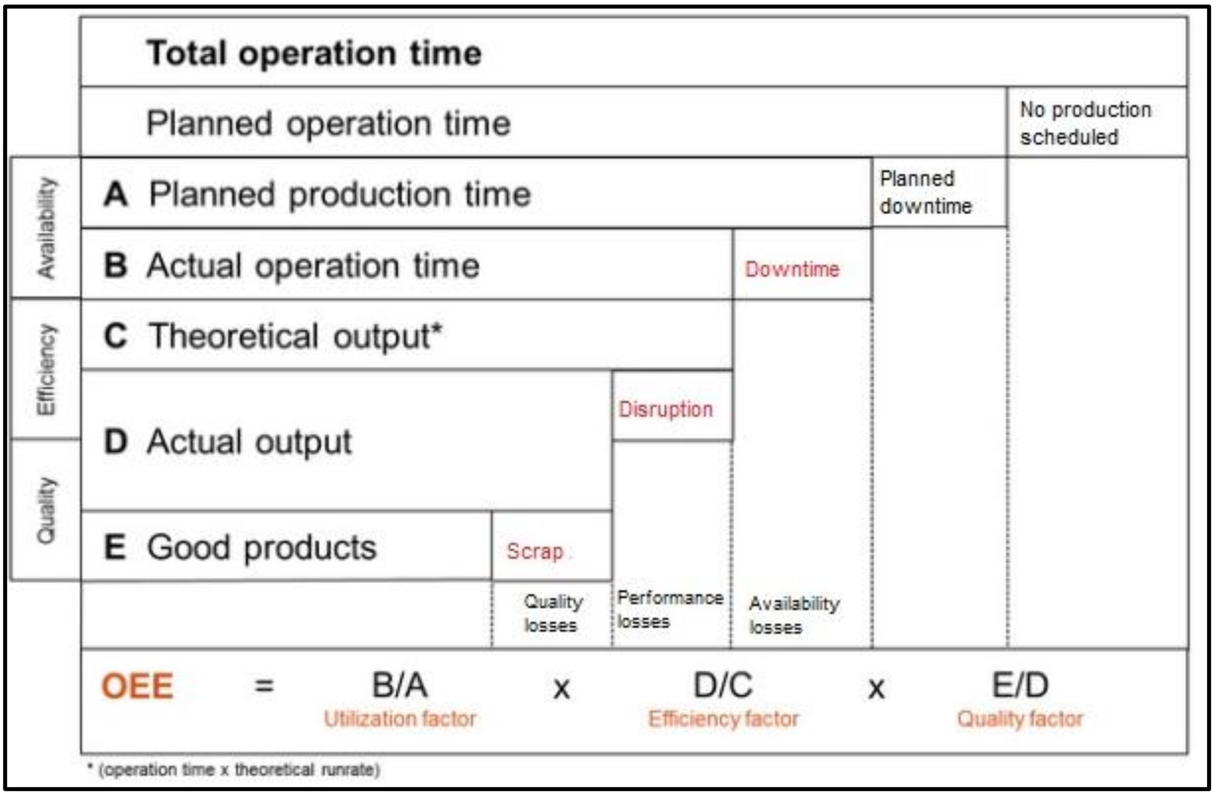

Figure 4.1 OEE calculation

Measuring the production line unavailability due to lack of spare parts is therefore an interesting KPI for the TD of Bolletje Almelo. The OEE enables Bolletje to measure the overall performance of the production lines. However, the TD does not have influence on the performance, but is mainly responsible for the availability of the production line. Therefore we only use the (un)availability as a measure for this KPI.

According to Figure 4.1 the production line unavailability due to lack of spare parts is calculated as follows:

$$\frac{Downtime\ due\ to\ lack\ of\ spare\ parts}{Planned\ production\ time}.$$

4.2 Requirements for adequate spare parts inventory management

Another result of the meeting with the manager of the TD and the warehouse manager is a list with requirements for adequate spare parts inventory management at the warehouse of the TD of Bolletje Almelo. During this meeting the following requirements are selected to address in this research, in accordance with both managers and the author of this thesis:

1) Using an easy method to classify the spare parts in the warehouse, which only requires a limited time for the warehouse manager. Besides that, this classification has to be included into Rimses, because Rimses is the system which includes almost all relevant data for the TD of Bolletje Almelo.
2) Generating and using price lists with the core suppliers of the TD of Bolletje Almelo, such as Schipper and Ammeraal. In these price lists the suppliers have to mention the dates for which the prices are valid (valid from ... to ...). In this way, we prevent the case that suppliers can ask prices which are much more higher than expected.
3) Dividing the object-ID MATERIAAL in different object-ID's in Rimses to distinguish between spare parts and working hours, so that a history is built from used spare parts. For example,

by adding the object-ID EXTERNE-UREN into Rimses, we can separate the working hours from the spare parts in Rimses. Detailing the object-ID MATERIAAL gives the TD of Bolletje Almelo the ability to analyze their usage of spare parts, and update their stocks in the warehouse based on this usage.

4) In consultation with suppliers, let the suppliers use the standard Bolletje purchase order numbers (*bestelbon nummers)* which start with 020. Besides that, the suppliers should only assign one invoice to one purchase order number, instead of assigning more invoices to one purchase order number. This purchase order number can only be used once, because otherwise Rimses creates errors.
5) There should be a closed warehouse environment when the warehouse manager is not present at the warehouse, where only the failure mechanics of Bolletje have the permission to enter the warehouse during these hours. This has to be designed to avoid the case that people other than failure mechanics from Bolletje (external mechanics, production personnel) can take spare parts from the warehouse without registering them in Rimses. If one of these people then needs something from the warehouse, they can ask one of the failure mechanics of Bolletje. The failure mechanics are using the smart phone and application, so they can correctly register the consumed spare parts in Rimses.
6) The warehouse manager should get automatic reorder suggestions from Rimses, so that he only has to check these proposals and consequently can order the required spare parts. The warehouse manager should be able to rely on Rimses, without checking the physically stock in the warehouse each time.
7) Getting insight in the current amount and value of the warehouse, and which is also obtainable quickly and easily from Rimses at any time. In this way the warehouse manager is able to send an up to date and correct record of the stock in the warehouse. Every year in December this is required by the accountant, because this person has to register the valuation of the stock.

The above mentioned topics are addressed in Chapter 5, where these activities are implemented at the warehouse of the TD of Bolletje Almelo. In Chapter 6 a pilot study is done to test the selected classification method and inventory control policies.

4.3 Decision making framework of stocking spare parts for Bolletje

As already mentioned in Section 3.3 the decision whether to stock (critical) spare parts or not is an important one when looking to inventory holding costs and downtime costs. At the moment it is too often the case that a specific spare part, which is very critical, expensive but little demanded, is not stocked at the warehouse of the TD of Bolletje Almelo. But on the other hand, the warehouse of the TD of Bolletje Almelo includes also a lot of spare parts which are very expensive, but have low demand. Besides stocking the spare part in their own warehouse, it is also possible to work together with suppliers by using supply chain collaboration. Consignment Inventory (CI), see Section 3.3, is a good option for Bolletje, because then the inventory is still owned by Bolletje but is held as stock by the supplier. In this way Bolletje has the security that the specific spare part is on stock, but it does not take space in the warehouse of the TD of Bolletje Almelo and Bolletje only pays the spare part when it is required.

So now the question arises: how can Bolletje justify when and where they should stock a specific spare part? For this reason we developed a decision making framework for Bolletje to justify when and where a specific spare part has to be stocked. Figure 4.2 and Figure 4.3 show the decision framework, which is developed in Excel.

Important note!

This decision making framework is especially developed for the expensive and less demanded spare parts, which are slow movers of the TD of Bolletje Almelo. We assume that these spare parts only fail once in a few years, so only for these spare parts we have to decide whether to stock or not. And if the decision is to stock the spare part, we only stock one spare part instead of more spare parts due to the low demand. We also assume that there is no chance of unavailability due to shortages or delivery lead time, because there is enough time to order, deliver and stock the spare part in the warehouse. On the other hand, the smaller and cheaper spare parts are always stocked in the warehouse, because they have a higher failure frequency. So this decision making framework is not used for the cheaper and frequently demanded spare parts of the TD of Bolletje Almelo.

The three choices which are compared in the framework of Figure 4.3 are as follows:

A) Not stocking the spare part in the warehouse of the TD of Bolletje Almelo.
B) Stocking the spare part in the warehouse of the TD of Bolletje Almelo.
C) Stocking the spare part at the supplier, by using Consignment Inventory (CI).

Decision making framework for stocking spare parts

Production Department	
Installation	
Process	
Installation costs per hour (costs associated with the consequential downtime)	*€ 1.000*
% of inventory holding costs	*25%*
Ratio of sharing inventory holding costs with supplier (CI)	*50%*

A: Spare part not on stock													**Consideration of choice**	
Spare part	**Technical lifetime in years**	**Administrative delay in hours**	**Logistic delay in hours**	**Setup time in hours**	**Diagnostic time in hours**	**Repair time in hours**	**Start up time in hours**	**Total downtime in hours when part not on stock (per failure)**	**Downtime costs in € (per failure)**	**Purchase costs in € of spare part**		**Total relevant costs in € (per failure)** Choice A	***Number >2, then consider to stock spare part.***	**Choice**
Motor	15	5	24	5	2	1	2	39	€ 39.000	€ 2.500		**€ 41.500**	1,00	Choice A
PLC	5	1	12	12	13	3	2	43	€ 43.000	€ 5.000		**€ 48.000**	1,00	Choice A
Mat	5	1	4	8	5	4	5	27	€ 27.000	€ 1.000		**€ 28.000**	1,00	Choice A

Figure 4.2 Decision making framework for stocking spare parts at Bolletje

B: Spare part on stock at warehouse of TD of Bolletje Almelo													Consideration of choice	
Spare part	**Technical lifetime in years**			**Setup time in hours**	**Diagnostic time in hours**	**Repair time in hours**	**Start up time in hours**	**Total downtime in hours when part not on stock**	**Downtime costs in €**	**Purchase costs in € of spare part**	**Inventory holding costs in € per year** *25%*	**Total relevant costs in € (per failure)** **Choice B**	***Number >2,* then consider to stock spare part at Bolletje.**	**Choice**
Motor	15			5	2	1	2	10	€ 10.000	€ 2.500	€ 9.375	**€ 12.500**	3,32	Choice B or C
PLC	5			12	0	3	2	17	€ 17.000	€ 5.000	€ 6.250	**€ 22.000**	2,18	Choice B or C
Mat	5			8	0	4	5	17	€ 17.000	€ 1.000	€ 1.250	**€ 18.000**	1,56	Choice A

C: Spare part on stock at warehouse of supplier													Consideration of choice	
Spare part	**Technical lifetime in years**		**Logistic delay in hours**	**Setup time in hours**	**Diagnostic time in hours**	**Repair time in hours**	**Start up time in hours**	**Total downtime in hours when part not on stock**	**Downtime costs in €**	**Purchase costs in € of spare part**	**Inventory holding costs in € per year** *25%* **By using CI**	**Total relevant costs in € (per failure)** **Choice C**	***Number >2,* then consider to stock spare part at supplier.**	**Choice**
Motor	15		1	5	2	1	2	11	€ 11.000	€ 2.500	€ 4.688	**€ 18.188**	0,69	Choice B
PLC	5		1	12	1	3	2	19	€ 19.000	€ 5.000	€ 3.125	**€ 27.125**	0,81	Choice B
Mat	5		1	8	1	4	5	19	€ 19.000	€ 1.000	€ 625	**€ 20.625**	0,87	Choice B

Figure 4.3 Decision making framework for stocking spare parts at Bolletje

4.3.1 Explanation and formulas of the decision making framework

In Table 4.2 three different spare parts are taken as example for the assessment whether and if so where to stock, namely a motor, PLC and mat. Some remarks on the framework:

- All red marked numbers in the decision making framework are variable, so they are changeable for each company, production line and process.
- The ratio of sharing the inventory holding costs with the supplier by using Consignment Inventory highly depends on the contract agreement with the supplier.
- The holding costs consists of among others costs for energy, material handling, maintenance, direct labour, obsolescence, product damage, product depreciation and IT system.
- For all three choices the total relevant costs are calculated, by using the formula from Section 3.3:

$$\textbf{Total relevant costs} = \textbf{inventory holding costs} + \textbf{downtime costs} + \textbf{purchase costs.}$$

- The following formulas are used for the above shown framework:

$$\begin{aligned}\textbf{Total downtime in hours (per failure)} \\ &= \textbf{administrative delay in hours} + \textbf{logistic delay in hours} \\ &+ \textbf{setup time in hours} + \textbf{diagnostic time in hours} \\ &+ \textbf{repair time in hours} + \textbf{start up time in hours}\end{aligned}$$

$$\begin{aligned}\textbf{Downtime costs in € (per failure)} \\ &= \textbf{installation costs in € per hour} * \textbf{total downtime in hours}\end{aligned}$$

$$\begin{aligned}\textbf{Inventory holding costs in € (per year)} \\ &= \% \textbf{ of inventory holding costs} * \textbf{purchase costs in €}\end{aligned}$$

$$\begin{aligned}\textbf{Inventory holding costs in € (per failure)} \\ &= \textbf{Inventory holding costs in € (per year)} \\ &* \textbf{technical life time in years}\end{aligned}$$

$$\begin{aligned}\textbf{Inventory holding costs in € by using CI (per year)} \\ &= \% \textbf{ of inventory holding costs} * \textbf{purchase costs in €}\end{aligned}$$

$$\begin{aligned}\textbf{Inventory holding costs in € by using CI (per failure)} \\ &= \% \textbf{ Ratio of sharing inventory holding costs} \\ &* \textbf{ Inventory holding costs in € by using CI (per year)} \\ &* \textbf{technical lifetime in years}\end{aligned}$$

$$\begin{aligned}\textbf{Total relevant costs in € (per failure)} \\ &= \textbf{inventory holding costs in € (per failure)} \\ &\quad + \textbf{downtime costs in € (per failure)} + \textbf{purchase costs in €}\end{aligned}$$

- After calculating the total relevant costs the choices are compared with each other, to decide whether and if so where to stock the spare part. In the above shown framework a factor of two is used to compare the total relevant costs of the different choices. The following formulas are used to compare the different choices:

$$\textbf{First comparison of choices} = \frac{\textbf{total relevant costs in € (per failure) of choice A}}{\textbf{total relevant costs in € (per failure) of choice B}}$$

$$\textbf{Second comparison of choices} = \frac{\textbf{total relevant costs in € (per failure) of choice B}}{\textbf{total relevant costs in € (per failure) of choice C}}$$

4.3.2 Example

To get more understanding of the above mentioned decision making framework for stocking spare parts, there is an example of this case, see Example 4 below. As example we take a motor as example, which is also used in the decision making framework shown in this section. This motor is an example of an expensive and bigger spare part, which only fails once in a few years. Therefore this spare part is suitable for the decision making framework whether to stock or not, see the corresponding note and assumptions on page 48.

Example 4

We assume that the specific motor has failed and needs to be replaced by a new motor. The installation costs per hour are € 1,000. The percentage of inventory holding costs per spare part per year is set to 25%. The ratio of sharing the inventory holding costs with the supplier (CI) is set to 50%. A factor of 2 is taken to compare the different choices with each other.

Choice A: Spare part not on stock.

We fill in the abovementioned decision making framework, by which we start with the first choice: not stocking the spare part at the warehouse of the TD of Bolletje Almelo. In this situation there are no inventory holding costs for Bolletje, so these costs are € 0. To calculate the different elements in the framework for choice A we use the following formulas:

$$\begin{aligned}\textbf{Total downtime in hours}\ (\textbf{per failure}) &= \textbf{administrative delay in hours} + \textbf{logistic delay in hours} \\ &+ \textbf{setup time in hours} + \textbf{diagnostic time in hours} \\ &+ \textbf{repair time in hours} + \textbf{start up time in hours} \\ &= 5 + 48 + 5 + 2 + 1 + 2 = 63\end{aligned}$$

$$\begin{aligned}\textbf{Downtime costs in €}\ (\textbf{per failure}) &= \textbf{installation costs in € per hour} * \textbf{total downtime in hours} \\ &= €\ 1{,}000 * 63 = €\ 63{,}000\end{aligned}$$

$$\begin{aligned}\textbf{Total relevant costs in €}\ (\textbf{per failure}) &= \textbf{inventory holding costs in €}\ (\textbf{per failure}) \\ &+ \textbf{downtime costs in €}\ (\textbf{per failure}) \\ &+ \textbf{purchase costs in €} \\ &= €\ 0 + €\ 63{,}000 + €\ 2{,}500 = €\ 65{,}500\end{aligned}$$

Choice B: Spare part on stock at warehouse of TD of Bolletje Almelo

To compare the costs of the choice not stocking the spare part with the choice of stocking the spare part at the warehouse of the TD of Bolletje Almelo, we also fill in the framework for choice B. In this situation there is no administrative and logistic delay, because Bolletje already has the spare part on stock in their warehouse. To calculate the different elements in the framework for choice B we use the following formulas:

Example 4 - continued

$$\textbf{Total downtime in hours (per failure)} = \textbf{administrative delay in hours} + \textbf{logistic delay in hours} + \textbf{setup time in hours} + \textbf{diagnostic time in hours} + \textbf{repair time in hours} + \textbf{start up time in hours} = 0 + 0 + 5 + 2 + 1 + 2 = 10$$

$$\textbf{Downtime costs in € (per failure)} = \textbf{installation costs in € per hour} * \textbf{total downtime in hours} = € 1{,}000 * 10 = € 10{,}000$$

$$\textbf{Inventory holding costs in € (per year)} = \% \textbf{ of inventory holding costs} * \textbf{purchase costs in €} = 0{,}25 * € 2{,}500 = € 625$$

$$\textbf{Inventory holding costs in € (per failure)} = \textbf{Inventory holding costs in € (per year)} * \textbf{technical life time in years} = € 625 * 15 = € 9{,}375$$

$$\textbf{Total relevant costs in € (per failure)} = \textbf{inventory holding costs in € (per failure)} + \textbf{downtime costs in € (per failure)} + \textbf{purchase costs in €} = € 9{,}375 + € 10{,}000 + € 2{,}500 = € 21{,}875$$

$$\textbf{First comparison of choices} = \frac{\textbf{total relevant costs in € (per failure) of choice A}}{\textbf{total relevant costs in € (per failure) of choice B}} = \frac{€ 65{,}500}{€ 21{,}875} = 2.99$$

The number 2.99 is higher than 2, so we consider to stock the spare part at the warehouse of Bolletje or at the supplier. Therefore we also investigate the third option: stocking the spare part at the warehouse of the supplier. If this number was lower or equal to 2, then we had chosen choice A: not stocking the spare part.

<u>Choice C: Spare part on stock at warehouse of supplier</u>

To compare the costs of the choice stocking the spare part at the warehouse of Bolletje with the choice of stocking the spare part at the warehouse of the supplier, we also fill in the framework for choice C. In this situation there is no administrative delay, because Bolletje already has arranged the stocking of the spare part at the supplier. To calculate the different elements in the framework for choice C we use the following formulas:

$$\textbf{Total downtime in hours (per failure)} = \textbf{administrative delay in hours} + \textbf{logistic delay in hours} + \textbf{setup time in hours} + \textbf{diagnostic time in hours} + \textbf{repair time in hours} + \textbf{start up time in hours} = 0 + 1 + 5 + 2 + 1 + 2 = 11$$

$$\textbf{Downtime costs in € (per failure)} = \textbf{installation costs in € per hour} * \textbf{total downtime in hours} = € 1{,}000 * 11 = € 11{,}000$$

Example 4 - continued

$$\textit{Inventory holding costs in € by using CI (per year)}$$
$$= \textit{\% of inventory holding costs} * \textit{purchase costs in €}$$
$$= 0.25 * €\,2{,}500 = €\,625$$

$$\textit{Inventory holding costs in € by using CI (per failure)}$$
$$= \textit{\% Ratio of sharing inventory holding costs}$$
$$* \textit{ Inventory holding costs in € by using CI (per year)}$$
$$* \textit{ technical lifetime in years}$$
$$= 0.50 * €\,625 * 15 = €\,4{,}688$$

$$\textit{Total relevant costs in € (per failure)}$$
$$= \textit{inventory holding costs in € (per failure)}$$
$$+ \textit{downtime costs in € (per failure)}$$
$$+ \textit{purchase costs in €}$$
$$= €\,4{,}688 + €\,11{,}000 + €\,2{,}500 = €\,18{,}188$$

$$\textit{First comparison of choices}$$
$$= \frac{\textit{total relevant costs in € (per failure) of choice A}}{\textit{total relevant costs in € (per failure) of choice B}}$$
$$= \frac{€\,21{,}875}{€\,18{,}188} = 1.20$$

The number 1.20 is lower than 2, so we choose to stock the spare part at the warehouse of Bolletje. If this number was higher than 2, then we had chosen choice C: stocking the spare part at the warehouse of the supplier.

4.4 Selection of classification method

In Section 3.3 several classification methods for managing spare parts are described:

- Original ABC analysis;
- Multi-criteria analysis:
    - Joint criteria matrix;
    - Analytic Hierarchy Process (AHP);
- FSN analysis;
- VED analysis.

After comparing these different classification methods and another meeting with the warehouse manager, the original ABC analysis is selected as classification method for the spare parts of the warehouse of the TD of Bolletje Almelo. The main reason for this choice is that Rimses already includes the possibility to use the ABC(DE) classification, see Figure 4.4. At the moment all parts in Rimses are registered as class E (default setting), but by correctly using the ABC analysis all parts get the code A, B or C.

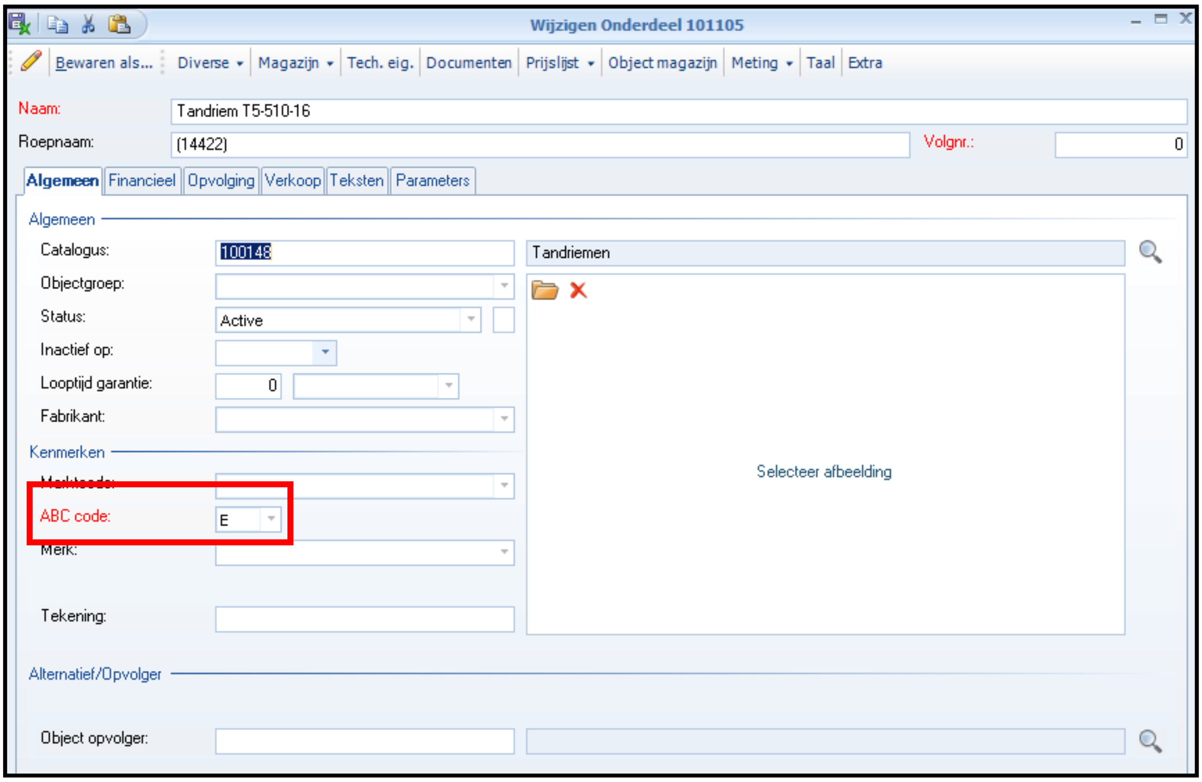

Figure 4.4 Classification of spare parts in Rimses

4.4.1 Criterion for classification method

Summarized from Section 3.3 the ABC analysis is described as a classification where spare parts are categorized into three classes: A, B and C. The analysis uses only one criterion to separate the spare parts from each other, such as annual dollar usage, annual demand, unit price or criticality.

As already mentioned in Section 2.4 the TD of Bolletje Almelo has little to no data about the usage of spare parts from the past few years, due to the incomplete registration of consumed spare parts and the incorrect registration of consumed spare parts. For this reason it is difficult to use annual dollar usage or annual demand as criterion for the ABC analysis. On the other hand, criticality is a useful criterion for the TD of Bolletje Almelo according to the warehouse manager and the author of this thesis, because we can estimate the criticality of spare parts based on the experience from the warehouse manager and the failure mechanics. Therefore, we opt for using criticality as criterion for the original ABC analysis. After one year Bolletje has to investigate if this is still the best criterion, because in the coming year the usage of spare parts is better registered in Rimses, which ensures more detailed data about the usage of spare parts. Bolletje has to analyze this data about the usage of spare parts and based on this analysis they have to determine how to continue in the future. The different options to continue with the classification method, depending on the available data, are as follows:

- Continuously using the original ABC analysis with criticality as criterion.
- Using the original ABC analysis, but then with annual dollar usage or annual demand as criterion.
- Using two different criteria through the joint criteria matrix.

4.4.2 ABC classification at Bolletje

Together with the warehouse manager and the manager of the TD we have defined the different classes of the original ABC analysis with criticality as criterion. For Bolletje the price of a spare part is not an issue since they strive for high production line availability. Therefore, the classes are defined as follows for Bolletje:

- Class A items consists of spare parts with very high criticality. This means that a spare part with very high criticality has long delivery time (more than two days), without this spare part there is downtime of the production line and no safety at the line, and there are no alternative spare parts to replace this part. The electrical and programmable spare parts at the warehouse of the TD of Bolletje Almelo are examples of class A items.
- Class B items consists of spare parts with intermediate criticality. This means that a spare part with intermediate criticality has less delivery time (less than or equal to two days), without this spare part the production line is still running, and sometimes there are alternative spare parts to replace this part or there is redundancy in the production line. The mechanical spare parts at the warehouse of the TD of Bolletje Almelo are examples of class B items.
- Class C items consists of spare parts with low criticality. This means that a spare part with low criticality is immediately available from the supplier, without this spare part the production line is still running and there are always alternative spare parts to replace this part or there is redundancy in the production line. The grab stock at the warehouse of the TD of Bolletje is an example of class C items.

In the next section, Section 4.5, we develop the (new) inventory control policies for each class of spare parts, based on the original ABC analysis. In Chapter 6, we execute a pilot study and classify the spare parts of the warehouse of the TD of Bolletje based on the abovementioned classes.

4.5 Development of (new) inventory control policies

Besides using the selected classification method from Section 4.3, the original ABC analysis with criticality as criterion, we choose an inventory control policy for each class of spare parts.

As already described in Section 2.3, Rimses includes five different restocking policies, divided into automatic and manual restocking policies. The following restocking policies are available in Rimses, as shown in Figure 4.5:

- No restocking.
- Automatic – via reorder point and EOQ: restocking the EOQ, if the inventory position is below the reorder point. The warehouse manager gets an automatic reorder suggestion from Rimses.
- Automatic – via reorder point and maximum stock (as defined in Rimses): restocking the difference between the current inventory position and the maximum stock (as defined in Rimses), if the inventory position is below the reorder point. The warehouse manager gets an automatic reorder suggestion from Rimses.
- Manual – physical stock, reorder point and EOQ: based on the inventory position, restocking the EOQ if the inventory position is below the reorder point. The warehouse manager has to order manually.
- Manual – physical stock, reorder point and maximum stock (as defined in Rimses): based on the inventory position, restocking the difference between the current inventory position and the maximum stock (as defined in Rimses), if the inventory position is below the reorder point. The warehouse manager has to order manually.

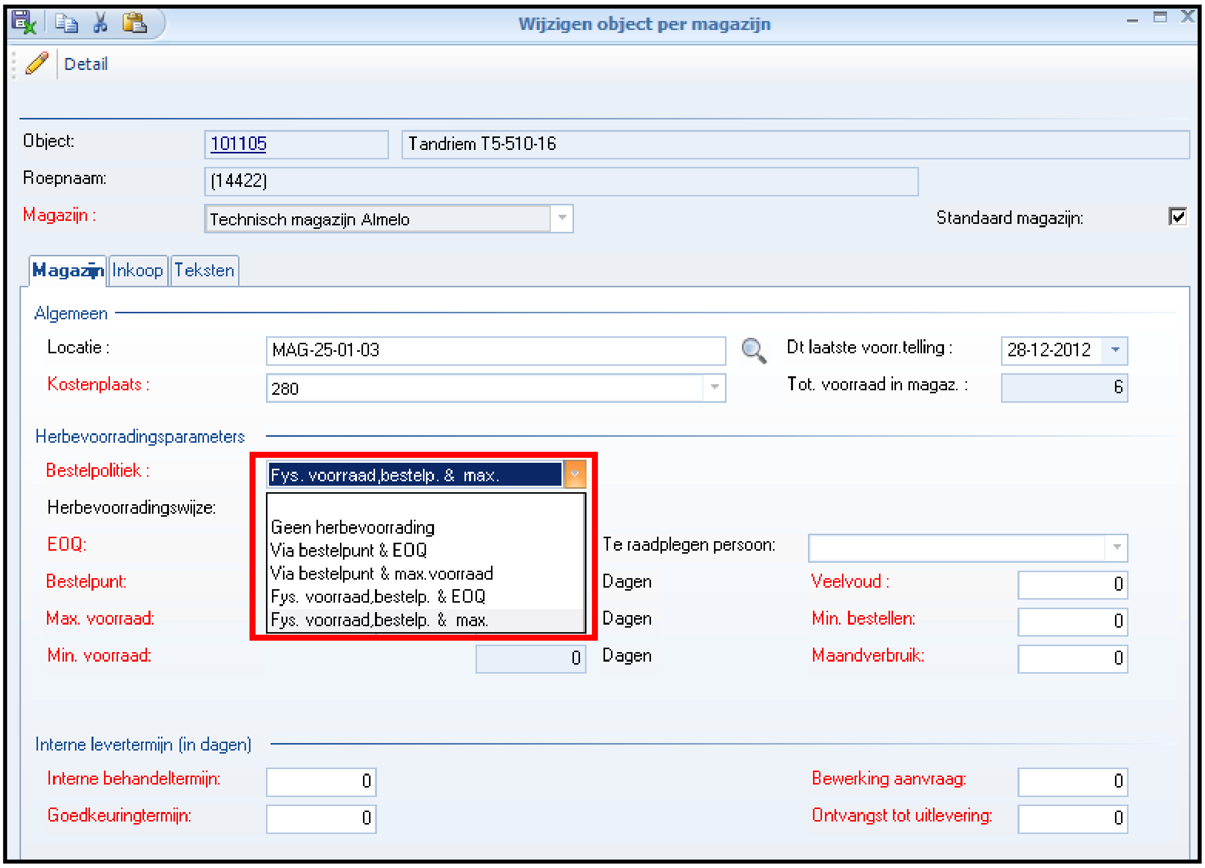

Figure 4.5 Restocking policies in Rimses

The continuous review policies, described in Section 3.5, are comparable with the abovementioned restocking policies from Rimses. The *(s,Q)* policy means that a fixed quantity batch *Q* is ordered whenever the inventory position drops to the reorder point *s* or lower. This *(s,Q)* policy is comparable with one of the policies from Rimses: restocking the EOQ if the inventory position is below the reorder point. The *(s,S)* policy means that a replenishment is made whenever the inventory position drops to the reorder point *s* or lower, and a variable replenishment quantity is ordered to raise the inventory position to the order-up-to-level *S* (also referred to a min-max system). This *(s,S)* policy is comparable with the another policy from Rimses: restocking the difference between the current inventory position and the maximum stock (as defined in Rimses), if the inventory position is below the reorder point.

As already mentioned in Section 3.5, Silver et al. (2017) use a simple rule of thumb for choosing the right inventory control policy for the right class of spare parts. For this reason we select the inventory control policies of Silver et al. (2017) for the spare parts of the warehouse of the TD of Bolletje Almelo. Rimses includes inventory control policies which are comparable with the policies of Silver et al. (2017), so due to the reason that Rimses already includes two continuous review policies, we select the two above mentioned restocking policies as inventory control policies for the different classes of spare parts. Table 4.1 shows the selected control policies from Silver et al. (2017) and the corresponding policies in Rimses.

	Inventory control policy according to Silver et al., (2017)	Corresponding control policy in Rimses
A items	*(s,S)*	*Automatic: via reorder point and maximum stock*
B items	*(s,Q)*	*Automatic: via reorder point and EOQ*
C items	*Manual ~ (s,Q)*	*Manual: via reorder point and EOQ*

Table 4.1 Inventory control policies for each class of spare parts (Silver et al., 2017)

The above mentioned control policies from Rimses are already used at the warehouse of the TD of Bolletje Almelo, but for most of the spare parts the inventory control policy is not correctly assigned. This is caused by the lack of classification of spare parts, the lack of a corresponding inventory control policy for each class of spare parts, and not up to date values of the current restocking parameters. To implement the inventory control policies from Table 4.1 in Rimses, we need to take three steps:

1) Classifying the spare parts in the different classes.
2) Selecting the right inventory control policies and (re)defining the values of the restocking parameters for all spare parts in Rimses.
3) When these restocking parameters are correctly defined in Rimses, the warehouse manager can rely on the subsequent reorder suggestions from Rimses. Finally, he only has to check the reorder suggestions and then he can order the required spare parts.

Chapter 5 describes the implementation plan, in which we also define how to implement the original ABC analysis with the selected inventory control policies from Table 4.1 for the different classes of spare parts.

4.6 Conclusion

In this chapter we found an answer to the third research question: "*How to organize (new) inventory control policies for the warehouse of the Technical Department of Bolletje Almelo?".*

First, we organized a meeting with the manager of the TD and the warehouse manager to select a number of KPIs to achieve effective performance management at the warehouse of the TD of Bolletje Almelo. The following KPIs are forthcoming from this meeting:

- Percentage of stock outs;
- Percentage of emergency purchases;
- Percentage of non moving parts;
- Percentage of target ship dates met (on time delivery).

Another results of the meeting with the manager of the TD and the warehouse manager is a list with requirements for adequate spare parts inventory management. The following requirements are addressed in this research:

1) Using an easy method to classify the spare parts in the warehouse.
2) Generating and using price lists with the core suppliers.
3) Dividing the object-ID MATERIAAL in different object-IDs in Rimses to distinguish between spare parts and working hours.
4) Let suppliers use the standard Bolletje purchase order numbers (*bestelbon nummers).*
5) A closed warehouse environment when the warehouse manager is not present in the warehouse.
6) Automatic reorder suggestions from Rimses.
7) Insight in the current amount and value of the warehouse.

We have selected the original ABC analysis as classification method for the different spare parts in the warehouse and we have chosen criticality as criterion for this ABC analysis. The (s,S) and (s,Q) review policies are selected as inventory control policies for the different classes of spare parts, see Table 4.2.

	Inventory control policy according to Silver et al., (2017)	Corresponding control policy in Rimses
A items	*(s,S)*	*Automatic: via reorder point and maximum stock*
B items	*(s,Q)*	*Automatic: via reorder point and EOQ*
C items	*Manual ~ (s,Q)*	*Manual: via reorder point and EOQ*

Table 4.2 Inventory control policies for each class of spare parts

The above mentioned requirements, classification method and inventory control policies are described in the implementation plan and implementation phase of Chapter 5.

5. Implementation plan and implementation phase

This chapter answers the fourth research question: "How to implement the (new) inventory control policies at the warehouse of the Technical Department of Bolletje?".

Section 5.1 describes the activities which should be carried out to reach a successful implementation of the (new) inventory control policies. Section 5.2 includes the implementation phase of the implementation plan from Section 5.1. Finally, Section 5.3 summarizes this chapter.

5.1 Implementation activities of this research

During this research the implementation phase of the (new) inventory control policies at the warehouse of the TD of Bolletje is already started. To implement these (new) inventory control policies several activities had to be carried out in this research. These activities are based on the requirements stated in Section 4.2, the selected classification method from Section 4.3, and the selected inventory control policies from Section 4.5. The implementation plan includes the following activities, which have to be performed in chronological order:

1) Writing instruction manuals for different processes in Rimses.
2) Generating and using pricelists with two of the core suppliers of the TD of Bolletje Almelo.
3) Adequately using the standard Bolletje purchase order numbers (*bestelbon nummers*).
4) Changing the current way of reception of spare parts, matching, and invoice registration.
5) Specifying the object-ID MATERIAAL in different object-IDs.
6) Generating a closed warehouse environment when the warehouse manager is not present in the warehouse.
7) Performing a pilot study for certain spare parts of the warehouse.

Section 5.2 includes the implementation phase of the above mentioned activities, so the implementation of these activities is part of this research. The last step of the implementation plan, performing a pilot study, is done in Chapter 6.

5.2 Implementation phase

As already stated before, during this research we have already started with the implementation phase of the (new) inventory control policies. In this section we describe the execution of the implementation activities from Section 5.1 one by one.

1. Writing instruction manuals for different processes in Rimses

Based on the available information from Rimses and by executing tests in Rimses, we have written different instruction manuals for different processes in Rimses. The selection of writing instruction manuals for specific processes in Rimses is based on the goal of this research and the main research question: "determining adequate inventory management and control policies for the spare parts of the warehouse of the TD of Bolletje Almelo by creating an environment where the spare parts are managed properly so as to balance the availability of machinery, the inventory costs and downtime of machinery". The following processes from Rimses are described in instruction manuals:

- Entering a new order line;
- Sending orders to suppliers;
- Approving purchase orders (authorization);
- Revision of purchase orders;

- Sending rappels (reminders) to suppliers;
- Receiving deliveries;
- Invoice registration;
- Using and generating price lists.

These instruction manuals are now available for among others the warehouse manager. In this way, all the processes are well documented for all employees of the TD of Bolletje Almelo. Appendix 5 and 6 show the two most important instruction manuals for this research: using and generating pricelists, and invoice registration.

2. Generating and using pricelists with two of the core suppliers

By using the instruction manual "Using and generating pricelists" (see Appendix 6) we have generated pricelists with two of the core suppliers of the TD of Bolletje Almelo, namely Schipper and Ammeraal. For both of the suppliers we have selected all their spare parts which are stocked in the warehouse of the TD of Bolletje Almelo. These pricelists are generated by performing the following steps:

- Creating and sending an electronic price quote from Rimses to the specific supplier;
- Receiving back the price quote from the supplier;
- Uploading the price quote into Rimses;
- Registering the price quote into Rimses.
- (Optionally, performing a price comparison in Rimses, for each spare part of the specific supplier).

The result is having up to date prices of all spare parts from Schipper and Ammeraal, so that the warehouse manager has always access to these prices and he can also rely on these prices. In the future Bolletje should generate and use pricelists with all suppliers, because then all spare parts from their warehouse are correctly priced in Rimses.

3. Adequately using the standard Bolletje purchase order numbers

In the current situation the suppliers of the TD of Bolletje Almelo are often wrongly assigning and using the purchase order numbers, when they sent an invoice or other document to Bolletje. Now they are assigning more invoices to one purchase order number, but they should only be able to assign one invoice to one purchase order number. Besides that, they are using this purchase order number more than once, which creates errors in Rimses and the warehouse manager has to change this number manually in Rimses.

To solve this problem we have added an additional line at this purchase order document, which is sent to the supplier. This line includes the following: "Please use the purchase order number which is stated on this purchase order when sending an invoice or other document to Bolletje. And be aware, this purchase order number is unique, so it can only be used once." By adding this line we want to ensure that the suppliers are using the purchase order numbers in the right way.

4. Changing the current way of reception of spare parts, matching, and invoice registration

As already described in this research, in the current situation the function invoice registration is not used in Rimses. To always have up to date stock quantities and economic values of the warehouse, it is necessary to use this important function in Rimses. The reception of spare parts is also related to this function, so we had to change the reception of spare parts, current way of matching, and invoice registration.

Process of change

To change the current way of matching and invoice registration we first needed permission from the Financial Department of Bolletje and the manager of the TD, because they do the final check of invoices. During several meetings with the manager of the TD and the Financial Department of Bolletje we have discussed the possibilities and consequences of using the invoice registration. Besides that, we have tested the invoice registration for some small invoices, to check if it actually works and to show the new process to the Financial Department and manager of the TD.

During this test phase several problems occurred, but in cooperation with the warehouse manager, the manager of the TD and the Financial Department we have solved some difficulties:

- The biggest issue of changing the current way of matching was the fear of losing control by the Financial Department and the manager of the TD. However, this is solved by writing down the intern invoice number from Rimses into D3, the financial accounting system of Bolletje. When the manager of the TD has to check and approve a specific invoice in D3, he has to use the corresponding intern invoice number from D3 to search for the specific invoice in Rimses. In this way the manager of the TD and the Financial Department still have the control of checking and approving invoices.
- The Financial Department uses their own invoice numbers, namely numbers starting with the description PA. After testing the invoice registration we have seen that this number is the final number in Rimses and D3, so the PA number overwrites the intern invoice number of Rimses. However, during the invoice registration it is necessary to also write the PA number of the specific invoice in Rimses, so that afterwards there is still a link between the invoice in D3 and the invoice in Rimses.
- Invoices which include extra costs, such as transport costs, which do not belong to the materials or hours on the invoice, have to be registered in another way. The warehouse manager has to write an additional order line, in which he registers the extra costs.
- If the unit price of a spare part in Rimses is different than the unit price at the invoice, Rimses generates an error during the invoice registration. To solve this error the warehouse manager has to change this unit price in Rimses, by which the spare part is assigned the right economic value.

After having these meetings and several tests in Rimses we have agreed on changing the current way of matching.

Differences between current and new processes

Appendix 3 and 4 show respectively the current processes of the delivery and reception of spare parts, and the current invoice registration. Appendix 7 and 8 show respectively the new processes of the delivery and reception of spare parts, and invoice registration.

The differences between the current and new process of delivery and reception of spare parts (as shown in Appendix 3, 4, 7 and 8) are as follows:

- The person who registers the delivery.
    - In the current situation the *warehouse manager* physically stocks the delivered spare parts in the warehouse after receiving the spare parts from the supplier. However, the materials are only stocked in Rimses after receiving the invoice and this is done by the *manager of the TD*.
    - In the new situation the *warehouse manager* registers the delivered spare parts in Rimses, by writing down the delivery document number into Rimses. Besides that, the *warehouse manager* physically stocks the delivered spare parts in the warehouse.

- The moment of this registration.
  - In the current situation the spare parts are only registered in Rimses *after receiving the invoice*.
  - In the new situation the spare parts are directly registered Rimses *after receiving the spare parts.*
- The registration number which is entered into Rimses.
  - In the current situation the manager of the TD writes down a wrong registration number into the field “Delivery document number” of Rimses, namely *the invoice number of the supplier*.
  - In the new situation the warehouse manager writes down the correct registration number into the field “Delivery document number” of Rimses, namely *the delivery document number of the specific delivery*.

The differences between the current and new process of invoice registration (as shown in Appendix 3, 4, 7 and 8) are as follows:

- The result of the invoice registration.
  - In the current situation the invoice cannot be found back in Rimses, because the invoice is *not registered in Rimses*. The invoice is *only registered in D3*, the financial accounting system of Bolletje.
  - In the new situation the invoice is *registered in Rimses*, because the warehouse managers uses the function invoice registration in Rimses. Besides that, the invoice is *also registered in D3*.
- The content which has to be checked.
  - In the current situation the manager of the TD *checks the sum and the content of the invoice from D3 with the available from Rimses*.
  - In the new situation the manager of the TD *checks the invoice from D3 with the invoice which is registered in Rimses*.
- The variable which is used for checking the invoice.
  - In the current situation the manager of the TD checks the invoice in Rimses by using the *purchase order number* which is written down in D3 by the warehouse manager.
  - In the new situation the manager of the TD checks the invoice in Rimses by using the *intern invoice number* which is written down in D3 by the warehouse manager.

Consequences

The warehouse manager has officially started using the function invoice registration in Rimses from the fifteenth of May, whereby the warehouse manager is supported by the written instruction manual “Invoice registration” (see Appendix 6).

The result is having up to date stock quantities and economic values of all spare parts stocked in the warehouse, due to the correctly used reception of spare parts and invoice registration. Besides that, the manager of the TD saves a lot of time by the new invoice registration. In the old situation he has to search, register and write several issues in D3 and Rimses, which took approximately ten minutes per invoice. In the new situation he only has to match the invoice from D3 with Rimses, which takes approximately two minutes per invoice. The TD of Bolletje Almelo gets approximately fifty invoices per week. So the manager of the TD saves approximately 400 minutes per week by using the new invoice registration.

5. Specifying the object-ID MATERIAAL in different object-IDs

In the current situation a lot of spare parts, but also working hours of external service mechanics are designated as MATERIAAL. Consequently there is no history available on the usage of spare parts and working hours. Therefore it is important to register the physical spare parts and working hours separately in Rimses, which gives the possibility for the future to analyze the usage of all different spare parts and the working hours of a specific supplier or installation in the factory. Together with the warehouse manager we have created some new object-IDs in Rimses, whereby the hours are registered separately from the spare parts. Besides that, the hours are registered separately for each supplier, so that for each supplier the total amount of working hours per period is available from Rimses. A (new) spare part which is yet not registered in Rimses also requires a unique object-ID. So this spare part also has to be registered separately in Rimses, instead of using the object-ID MATERIAAL. The object-ID MATERIAAL is removed from Rimses, so it is not longer possible to use this object-ID. Figure 5.1 shows the new object-IDs which are now ready for use in Rimses.

Object-ID	Te gebruiken voor:
UREN	Gepland TD uitbesteed werk (STS, Löwik, etc.)
DIENST	Inhuur storingsmonteur
SPOEDUREN	Ongepland TD uitbesteed werk
CONTRACT	Onderhoudscontracten TD Bolletje
MATERIEEL	Huur machines, hoogwerkers, etc.
MATERIAAL	Materiaal dat niet in opbouw Rimses staat*
TRANSPORTKOSTEN	Algemene transportkosten
KOERIERKOSTEN	Spoedkosten voor transport

*** Wanneer het materiaal WEL in de opbouw van Rimses staat/thuishoort, dan het desbetreffende object-ID voor dit materiaal selecteren/een nieuw object-ID aanmaken in Rimses!!**

Figure 5.1 New object-IDs to be used in Rimses

The people from the TD of Bolletje Almelo who are also working with Rimses have had a presentation and explanation about the new way of registration of spare parts and working hours in Rimses.

6. Generating a closed warehouse environment when the warehouse manager is not present

In the current situation it is too often the case that spare parts are moved from the warehouse, but without registering in Rimses. This often occurs when the warehouse manager is not present in the warehouse, so during night hours. Then the warehouse manager and the failure mechanics have problems with picking spare parts, because the stock quantities in the warehouse and Rimses do not always match with each other.

Together with the warehouse manager and the manager of the TD we have found a solution for this problem. All employees of Bolletje have an access card, allowing them to enter different buildings and areas at the site of Bolletje. The warehouse also features the system that requires your access card to enter, but at the moment all access cards of all employees are active at the warehouse. The solution we have generated is that only the failure mechanics of Bolletje have the permission to enter the warehouse during the absence hours of the warehouse manager. This means that only the access cards of the failure mechanics are active at the warehouse during these absence hours. People other than failure mechanics from Bolletje (external mechanics, production personnel) cannot enter the warehouse, so if they need something from the warehouse they have to ask one of the failure mechanics of Bolletje. The failure mechanics are using the smart phone and application, allowing them to correctly register the used spare parts in Rimses.

If there is now a problem with the stock quantities in the warehouse and Rimses, the failure mechanics and the warehouse manager are the only persons who are responsible for this. To solve any stock difference you only have to ask these persons, instead of sending a mail to almost all employees of Bolletje.

By generating this closed warehouse environment, when the warehouse manager is not present at the warehouse, the picking problem has been solved to a large extent. It is still possible to have differences between the stock quantities of the warehouse and Rimses, for example by incorrect registration of used spare parts, but in general there is more similarity in stock quantities between the warehouse and Rimses.

7. Performing a pilot study

To test the selected classification method and inventory control policies we perform a pilot study for certain parts of the warehouse of the TD of Bolletje Almelo. Chapter 6 describes this pilot study and the corresponding results.

5.3 Conclusion

In this chapter we found an answer to the fourth research question: *How to implement the (new) inventory control policies at the warehouse of the Technical Department of Bolletje?".*

To implement the (new) inventory control policies several activities are carried out in this research:

1) Writing instruction manuals for different processes.
2) Generating and using pricelists with two of the core suppliers.
3) Adequately using the standard Bolletje purchase order numbers.
4) Changing the current way of reception of spare parts, matching, and invoice registration.
5) Specifying the object-ID MATERIAAL in different object-IDs.
6) Generating a closed warehouse environment when the warehouse manager is not present.
7) Performing a pilot study to implement the (new) inventory control policies.

Steps one to seven are executed during this research, in order to implement the (new) inventory control policies. To test the (new) inventory control policies we perform a pilot study, which is done in Chapter 6.

6. Pilot study and results

This chapter answers the fifth research question: "Based on a pilot study, what are the expected results of the chosen method and policies for the inventory management of the Technical Department of Bolletje Almelo?".

Section 6.1 describes the execution of the pilot study, which is executed during four weeks at the warehouse of the TD of Bolletje of Almelo. Section 6.2 includes some results of the pilot study. Section 6.3 describes the expected results by implementing the classification method and (new) inventory control policies at the whole warehouse of the TD of Bolletje Almelo. Finally, Section 6.4 gives a summary of this chapter.

6.1 Execution of the pilot study

We executed a pilot study during a time period of four weeks to analyze the expected results of the chosen method and policies from Chapter 4. After each usage in the warehouse, the warehouse manager has to follow the following steps:

1) Decide whether to stock a (critical) spare part or not, based on the decision making framework for spare parts in Section 4.3.
2) Classifying the spare part in Rimses according to the original ABC analysis, so by using criticality as criterion. The result is that each reviewed spare part gets the code A, B or C in Rimses, according to the ABC analysis. The classes are divided as follows (see Section 0):
    - Class A items consists of spare parts with very high criticality. This means that a spare part with very high criticality has long delivery time (more than two days), without this spare part there is downtime of the production line, and there are no alternative spare parts to replace this part. The electrical and programmable spare parts at the warehouse of the TD of Bolletje Almelo are examples of class A items.
    - Class B items consists of spare parts with intermediate criticality. This means that a spare part with intermediate criticality has less delivery time (less than or equal to two days), without this spare part the production line is still running, and sometimes there are alternative spare parts to replace this part. The mechanical spare parts at the warehouse of the TD of Bolletje Almelo are examples of class B items.
    - Class C items consists of spare parts with low criticality. This means that a spare part with low criticality is immediately available from the supplier, without this spare part the production line is still running and there are always alternative spare parts to replace this part. The grab stock at the warehouse of the TD of Bolletje is an example of class C items.

   The classification is done in cooperation with the warehouse manager and the failure mechanic(s), because they have knowledge about among others the criticality of different spare parts.
3) Correctly registering the status of the reviewed spare parts in Rimses: *active.*
4) Setting the parameters for restocking (*herbevoorradingsparameters)* in Rimses, based on the ABC analysis and the corresponding reorder policy:
    - A items: automatic -> via reorder point and maximum stock – *(s,S) policy*
    - B items: automatic -> via reorder point and EOQ – *(s,Q) policy*
    - C items: manual -> via reorder point and EOQ – *(s,Q) policy*
5) Ordering according to the reorder suggestions (Voorraadregistratie / Voorraadcontroles / Controle van de voorraad / Bestelvoorstellen).

After one year, all spare parts which are still classified as an E item (the default setting) are titled as non movers. For the spare parts in warehouse area 3, we can identify these non movers after five year, as defined in Section 4.1. The identified non movers are then eliminated from the warehouse and registered as *incourant* or *inactive* in Rimses.

6.2 Results of the pilot study

To show some results of the pilot study, we show one example per class of the ABC analysis in the following sections. For each spare part we have calculated the reorder point, and EOQ or maximum stock. Table 6.1 shows the examples per class, including a picture and the corresponding inventory control policy. As already mentioned in Section 3.1 the TD of Bolletje uses the item approach, so this approach is also used for the pilot study. This means that we use the same service level for all different spare parts, namely 95 percent, which is decided by the management of Bolletje Almelo. For the service level we take the cycle service level, instead of using the no stock out probability or the fill rate. The cycle service level is defined as the expected probability of not hitting a stock out during the next replenishment cycle, and it is also the probability of not losing sales (Li, 2007).

Class & example	Spare part	Inventory control policy according to Silver et al., (2017)	Control policy in Rimses
Class A **PLC**		*(s,S)*	*Automatic: via reorder point and maximum stock*
Class B **Bearing**		*(s,Q)*	*Automatic: via reorder point and EOQ*
Class C **Lamp**		*Manual ~ (s,Q)*	*Manual: via reorder point and EOQ*

Table 6.1 Examples of pilot study

6.2.1 Examples – Class A item

As an example for a class A item we take one specific Programmable Logic Controller (PLC). A PLC is an digital computer used for the control of manufacturing processes such as assembly lines, robot devices or any activity that requires high reliability control and ease of programming and process fault diagnosis. Different PLCs are used at different production lines at the factory of Bolletje Almelo. These PLCs have long delivery times (>2 days), without these PLCs there is downtime of the production line, and these PLCs are not replaceable by alternative spare parts.

As described in Section 4.5 we use the *(s,S)* policy for class A items, which means that these items are automatically ordered in Rimses via the reorder point and maximum stock (see Table 6.2).

	Inventory control policy according to (Silver, Pyke, & Thomas, 2017)	Control policy in Rimses
A items	*(s,S)*	*Automatic: via reorder point and maximum stock*

Table 6.2 Inventory control policy for class A items

Table 6.3 shows the data which is available from Rimses for these calculations.

Cycle service level	95%	Lead time in days	14
Demand per day	0.0548	St. Dev. of demand	0.02
St. Dev. of lead time	0.01		

Table 6.3 Available data of PLC, obtained from Rimses

To determine the correct distribution for the service factor *Z* we use the rule of thumb of Silver et al. (2017) from Section 3.5:

If the ratio $\frac{\sigma_L}{\hat{x}_L}$ is greater than 0.5, consider a distribution other than the normal.

In this example this ratio is as follows: $\frac{\mathbf{0.02}}{\mathbf{0.0548}} = \mathbf{0.365.}$ This ratio is not greater than 0.5, so we use the ***Normal distribution***.

To determine the reorder point of this PLC we have to make the following calculations:

$$\boldsymbol{Z = Normsinv(cycle\ service\ level) = Normsinv(0.95) = 1.645}$$

$$\boldsymbol{Safety\ stock = Z * \sqrt{(L * (st.dev.(D))^2) + (D * st.dev.(L))^2}}$$

$$\boldsymbol{= 1.645 * \sqrt{(14 * 0.02^2) + (0.0548 * 0.01)^2} = 0.1231}$$

$$\boldsymbol{Reorder\ point = (L * D) + SS = (14 * 0.0548) + 0.1231 = 0.8903 \approx 1.}$$

The maximum stock of the PLC is set to 1.

6.2.2 Examples – Class B item

As an example for a class B item we take one specific bearing. This bearing has less delivery time (≤ 2 days), because it is almost always directly available from the suppliers of Bolletje. Besides that, this specific bearing is sometimes replaceable by another alternative bearing.

As described in Section 4.5 we use the *(s,Q)* policy for class B items, which means that these items are automatically ordered in Rimses via the reorder point and EOQ (see Table 6.4).

	Inventory control policy according to (Silver, Pyke, & Thomas, 2017)	Control policy in Rimses
B items	*(s,Q)*	*Automatic: via reorder point and EOQ*

Table 6.4 Inventory control policy for class B items

Table 6.5 shows the available data which is available from Rimses for these calculations.

Cycle service level	95%	Lead time in days	2
Demand per day	0.03333	St. Dev. of demand	0.44
St. Dev. of lead time	0.38	Ordering cost per order	10
Holding cost	20 (=0.25*80)	Unit price	80

Table 6.5 Available data of bearing, obtained from Rimses

To determine the correct distribution for the service factor *Z* we use the rule of thumb of Silver et al. (2017) from Section 3.5:

If the ratio $\frac{\sigma_L}{\hat{x}_L}$ is greater than 0.5, consider a distribution other than the normal.

In this example this ratio is as follows: $\frac{0.44}{0.03333} = 13.2$. This ratio is greater than 0.5, so we use the ***Gamma distribution***.

To determine the reorder point and EOQ of this bearing we have to make the following calculations:

$$\alpha = \frac{E(x)^2}{Var(x)} \qquad \beta = \frac{Var(x)}{E(x)}$$

$$Z = GAMMA.INV(cycle\ service\ level; \alpha; \beta) = GAMMA.INV(0.95; 27.7; 0.0722) = 2.663$$

$$Safety\ stock = Z * \sqrt{\left(L * (st.dev.(D))^2\right) + (D * st.dev.(L))^2}$$

$$= 2.663 * \sqrt{\left(2 * 0.44^2\right) + (0.03333 * 0.38)^2} = 1.6576$$

$$Reorder\ point = (L * D) + SS = (2 * 0.03333) + 1.6576 = 1.7243 \approx 2$$

$$EOQ = \sqrt{\frac{2 * A * D}{h}} = \sqrt{\frac{2 * 10 * 0.0333}{20}} = 0.1826 \approx 1$$

6.2.3 Examples – Class C item

As an example for a class C item we take one specific lamp. This lamp is immediately available from the supplier, without lamp the production line is still running and there are always alternatives lamps to replace this specific lamp.

As described in Section 4.5 we use the manual *(s,Q)* policy for class C items, which means that these items are manually ordered in Rimses via the reorder point and EOQ (see Table 6.6). Instead of automatically ordering the spare parts the two bin system is used for the C items. This means that the capacity of one bin is set equal to the reorder point.

	Inventory control policy according to (Silver, Pyke, & Thomas, 2017)	Control policy in Rimses
C items	*Manual ~ (s,Q)*	*Manual: via reorder point and EOQ*

Table 6.6 Inventory control policy for class C items

Table 6.7 shows the available data which is available from Rimses for these calculations.

Cycle service level	95%	Lead time in days	1
Demand per day	10	St. Dev. of demand	0.32
St. Dev. of lead time	0.01	Ordering cost per order	10
Holding cost	0.125 (=0.25*0.50)	Unit price	0.50

Table 6.7 Available data of screw, obtained from Rimses

To determine the correct distribution for the service factor *Z* we use the rule of thumb of Silver et al. (2017) from Section 3.5:

If the ratio $\frac{\sigma_L}{\hat{x}_L}$ is greater than 0.5, consider a distribution other than the normal.

In this example this ratio is as follows: $\frac{0.32}{10} = 0.032$. This ratio is not greater than 0.5, so we use the ***Normal distribution***.

To determine the reorder point of this lamp we have to make the following calculations:

$$Z = Normsinv(cycle\ service\ level) = Normsinv(0.95) = 1.645$$

$$Safety\ stock = Z * \sqrt{(L * (st.dev.(D))^2) + (D * st.dev.(L))^2}$$

$$= 1.645 * \sqrt{(1 * 0.32^2) + (10 * 0.01)^2} = 0.5515$$

$$Reorder\ point = (L * D) + SS = (1 * 10) + 0.5515 = 10.5515 \approx 11$$

$$EOQ = \sqrt{\frac{2 * A * D}{h}} = \sqrt{\frac{2 * 10 * 10}{0.125}} = 40$$

6.3 Expected results of complete implementation

As already mentioned, the (new) inventory control policies are not yet implemented at the whole warehouse of the TD of Bolletje Almelo. However, we can already say something about the results of the implementation of the invoice registration and the (new) inventory control policies:

- The function invoice registration is now correctly used by the warehouse manager. This leads to up to date economic values of the stock and historical data of the invoices in Rimses.
- Correct registration of used spare parts and working hours of external mechanics and companies through the specification of the object-ID MATERIAAL.
- Rimses contains complete and up to date quantities and economic values of the stock in the warehouse. So there are (almost) no differences anymore between the quantities of stock in the physical warehouse and the quantity of stock registered in Rimses. This means that the reliability of Rimses has increased a lot.
- The warehouse manager is able to reorder according to the reorder suggestions from Rimses instead of manual reordering.
- In Rimses there is (more) historical data available of usage of spare parts. This data is required to determine reorder point, EOQ, maximum stock, but also to plan predictive maintenance. This can be done manually, as implemented in the pilot study of Section 6.2, or automatically in Rimses.
- There are a lot of time savings for both the warehouse manager and the manager of the TD. This is achieved because of using the new way of reception of delivery, the invoice registration, specifying the object-ID MATERIAAL, the reorder suggestions from Rimses. The manager of the TD saves approximately eight minutes per invoice, whereby about fifty invoices have to be matched per week.
- There is better performance in the warehouse, due to the more accurate registration of spare parts. This leads to less chance of stock out situations, which leads to less production loss and emergency order costs.

6.4 Conclusion

We have performed a pilot study to investigate the results of the chosen classification method and inventory control policies. This pilot study consisted of five different steps:

1) Deciding whether a spare part has to be stocked or not.
2) Classifying the spare part according to the original ABC analysis.
3) Correctly registering the status of the spare part in Rimses.
4) Setting the parameters for restocking in Rimses.
5) Ordering according to the reorder suggestions in Rimses.

The pilot study is performed during four weeks, so the inventory control policies are not yet implemented at the whole warehouse of the TD of Bolletje Almelo. Nevertheless, we can say something about the (expected) results:

- Up to date economic values of the stock and historical data of invoices.
- Correctly registration of used spare parts and working hours.
- Complete and up to date quantities and economic values in Rimses of the stock in the warehouse.
- Warehouse manager is able to reorder according to the reorder suggestions from Rimses.
- Ability to determine the reorder point, EOQ and maximum stock based on the historical data from Rimses
- Time savings for the warehouse manager and manager of the TD.
- Better performance in the warehouse, due to higher reliability of the Rimses system and less chance of stock outs.

7. Conclusions and recommendations

This final chapter concludes this research, by answering the following research question: "What are the conclusions and recommendations for the warehouse of the Technical Department of Bolletje Almelo?".

In Section 7.1 we provide a conclusion to the entire research, and especially to the main research question. Section 7.2 presents the recommendations which follow from this research, including a roadmap of the recommended actions.

7.1 Conclusions

The objective of this research is to gain insight in how to determine adequate inventory management and control policies of the spare parts at the warehouse of the TD of Bolletje Almelo. The main research question of this research is formulated as follows:

How can adequate inventory management and control policies for the spare parts in the warehouse of the Technical Department of Bolletje Almelo be determined by creating an environment where the spare parts of the Technical Department are managed properly so as to balance the inventory costs and downtime of machinery?

In the current situation the TD of Bolletje Almelo has its own warehouse to stock spare parts for maintenance. The TD uses an IT system called Rimses to register different activities such as usage of spare parts and maintenance tasks. However, at the moment there are multiple problems which cause the lack of adequate inventory management and structure at the warehouse, and lack of adequate use of Rimses. Due to this it is difficult for the TD to make decisions based on historical data and make correct estimations of required spare parts.

By performing a literature study we found literature about relevant Key Performance Indicators (KPIs), variables whether to stock or not, classification methods, and inventory control policies. Based on requirements stated by the manager of the TD and the warehouse manager and the literature study we have selected five KPIs to create insight in the performance of the TD:

- Percentage of stock outs;
- Percentage of emergency purchases;
- Percentage of non moving parts;
- Percentage of target ship dates met;
- Production line availability.

The Overal Equipment Effectiveness (OEE) tool of the Production Department allows to extract the production line availability. The Rimses database is the data source for the other KPIs.

Besides that we have developed a decision making framework for the TD of Bolletje Almelo to justify when and where a specific spare part has to be stocked. The following three choices are compared in this framework: 1) Not stocking the spare part in the warehouse of the TD of Bolletje Almelo, 2) Stocking the spare part in the warehouse of the TD of Bolletje Almelo, 3) Stocking the spare part at the supplier, by using Consignment Inventory. These choices are compared with each other by calculating the total relevant costs for each choice.

As classification method for the spare parts we have selected the ABC analysis, whereby criticality is used as criterion. Based on the policies of Silver et al. (2017) and Rimses we have chosen an inventory control policy for each class of spare parts, see Table 7.1.

	Inventory control policy according to Silver et al., (2017)	Corresponding control policy in Rimses
A items	*(s,S)*	*Automatic: via reorder point and maximum stock*
B items	*(s,Q)*	*Automatic: via reorder point and EOQ*
C items	*Manual ~ (s,Q)*	*Manual: via reorder point and EOQ*

Table 7.1 Inventory control policies for ABC classification

This reserach also includes the implementation of the above mentioned inventory control policies. The following activities are proposed and implemented at the TD:

- Writing instruction manuals for different processes in Rimses.
- Generating and using pricelists with two of the core suppliers.
- Adequately using the standard Bolletje purchase numbers.
- Changing the current way of reception of spare parts, matching, and invoice registration.
- Specifying the object-ID MATERIAAL in Rimses in different object IDs.
- Generating a closed warehouse environment when the warehouse manager is not present.

We executed a pilot study at the warehouse of the TD of Bolletje Almelo during a time period of four weeks to analyze the expected results of the chosen method and policies from Chapter 4.

The impact of implementing this adequate inventory management and inventory control policies at the TD of Bolletje Almelo is described by the following results:

- Up to date economic values of the stock and historical data of invoices.
- Correctly registration of used spare parts and working hours.
- Complete and up to date quantities and economic values in Rimses of the stock in the warehouse.
- Warehouse manager is able to reorder according to the reorder suggestions from Rimses.
- Ability to determine the reorder point, EOQ and maximum stock based on the historical data from Rimses. This can be done manually, as implemented in the pilot study of Section 6.2, or automatically in Rimses.
- Time savings for the warehouse manager and manager of the TD. The manager of the TD saves approximately eight minutes per invoice, whereby about fifty invoices have to be matched per week.
- Better performance in the warehouse, due to higher reliability of the Rimses system and less chance of stock outs.

7.2 Recommendations

From the analysis we provide some recommendations for the TD of Bolletje Almelo, to further improve the management and structure of the warehouse, and the use of Rimses. We propose the following recommendations:

- Firstly, we recommend to count and register all spare parts in the warehouse. At the moment we only know the quantities and economic values from Rimses, instead of the actual quantities and economic values from the warehouse. So there are differences between the values from Rimses and the physical warehouse. To implement the classification method and inventory control policies from this research, it is really important to first count the physical warehouse. After the physical counting all reorder points have to be set equal to the stock level of the spare part minus one. This is done to structurally set the inventory control parameters in Rimses for the different spare parts. Besides that, after a year we see which spare parts are not used during the year. So after each usage in the warehouse, the warehouse manager gets a reorder suggestion from Rimses.

- Secondly, we recommend to implement the classification method and inventory control policies at the whole warehouse, so for all spare parts in the warehouse. After one year the TD has to investigate if criticality is still the best criterion for the classification of the spare parts. Other criteria could also be relevant for this classification, such as usage or a combination of usage and criticality. Besides that, the TD has to review the reorder points, EOQ and maximum stock levels of the spare parts, to continuously have up to date stock levels. Finally, the spare parts which are not used the past year (still registered as E items in Rimses), should be eliminated from the warehouse and Rimses.
- We also recommend to generate and use the price lists in Rimses with all suppliers of the TD of Bolletje Almelo. At the moment the TD only uses a price list with one specific supplier, but to get up to date purchase prices of all spare parts, it is necessary to generate price lists with (almost) all suppliers.
- A start can be made towards performance measurement of the TD by measuring the five KPIs mentioned above. We recommend to use Rimses Analyzer to generate an interactive KPI dashboard for the selected KPIs of this research, and other relevant KPIs for the TD of Bolletje Almelo.
- The TD of Bolletje Almelo is able to improve their complete maintenance plan, because the availability and reliability of data in Rimses increases after implementing the different inventory control policies and the better registration of spare parts. Since several months the TD already moves towards a more preventive maintenance environment, instead of a corrective maintenance environment. More data about the usage of spare parts and maintenance helps moving towards this preventive maintenance environment.
- We recommend to reserve spare parts in Rimses for preventive maintenance tasks and/or weeks. Since the beginning of 2017 the TD of Bolletje Almelo is executing these so called preventive maintenance weeks, which means that once in a year a production line stops for one week to perform preventive maintenance tasks. If spare parts are correctly registered in Rimses during each maintenance week, it is easier to search in Rimses which spare parts have to be changed during another maintenance week. In this way the required spare parts are always on time available, which decreases the downtime of machinery. To structurally perform these maintenance tasks, we also recommend to set maintenance schedules in Rimses. A maintenance schedule is a continuous sequence of certain standard activities. In this way it is possible to set a preventive maintenance plan according to a fixed schedule. For example:
    - Month 1: small maintenance
    - Month 2: lubricate installation
    - Month 3: small maintenance
    - Month 4: major maintenance.
    - Repeat this schedule.
- This research did not include the layout and arrangement of the warehouse of the TD. To reduce the number of mispicks in the order picking process and the walking distance in the warehouse, we recommend to rearrange the warehouse so that a more efficient warehouse arises.
- At the moment the warehouse uses a so called Kanban system for several spare parts. To get more control over the inventory control parameters in Rimses, we recommend to implement the Kanban system for more spare parts. This Kanban system is especially useful for the smaller parts (grab stock) in the warehouse, because often there are lots of these spare parts stocked in the warehouse, so for these spare parts it is difficult to see how many parts are still on stock.
- Finally, we recommend to implement as much as possible standardization in the spare parts of different machinery. In this way the spare parts are replaceable for the different machinery, which reduces the chance of stock outs and downtime. For example, one specific

motor can be used for more than one machine instead of one specific motor for each machine.

7.2.1 Roadmap

We have translated the above mentioned recommendations for accomplishing more adequate inventory management and structure of the warehouse, and the use of Rimses, towards some actions. These actions and the related actors are listed in Table 7.2 and the suggested sequence of these actions is shown in the roadmap of Figure 7.1.

	Action	**Actor(s)**
1	Educate and supervise failure mechanics and other employees on correctness and completeness of registration of spare parts usage in Rimses.	Team Leader
2	Classify spare parts according to classification method, select corresponding inventory control policy and set inventory control parameters in Rimses.	Warehouse Manager
3	Counting and registering all spare parts in the warehouse	New Master Thesis Student (to be announced) and Warehouse Manager
4	Process inventory control policies in Rimses.	Warehouse Manager
5	Generate and use price lists with all suppliers in Rimses.	Warehouse Manager
6	Display and monitor KPIs at dashboard.	Team leader and Manager of TD
7	Reservation of spare parts in Rimses for preventive maintenance tasks/week.	Maintenance Engineer and New Master Thesis Student (to be announced)
8	Implement as much as possible standardization in the spare parts of different machinery.	Team leader, Maintenance Engineer, Manager of TD
9	Rearrange the layout of the warehouse.	New Master Thesis Student (to be announced)
10	Implement Kanban system for more spare parts in the warehouse.	New Master Thesis Student (to be announced) and warehouse manager
11	After a year, investigate if criticality is still the best criterion for the ABC analysis, based on the available data in Rimses.	Warehouse Manager and Manager of TD
12	After a year, review the reorder points, EOQ, maximum stock levels in Rimses	Warehouse manager
13	After a year, review or eliminate non-moving/slow moving spare parts in Rimses	Warehouse manager
14	More adequate management and structure of the warehouse, and the use of Rimses	

Table 7.2 Recommended actions and corresponding actor(s)

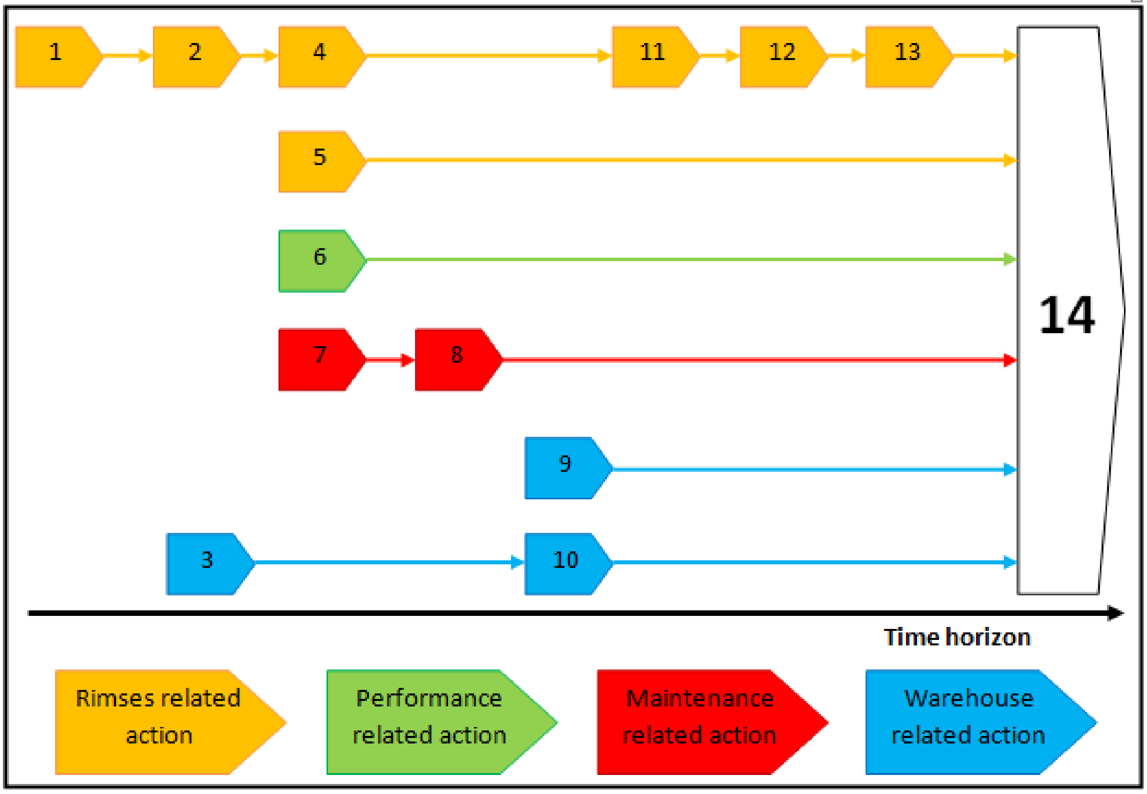

Figure 7.1 Roadmap including sequence of actions

7.3 Suggestions for further research

In this section, we provide suggestions for further research in order to take full advantage of the implementation of the inventory control policies.

One of the recommendations for the TD of Bolletje Almelo, mentioned in Section 7.2, is to improve their complete maintenance plan. This improved maintenance plan helps them to moves towards a more preventive maintenance environment, instead of the current corrective maintenance environment. To organize the preventive maintenance the TD of Bolletje Almelo should do research towards methods which are able to determine when and where to perform preventive maintenance. For example in which week(s) of the year do we perform preventive maintenance for a certain production line, such as the newest *beschuit* production line?

Besides that, the TD should research which preventive maintenance tasks have to be performed during these preventive maintenance weeks. Since preventive maintenance tasks often require one or more preparatory setup activities, there could be significant savings in both setup times and costs by conducting these maintenance tasks simultaneously, which is also called maintenance grouping or maintenance clustering.

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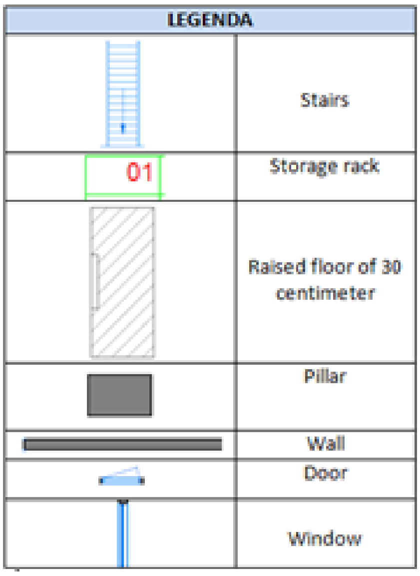
Appendices

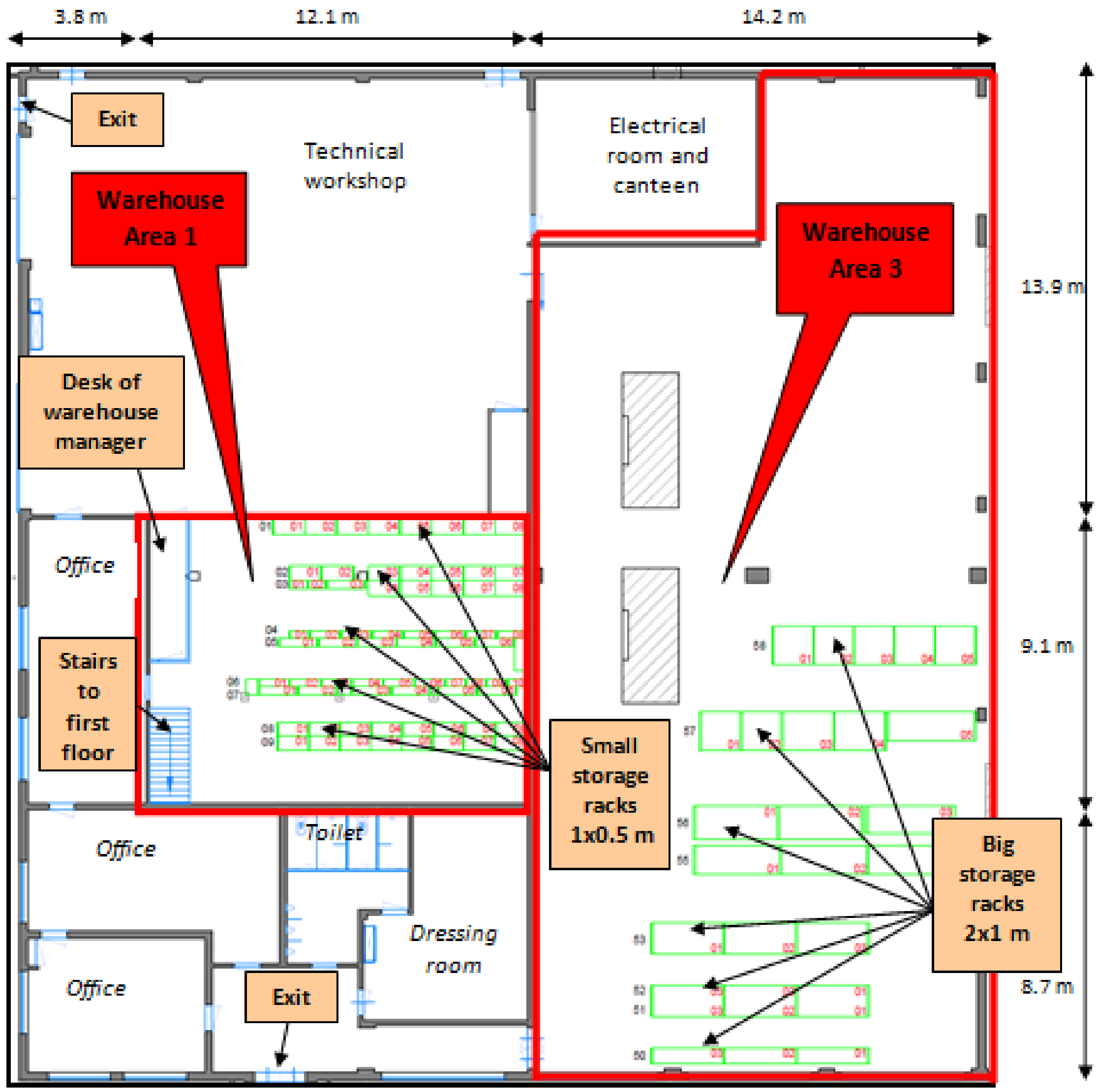
Appendix 1: Map of the TD warehouse – ground floor



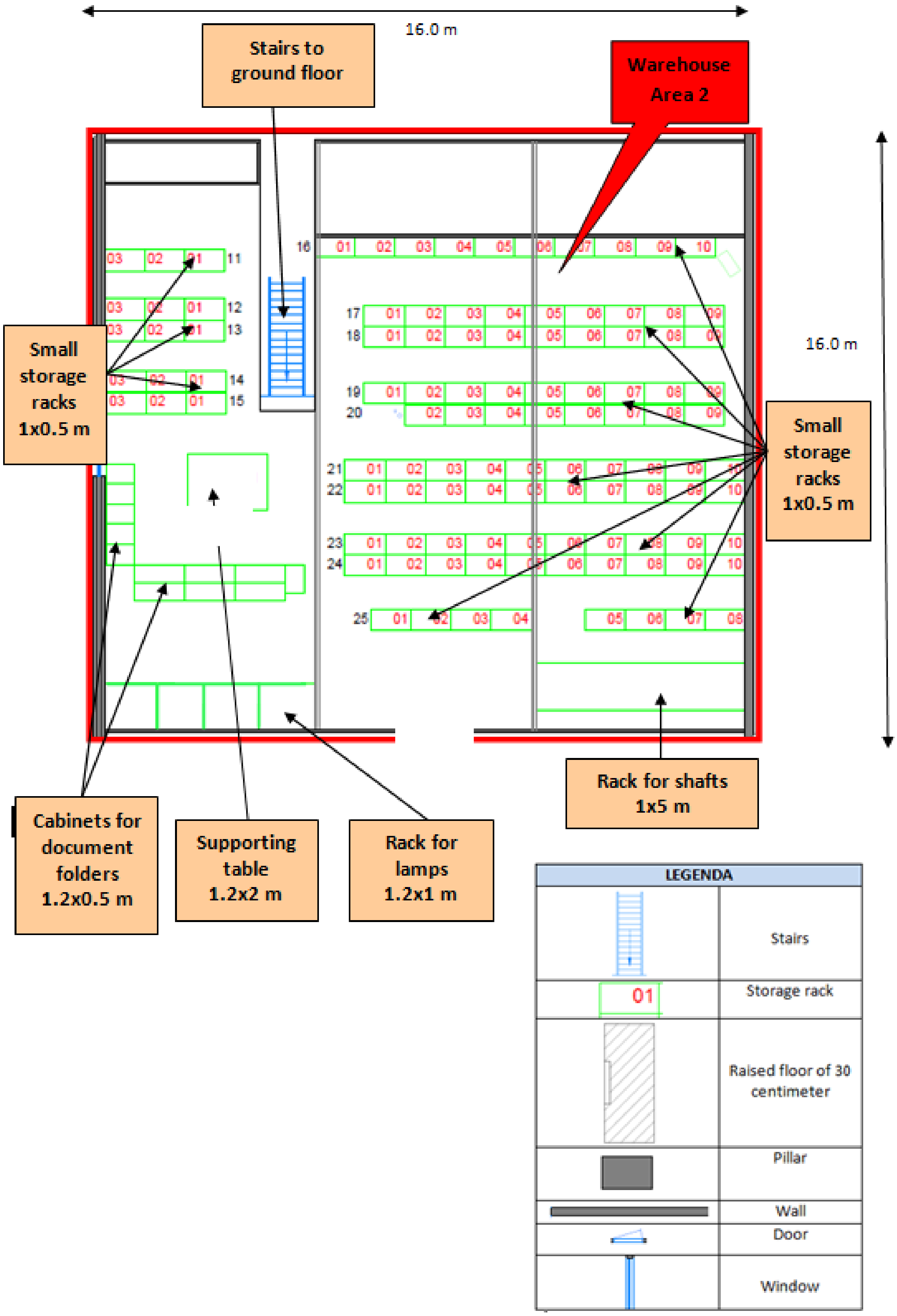
The building of the Technical Department of Bolletje consists of several areas, among which the several areas of the warehouse, technical workshop, offices, toilets, dressing room, electrical room and canteen.

The warehouse of the TD of Bolletje Almelo is divided into different areas, namely a ground floor within the warehouse (area 1), a upper floor within the warehouse (area 2) and a storage area within one of the old production halls (area 3). With stairs it is possible to move from area 1 to area 2 and back.

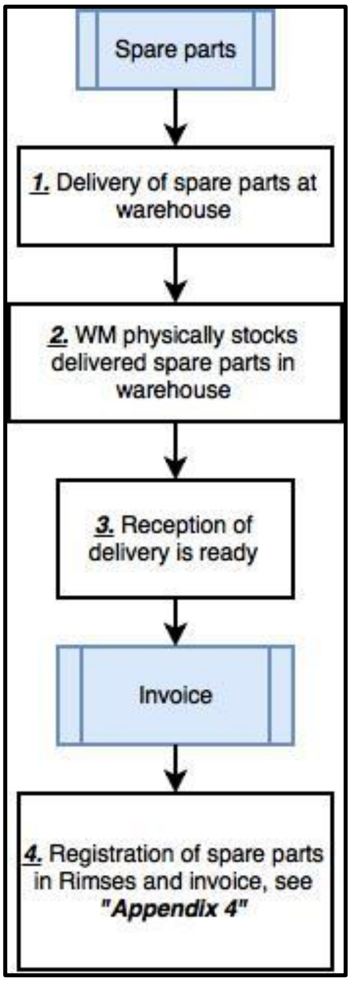
Area 1 and 2 include the smaller spare parts, such as lamps and bearings. Area 3 (storage racks 50 – 58) includes especially the bigger spare parts which are too big to store within the warehouse, such as motors, cables, pipes, and other mechanical or electrical components.



Appendix 2: Map of the TD warehouse – first floor

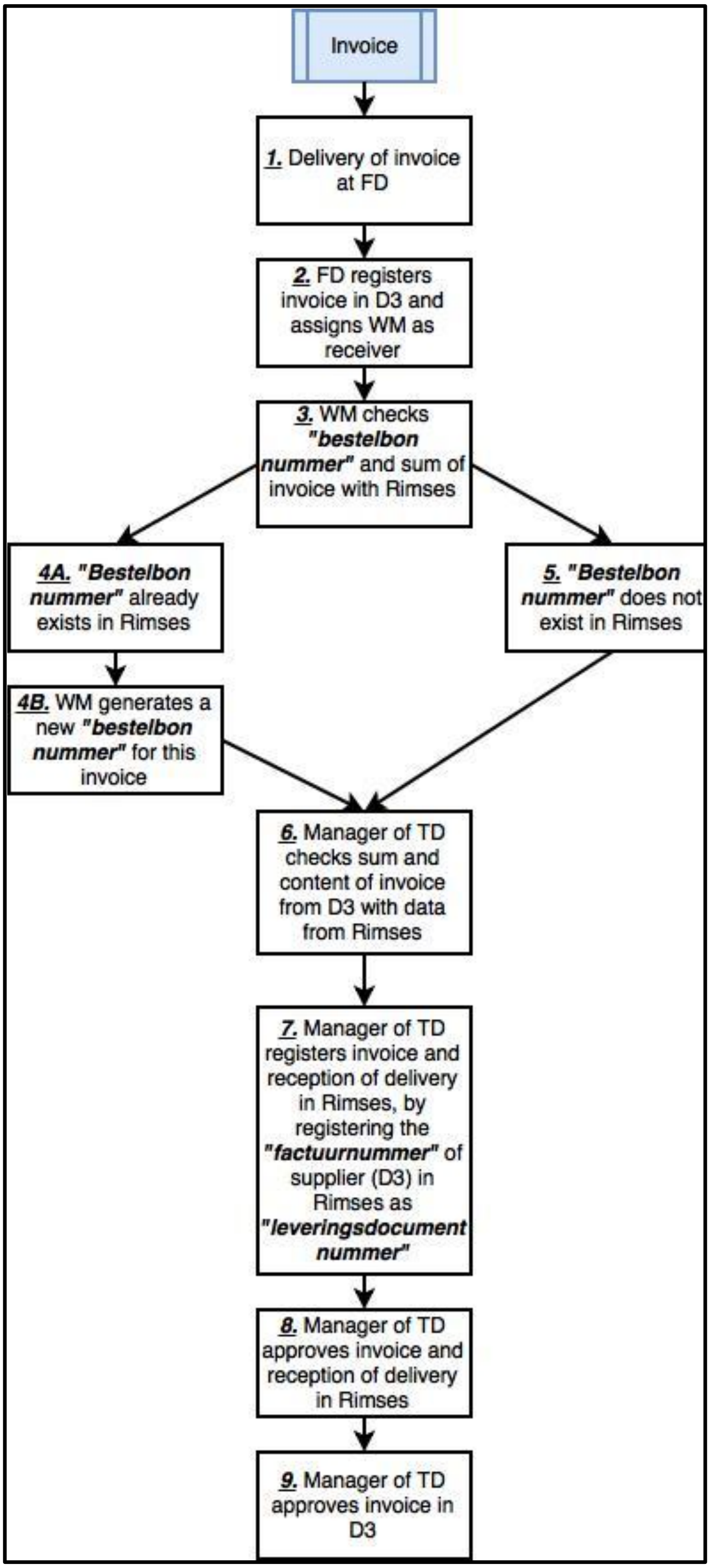


Appendix 3: Current process of delivery & reception of spare parts



Explanation of this process:	
1.	The supplier delivers spare parts at the warehouse and the warehouse manager (WM) receives these spare parts.
2.	The WM physically stocks the delivered spare parts in the warehouse.
3.	The physically reception of the delivered spare parts is now ready.
4.	After receiving the invoice, the delivered spare parts are stored and registered in Rimses. Now the invoice is ready to register in Rimses, see Appendix 4.

Appendix 4: Current process of invoice registration



Explanation of this process:	
1.	A supplier sends an invoice to the Financial Department (FD).
2.	When the FD has received an invoice, they scan this invoice into D3, the accounting system of Bolletje. The WM is assigned as receiver.
3.	Then this invoice is sent to the WM in D3, so that he can check the sum of the invoice with the sum of the order line in Rimses. If there are any deviations, the WM can change the sum of the order line in Rimses. Besides that, he checks if the "**bestelbon nummer**" of the invoice already exists in Rimses.
4A.	The "**bestelbon nummer**" already exists in Rimses.
4B.	The WM generates a new "**bestelbon nummer**" for this invoice.
5.	If the "**bestelbon nummer**" does not exist in Rimses, there is no problem.
6.	Consequently, the manager of the TD checks the sum and content of the invoice from D3 with the available data from D3.
7.	The manager of the TD registers the invoice and the reception of the delivery in Rimses, by registering the "**factuurnummer**" of the supplier in Rimses as the "**leveringsdocument nummer**".
8.	Then the manager of the TD approves the invoice and reception of the delivery in Rimses.
9.	Finally, the manager of the TD approves the invoice in D3, so that the FD can see if the invoice is ready for payment.

Appendix 5: Instruction manual for Rimses – Using and generating pricelists

PRIJSLIJSTEN

Een prijslijst bevat de inkoopprijs van een object, eventueel opgesplitst in staffelprijzen. Voor een object kunnen er prijslijsten voor verschillende leveranciers bestaan. Een object kan daarnaast ook bij één leverancier slechts één prijslijst hebben. Één leverancier kan voorkeursleverancier zijn.

Wanneer je een bestelaanvraag of een bestellijn ingeeft, haalt Rimses de prijslijst op die geldig is op het moment van de berekende leverdatum. Om een prijslijst op te vragen moet je eerst een prijsaanvraag doen bij de desbetreffende leverancier, welke zowel ***handmatig*** als ***elektronisch*** kan worden opgesteld.

Elektronische prijsaanvragen maak je aan in Rimses op basis van een Excel werkblad in de taal van de leverancier. De elektronische prijsaanvraag heeft de voorkeur wanneer men voor een groot aantal materialen een prijs aanvraagt, omdat de prijzen dan automatisch worden opgeladen in Rimses.

Bij ***handmatige prijsaanvragen*** moet je de offerte van de leverancier manueel in Rimses verwerken, dus dit is geschikt wanneer je slecht één of enkele prijzen opvraagt.

Elektronische prijsaanvragen

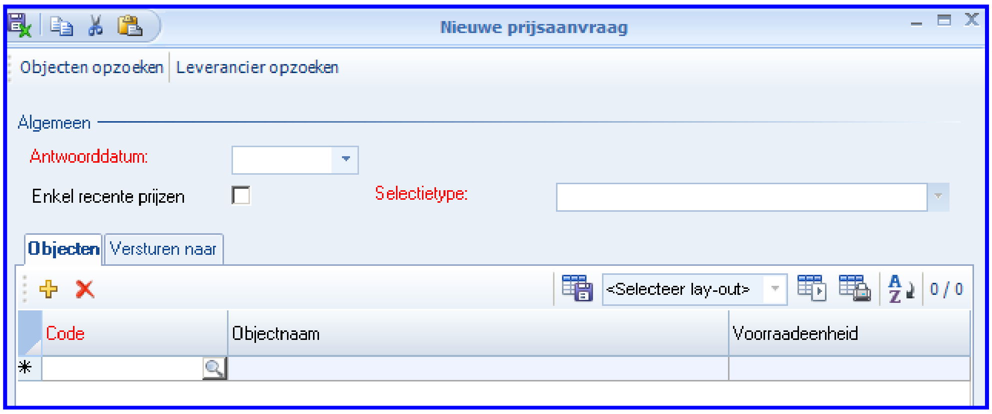
De verschillende stappen in de verwerking van de elektronische prijsaanvraag zijn:

- Elektronische prijsaanvraag aanmaken en versturen
- Offerte elektronische prijsaanvraag opladen
- Offerte elektronische prijsaanvraag behandelen en verwerken
- Automatische prijsvergelijking maken

❖ Een elektronische prijsaanvraag aanmaken en versturen:

1. Selecteer ***Inkoop/Prijsaanvragen/Beheer elektronische prijsaanvragen.***

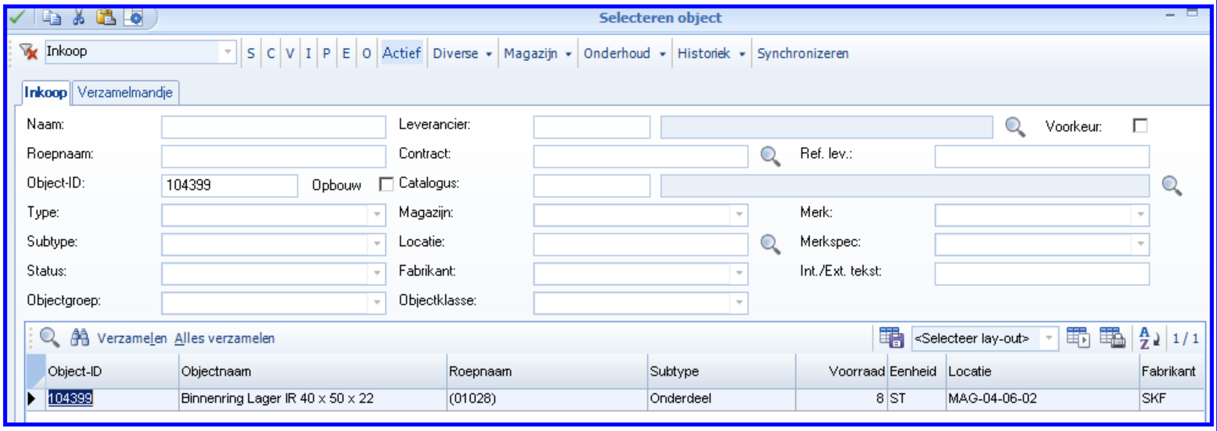
2. Vul eventueel de selectiecriteria in. Klik op ***OK.***
3. Klik op ***Nieuw.***
   Als voorbeeld wordt er een prijsaanvraag aangemaakt voor een lager.



4. Vul de ***Antwoorddatum in*** en selecteer het selectietype ***Objectselectie*** (indien je de optie Objectselectie kiest, verstuur je een prijsaanvraag voor een of meerdere objecten. Indien je de optie Contractselectie kiest, verstuur je een prijsaanvraag naar een leverancier met wie je een contract hebt afgesloten. Alle objecten van het desbetreffende contract worden dan automatisch aan de prijsaanvraag gekoppeld.)

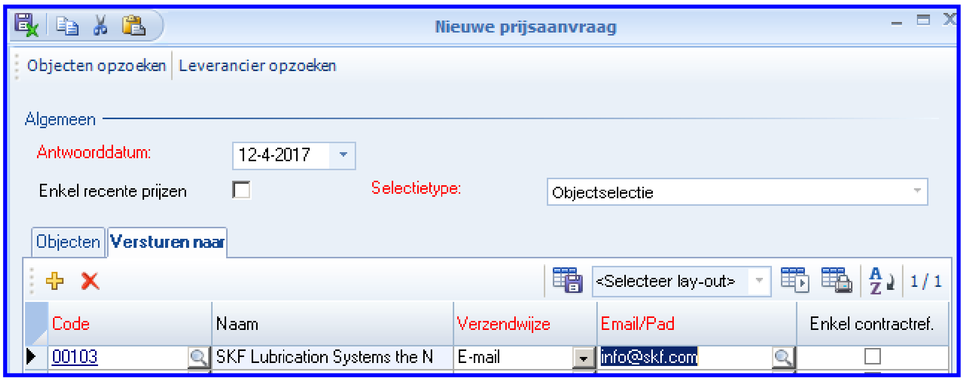
Antwoorddatum: 12-4-2017.
Selectietype: Objectselectie.

5. Op het tabblad ***Objecten:*** klik op links bovenaan op ***Objecten opzoeken*** en zoek het object/de objecten op waarvoor je een prijsofferte aanvraagt. Het is ook mogelijk om (alle) objecten selecteren van bijvoorbeeld een bepaalde leverancier of van een bepaalde magazijnlocatie. Klik vervolgens op het ***verrekijker*** icoon. Klik op ***Verzamelen*** om per object te bepalen of je hiervan een prijsaanvraag wilt doen. Klik op ***Alles verzamelen*** om voor alle objecten een prijsaanvraag te doen.



Object-ID: 104399.
Objectnaam: Binnenring lager IR 40 x 50 x 22.
Klik op ***OK.***

6. Op het tabblad ***Versturen naar:*** klik op ***Nieuw*** en vul op de nieuwe lijn de leverancier en het e-mailadres in naar wie je de prijsaanvraag wilt versturen.
Code: 00103.
Naam: SKF Lubrication Systems the Netherlands.
Verzendwijze: E-mail.
E-mail/Pad: info@skf.com.



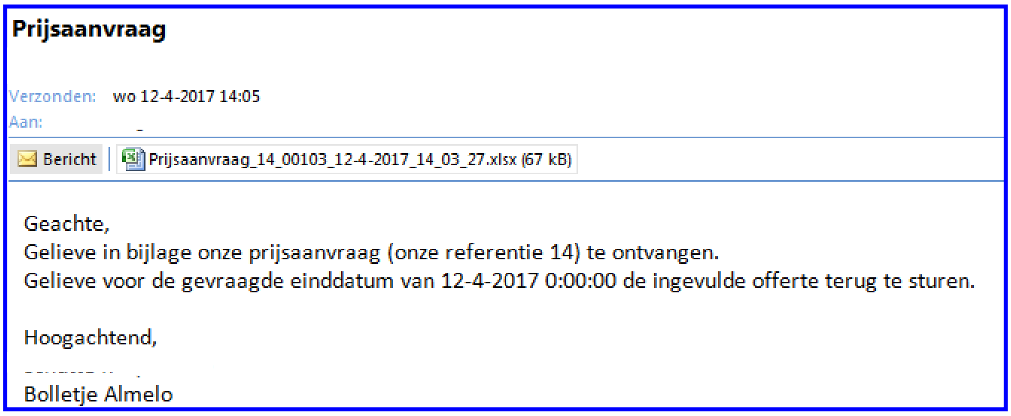
Klik op ***OK.***

7. De prijsaanvraag wordt nu opgenomen in het ***Overzicht elektronische prijsaanvragen*** met de status ***Ingegeven.***
   Donkerblauw gemarkeerde regel met Aanvraagnr.: 14 en Status:: Ingegeven.

Aanvraagnr	Opgemaakt door	Antwoorddatum	Status	Datum versturen	Verstuurd door	Datum verwerking	Selectietype	Enkel rece prijzen
8	[redacted]	12-9-2014	Verstuurd	12-9-2014	[redacted]		Objectselectie	
9		26-9-2014	Verstuurd	23-2-2017			Objectselectie	
10		23-9-2014	Ingegeven				Objectselectie	
11		23-2-2017	Verstuurd	23-2-2017			Objectselectie	
13		10-4-2017	Ingegeven				Objectselectie	
14		12-4-2017	Ingegeven				Objectselectie	

8. Klik op ***Versturen.***
9. Rimses geeft als boodschap ***Bezig met het versturen van prijsaanvraag x.***
   De status van de prijsaanvraag is nu ***Versturd.***

De leverancier krijgt vervolgens een e-mail met de vraag om de prijsaanvraag in te vullen.



Prijsaanvraag

Verzonden: wo 12-4-2017 14:05
Aan:

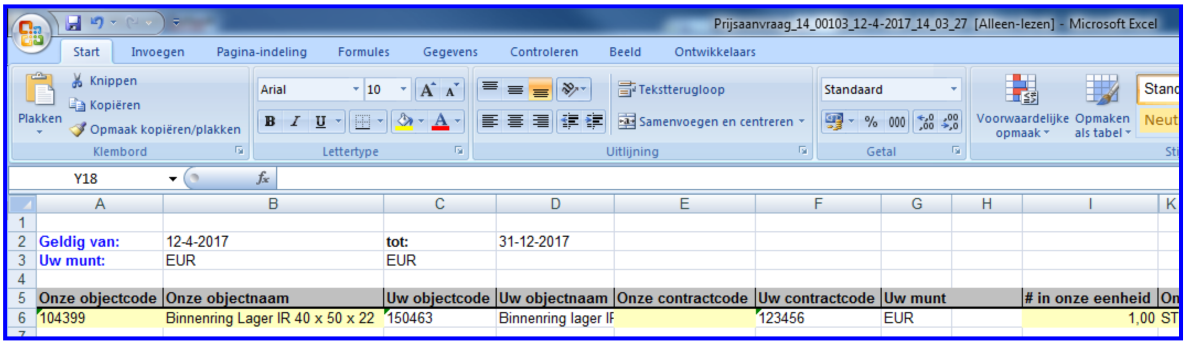
Bericht | Prijsaanvraag_14_00103_12-4-2017_14_03_27.xlsx (67 kB)

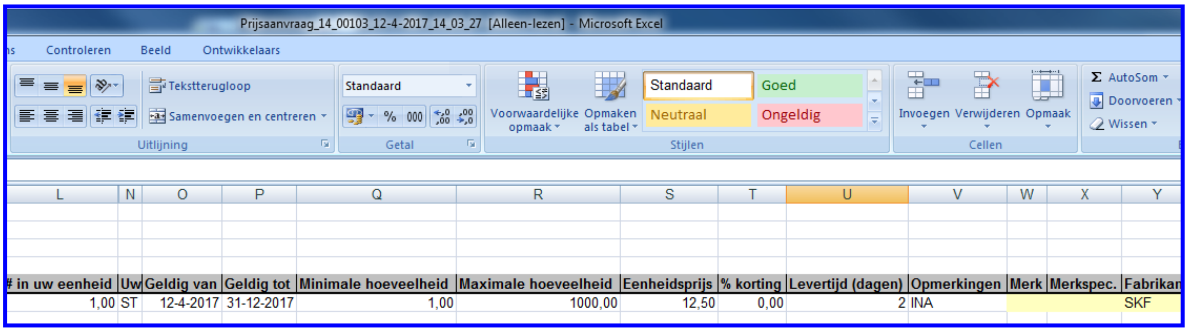
Geachte,
Gelieve in bijlage onze prijsaanvraag (onze referentie 14) te ontvangen.
Gelieve voor de gevraagde einddatum van 12-4-2017 0:00:00 de ingevulde offerte terug te sturen.

Hoogachtend,

Bolletje Almelo

In de bijlage is een Excel document bijgevoegd waarin de leverancier de opgevraagde data (Objectcode, Eenheidsprijs, Geldig van – tot, levertijd, etc.) kan invullen, inclusief een handleiding.
Geldig van: 12-4-2017 tot: 31-12-2017.
Uw objectcode: 150463.
Uw objectnaam: Binnenring lager IR 40 x 50 x 22.
Uw contractcode: 123456.
Minimale hoeveelheid: 1,00.
Maximale hoeveelheid: 1000,00.
Eenheidsprijs: 12,50.
Levertijd (dagen): 2.





Wanneer je in antwoord op de elektronische prijsaanvraag de offerte ontvangt van de leverancier, kun je de offerte opladen in Rimses. Je laadt de gegevens uit het Excel werkblad op in Rimses.

❖ Een offerte van de elektronische prijsaanvraag opladen:

1. Selecteer ***Inkoop/Prijsaanvragen/Beheer elektronische prijsaanvragen/Selecteren van prijsaanvragen: OK.***
   Donkerblauw gemarkeerde regel met Aanvraagnr.: 14 en status: Verstuurd.

2. Selecteer de gewenste Elektronische prijsaanvraag. Klik op ***Opladen.***
3. Het systeem opent het Windows venster ***Open.***
   Ga naar de plaats waar je de Excel bestanden hebt opgeslagen en klik één voor één de Excel werkbladen aan die je wilt opladen.
   Klik op ***Open.***

Na het opladen wordt de ***Status*** van de prijsaanvraag:

- ***Gedeeltelijk ontvangen*** als nog niet alle Excel werkbladen zijn opgeladen
- ***Volledig ontvangen*** als alle Excel werkbladen zijn opgeladen

Donkerblauw gemarkeerde regel met Aanvraagnr.: 14 en Status: Volledig ontvangen.

Zodra je de offerte van de leverancier hebt opgeladen, kun je de elektronische prijsaanvraag (de offerte) behandelen. Je kunt tijdens het behandelen van de prijsaanvraag:

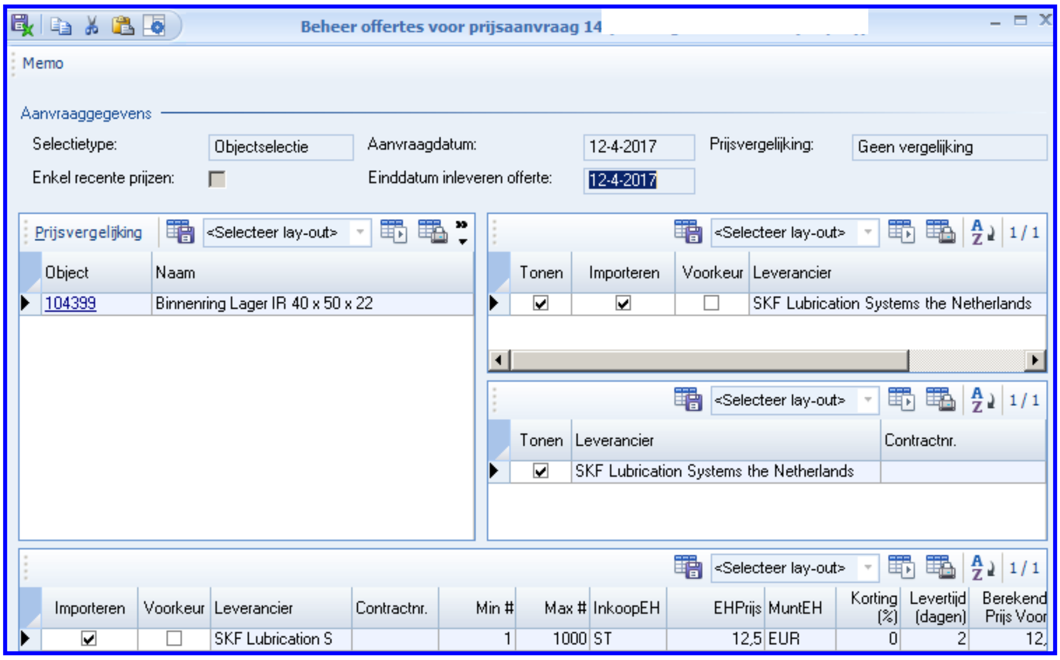
- Behandelen welke prijzen je wenst door te voeren in Rimses (***Importeren)***
- Bepalen welke leverancier voor alle objecten of voor een bepaald object de ***Voorkeursleverancier*** in Rimses wordt (***Voorkeur)***
- De prijzen van de verschillende leveranciers vergelijken, handmatig of geautomatiseerd

Nadat je de offertes behandeld hebt, kun je de ***prijzen verwerken*** in Rimses.

❖ Een offerte van de elektronische prijsaanvraag behandelen en verwerken:

1. Selecteer ***Inkoop/Prijsaanvragen/Beheer elektronische prijsaanvragen/Selecteren van prijsaanvragen: OK.***
   Donkerblauw gemarkeerde regel met Aanvraagnr.: 14 en Status: Volledig ontvangen.

2. Selecteer de gewenste elektronische prijsaanvraag en klik op ***Behandelen.***



3. ***Links*** zie je een lijst van alle ***objecten*** waarvoor je een prijs hebt aangevraagd in de geselecteerde elektronische prijsaanvraag.
   Object: 104399.
   Naam: Binnenring Lager IR 40 x 50 x 22.
   Rechts zie je alle ***leveranciers*** waarvan de Excel werkbladen met de antwoorden op de ***Elektronische prijsaanvraag*** zijn opgeladen.
   Leverancier: SKF Lubrication Systems the Netherlands.
   Wanneer je het veld ***Tonen*** aanvinkt naast een leverancier, zie je onderaan de prijsofferte van die leverancier voor het geselecteerde object.
4. Vink het veld ***Importeren*** aan. Op die manier kun je de prijslijsten van deze leverancier voor ALLE ***objecten*** uit het vak ***Objecten*** doorvoeren in Rimses na verwerking.
5. Vink het veld ***Voorkeur*** aan indien je de leverancier tot ***voorkeursleverancier*** wilt maken voor ALLE ***objecten*** uit het vak ***Objecten*** na verwerking.
6. Klik op ***OK.***
7. Klik op ***Verwerken.***
8. De elektronische prijsaanvraag krijgt nu de status ***Verwerkt.***
   Donkerblauw gemarkeerde regel met Aanvraagnr.: 14 en Status: Verwerkt.

Aanvraagnr.	Opgemaakt door	Antwoorddatum	Status	Datum versturen	Verstuurd door	Datum verwerking	Selectietype	Enkel recente prijzen	Prijs
8	[redacted]	12-9-2014	Verstuurd	12-9-2014	[redacted]		Objectselectie		Gee
9		26-9-2014	Verstuurd	23-2-2017			Objectselectie		Gee
10		23-9-2014	Ingegeven				Objectselectie		Gee
11		23-2-2017	Verstuurd	23-2-2017			Objectselectie		Gee
13		10-4-2017	Ingegeven				Objectselectie		Gee
14		12-4-2017	Verwerkt	12-4-2017		12-4-2017	Objectselectie		Gee

Let op: indien er een overlapping is van de geldigheidsperiode tussen een bestaande prijslijst en een te verwerken prijslijst, die door het systeem niet gesplitst kan worden in twee prijslijsten voor nieuwe periodes, dan kan de prijslijst van de elektronische prijsaanvraag niet verwerkt worden. Rimses geeft de prijslijst een rode kleur. Door de geldigheidsperiode aan te passen op het Excel werkblad kan de prijslijst wel worden aangepast.

❖ Een prijsvergelijking per object laten uitvoeren:

1. Selecteer ***Inkoop/Prijsaanvragen/Beheer elektronische prijsaanvragen/Selecteren van prijsaanvragen.***
2. Selecteer de gewenste prijsaanvraag en klik op ***Behandelen.***
3. Klik op de knop ***Prijsvergelijking.*** Door de ***leveranciers*** al dan niet aan te vinken in het veld ***Tonen*** kun je de keuzes beperken voor de vergelijking.
4. Selecteer de optie ***Individuele vergelijking.*** Klik op ***OK.***
   Indien je de optie ***Geen vergelijking*** selecteert, wordt er geen automatische prijsvergelijking doorgevoerd.

Rimses voert nu een automatische ***prijsvergelijking*** uit voor ***alle objecten.***
Het ***resultaat*** van de prijsvergelijking zie je onderaan. Rimses heeft per object de prijzen vergeleken tussen ***alle leveranciers*** die werden aangevinkt via ***Tonen.***
De ***netto eenheidsprijs voor inkoop*** wordt gebruikt voor de vergelijking.
Bij de ***goedkoopste leverancier*** heeft Rimses automatisch het veld ***Voorkeur*** aangevinkt.

HANDMATIGE PRIJSAANVRAGEN

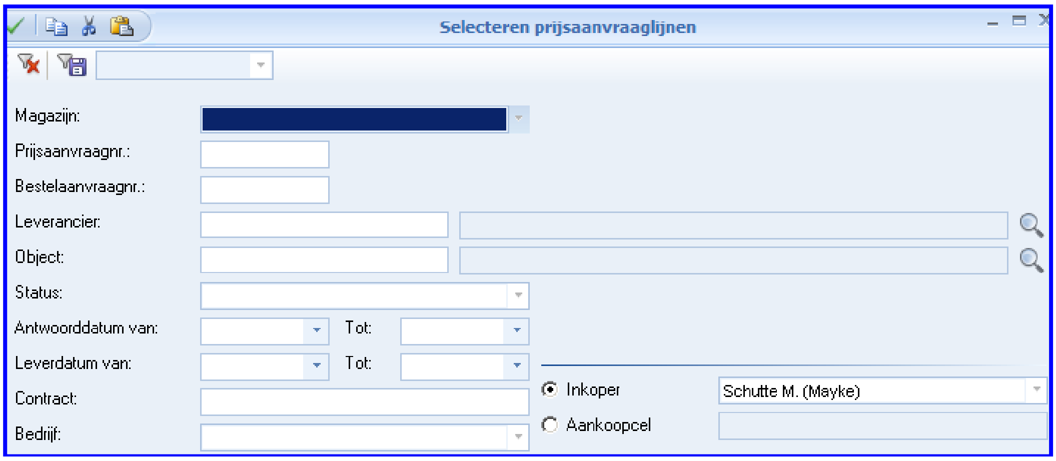
Een handmatige prijsaanvraag is een prijsaanvraag die je in Rimses aanmaakt en daarna afdrukt in PDF. Je verstuurt de aanvraag per post, fax of e-mail naar de leverancier. Je kunt de prijsaanvraag niet meer bewerken en de offerte van de leverancier moet je uiteindelijk manueel in Rimses verwerken.

Een prijsaanvraag kan op twee manieren ontstaan:

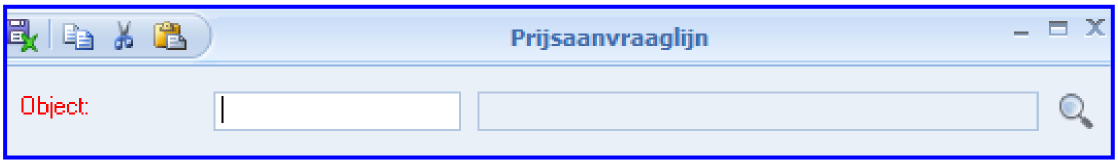
1. ***De inkoper*** stuurt een prijsaanvraag naar de leverancier voor een object, ***zonder dat de aanvraag gekoppeld is aan een bestelaanvraag of een bestellijn*** (dit kan enkel bij een leverancier voor wie al een prijslijst (leverancier + object) bestaat)
2. ***De inkoper*** stuurt een bestelaanvraag naar de leverancier ***voordat hij de bestelling plaatst = prijsaanvraag voor bestelling***

❖ Een handmatige prijsaanvraag voor een object aanmaken:

1. Selecteer ***Inkoop/Prijsaanvragen/Beheer prijsaanvraaglijnen/Selecteren prijsaanvraaglijnen: OK.***



2. Vul de selectiecriteria in en klik op ***OK.***
3. Klik op ***Nieuw.***



4. Vul het object in waarvoor je een prijsofferte wilt aanvragen. Klik op ***OK.***
   Object: 114377, Oliekering Diosna 55 x 70 x 8 RP
5. Klik op ***Prijsaanvraag.***
6. Vink de optie ***Nieuwe prijsaanvragen*** aan. Klik op ***OK.***
7. De nieuwe prijsaanvraag verschijnt in het overzicht ***Prijsaanvraaglijnen.*** Je kunt de prijsaanvraag nu versturen.

Via het venster ***Prijsaanvraaglijnen*** kun je als inkoper prijsaanvragen van bijvoorbeeld de aanvrager bekijken, behandelen en versturen naar de leverancier.

Via de knop ***Prijsaanvr. per lev.*** op het venster ***Prijsaanvraaglijnen*** kun je voor alle bestaande prijslijsten van een bepaalde leverancier in één keer nieuwe prijsaanvragen maken en versturen.

Je kunt ook rechtstreeks vanuit een bestaande prijslijst een nieuwe prijsaanvraag maken via de knop ***Prijsaanvraag.***

❖ Een handmatige prijsaanvraag voor een bestelling aanmaken:

1. Selecteer ***Inkoop/Bestellijnen/Beheer bestellijnen.***
2. Klik op ***Nieuw*** om een nieuwe bestellijn aan te maken OF Klik op ***Wijzigen*** om voor een bestaande bestellijn een prijsaanvraag te maken.
3. Klik op de knop ***Prijsaanvragen.***
4. Controleer de prijsaanvraag:
    - Wil je het bevestigen? Klik op ***OK.***
    - Wil je het annuleren? Klik op ***Verwijderen.***
    - Wil je voor hetzelfde object een prijs aanvragen bij een andere leverancier? Klik op ***Nieuw.***
5. Klik na de gewenste actie op ***OK*** om het venster te sluiten. De prijsaanvraag krijgt de status ***PA voor bestelling.***
6. Klik op ***OK*** om de bestellijn te bevestigen. De bestellijn krijg de status ***Inkoop: wacht op PA.***
7. Klik op ***Sluiten*** om het venster te sluiten.
8. Selecteer ***Inkoop/Prijsaanvragen/Beheer prijsaanvraaglijnen.*** Maak de gewenste selectie en klik op ***OK.***
9. Selecteer de prijsaanvraag die je net hebt aangemaakt en klik op de knop ***Versturen.*** Het venster ***Te versturen prijsaanvragen*** wordt vervolgens geopend.
10. Selecteer de prijsaanvragen die je wilt versturen. Je ziet hier voor een zelfde object de prijsaanvragen naar de verschillende leveranciers. Klik op ***OK.*** De prijsaanvraaglijn krijgt nu de status ***Prijsaanvraag verstuurd.***

❖ Een handmatige prijsaanvraag versturen:

1. Selecteer ***Inkoop/Prijsaanvragen/Beheer prijsaanvraaglijnen/Selecteren prijsaanvraaglijnen: OK.***
2. Selecteer de prijsaanvraaglijn die je naar de leverancier wilt versturen. Klik op ***Versturen.***
3. Selecteer de leverancier. Vink het veld ***Versturen?*** aan. Vul de datum in waarop je een antwoord verwacht van de leverancier. Klik op ***OK.***
4. De prijsaanvraaglijn krijgt nu de status ***PA verstuurd.***

Als antwoord op deze prijsaanvraag stuurt de leverancier je een offerte, welke je vervolgens kunt registreren in Rimses.

❖ Een offerte van een leverancier registreren:

1. Selecteer ***Inkoop/Prijsaanvragen/Beheer prijsaanvragen/Selecteren lopende prijsaanvragen: OK.***
2. Selecteer de gewenste prijsaanvraag met status ***Verstuurd.***
3. Klik op de knop ***Offerte registreren.***
4. Vul de gegevens van de offerte in. Klik op ***OK.***
5. De prijsaanvraag krijgt nu de status ***Afgehandeld.*** De nieuwe prijs kom in een nieuwe prijslijst. Als de prijs geldig is volgens de geldigheidsdata van de prijslijst of de offerte, is de status ***Actuele prijs.***

Appendix 6: Instruction manual for Rimses – Factuurregistratie

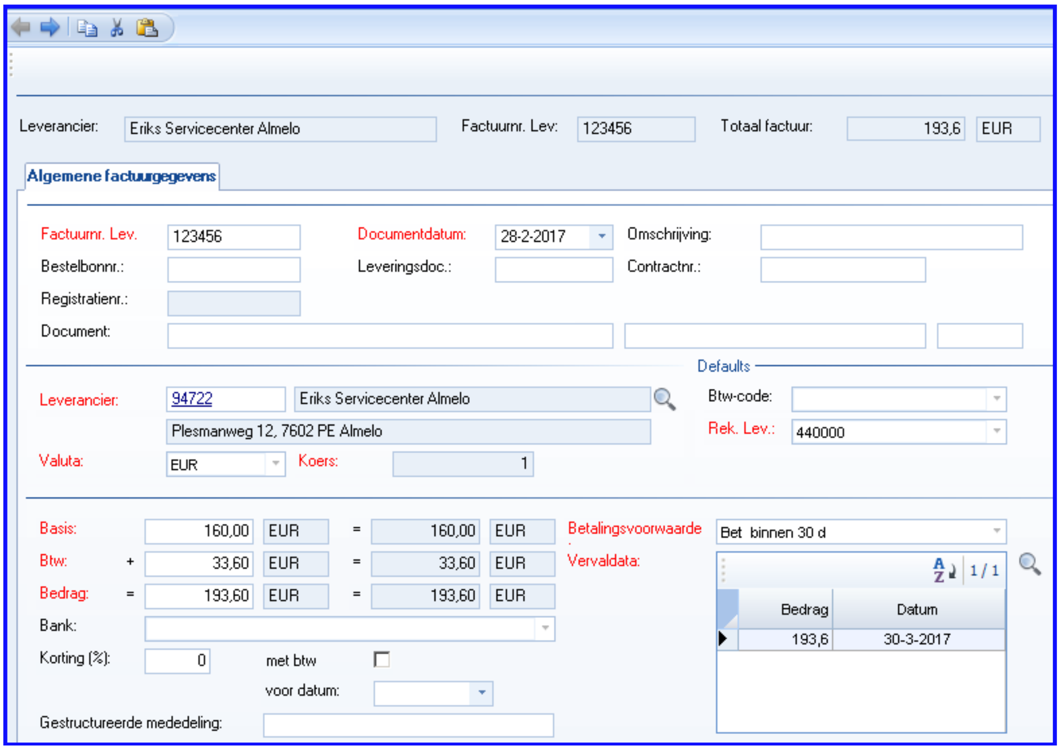
FACTUURREGISTRATIE

In de rol Inkoop kun je onder het menupunt Factuurregistratie inkomende facturen en creditnota's controleren en registreren. Je controleert of de factuur van de leverancier overeenkomt met de goederen en/of diensten die je besteld had, je controleert prijzen en hoeveelheden, registreert eventuele afwijkingen en registreert de factuur voor de boekhouding.

o Om een factuur te controleren en registreren:

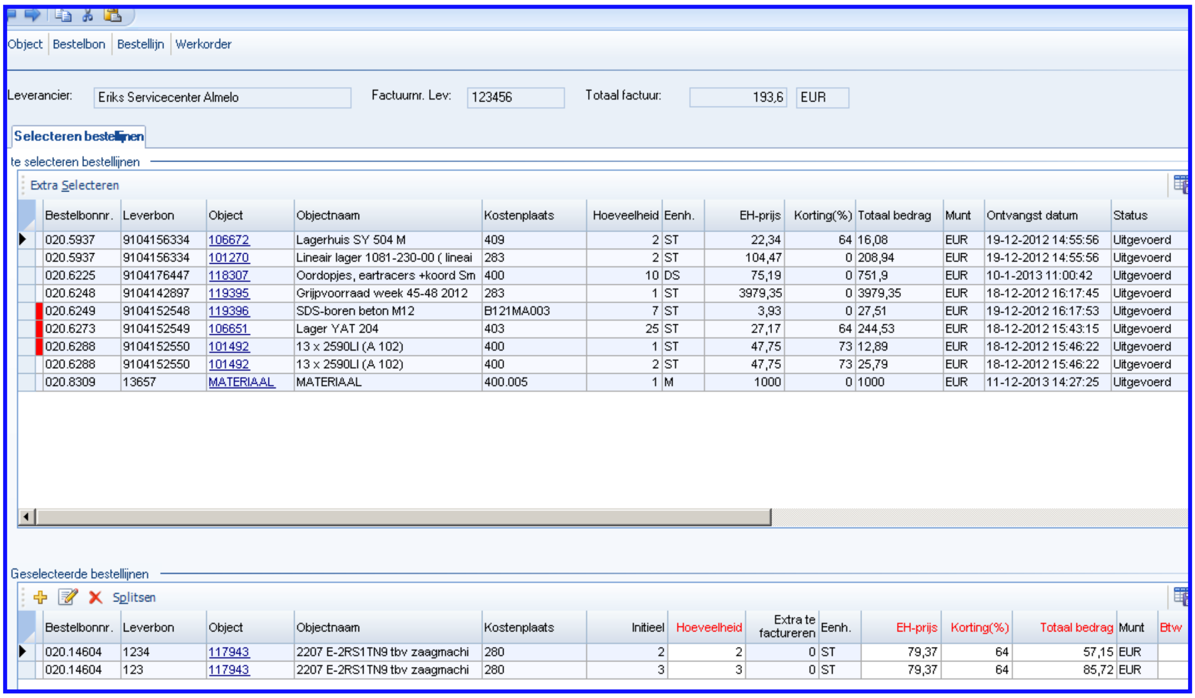
1. Selecteer ***Inkoop/Factuurregistratie/Wizard voor factuurregistratie***.
2. Vul het ***bedrijf***, het ***journaal*** voor inkomende facturen en de ***boekdatum*** voor de te registreren factuur in. De boekdatum moet in een openstaande boekperiode vallen. Als de boekperiodes correct zijn opgezet voor je bedrijf, wordt automatisch de juiste boekperiode ingevuld.
   Bedrijf: Bolletje Almelo.
   Journaal IF Januari 2017.
   Boekdatum: 28-2-2017.
   Let op: de boekdatum is niet hetzelfde als de documentdatum van de factuur of de creditnota!
   Klik op ***Volgende***.

3. Vul in het volgende venster de algemene gegevens van de inkomende factuur in.. Je moet minstens de verplichte (rode) velden invullen.
   Factuurnr. Lev: 123456.
   Documentdatum: 28-2-2017.
   Bestelbonnr: 020.14604.
   Basis: 160,00 EUR.
   Btw: 33,60 EUR.
   De velden ***Bestelbon, Leveringsdoc***. en ***Contractnr***. zijn optioneel.
   - Wanneer je ***geen*** van deze velden invult, haalt de wizard de ***betalingsvoorwaarden*** op die gekoppeld zijn aan de ***leverancier***.
   - Wanneer je deze velden ***wel*** invult (1 of allemaal), dan haalt de wizard de ***betalingsvoorwaarden*** op van de ingevulde ***bestelbon*** of van de bestelbon die gekoppeld is aan het leveringsdocument of het contract.
   - Indien er meer dan 1 bestelbon gekoppeld is aan het leveringsdocument/contract, dan gelden de betalingsvoorwaarden van de ***eerste bestelbon***.



Klik op ***Volgende***.

4. In dit venster zie je de logistieke lijnen die je tegenover een inkomende factuur kunt plaatsen (factuurmatching).



Bestelbonnr.	Leverbon	Object	Objectnaam	Kostenplaats	Hoeveelheid	Eenh.	EH-prijs	Korting(%)	Totaal bedrag	Munt	Ontvangst datum	Status
020.5937	9104156334	106672	Lagerhuis SY 504 M	409	2	ST	22,34	64	16,08	EUR	19-12-2012 14:55:56	Uitgevoerd
020.5937	9104156334	101270	Lineair lager 1081-230-00 (lineai	283	2	ST	104,47	0	208,94	EUR	19-12-2012 14:55:56	Uitgevoerd
020.6225	9104176447	118307	Oordopjes, eartracers +koord Sm	400	10	DS	75,19	0	751,9	EUR	10-1-2013 11:00:42	Uitgevoerd
020.6248	9104142897	119395	Grijpvoorraad week 45-48 2012	283	1	ST	3979,35	0	3979,35	EUR	18-12-2012 16:17:45	Uitgevoerd
020.6249	9104152548	119396	SDS-boren beton M12	B121MA003	7	ST	3,93	0	27,51	EUR	19-12-2012 16:17:53	Uitgevoerd
020.6273	9104152549	106651	Lager YAT 204	403	25	ST	27,17	64	244,53	EUR	18-12-2012 15:43:15	Uitgevoerd
020.6288	9104152550	101492	13 x 2590LI (A 102)	400	1	ST	47,75	73	12,89	EUR	18-12-2012 15:46:22	Uitgevoerd
020.6288	9104152550	101492	13 x 2590LI (A 102)	400	2	ST	47,75	73	25,79	EUR	18-12-2012 15:46:22	Uitgevoerd
020.8309	13657	MATERIAAL	MATERIAAL	400.005	1	M	1000	0	1000	EUR	11-12-2013 14:27:25	Uitgevoerd

Bestelbonnr.	Leverbon	Object	Objectnaam	Kostenplaats	Initieel	Hoeveelheid	Extra te factureren	Eenh.	EH-prijs	Korting(%)	Totaal bedrag	Munt	Btw
020.14604	1234	117943	2207 E-2RS1TN9 tbv zaagmachi	280	2	2	0	ST	79,37	64	57,15	EUR	
020.14604	123	117943	2207 E-2RS1TN9 tbv zaagmachi	280	3	3	0	ST	79,37	64	85,72	EUR	

- In het hoofdvenster bovenaan zie je de leverancier voor wie je facturen wilt registreren en het ***totaalbedrag*** van de factuur ***inclusief btw***. Deze gegevens worden overgenomen van stap 3. Leverancier: Eriks Servicecenter Almelo. Factuurnr. Lev: 123456. Totaal factuur: 193,6 EUR.

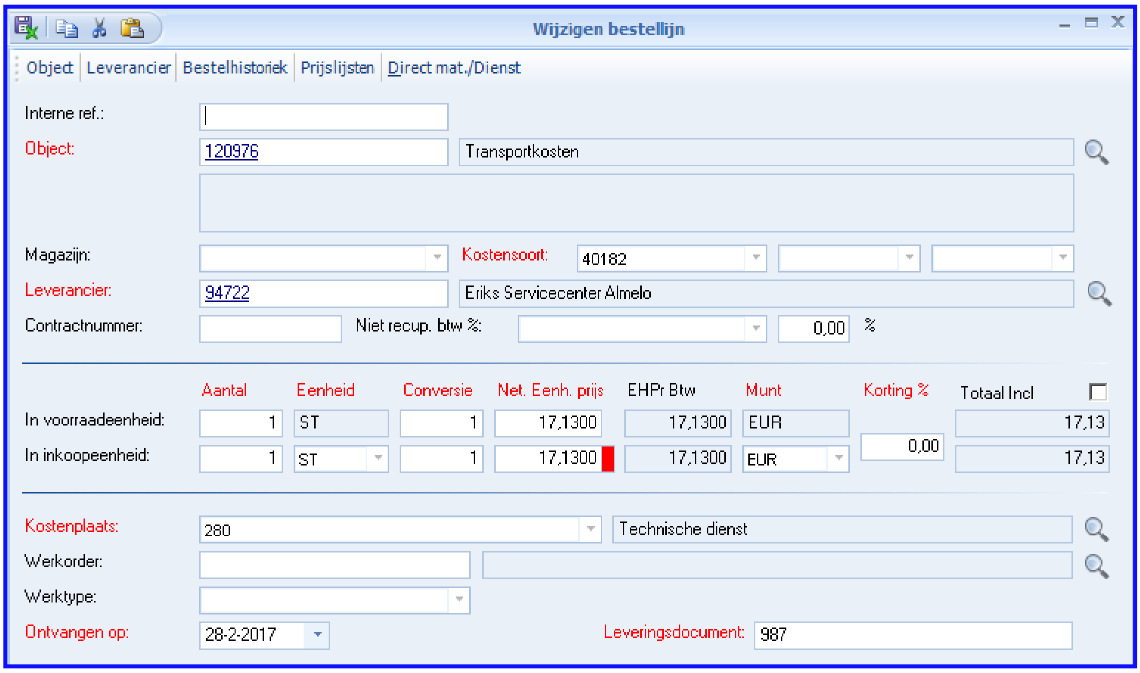
- ***Bovenaan*** het venster staan de bestellijnen waarvoor nog geen factuurmatching gedaan is.
- ***Onderaan*** staan de bestellijnen waarvoor je factuurmatching wilt doen. Bestellijnen die overeenkomen met het bestelbonnummer dat je in stap 3 hebt ingevuld, komen automatisch in de lijst onderaan.
- Je kunt lijnen van boven naar onder en omgekeerd verplaatsen d.m.v. de pijltjestoetsen.
- In de geselecteerde lijnen onderaan kun je indien nodig onder andere de prijs en hoeveelheid aanpassen. Dit zijn ***financiële gegevens***, dat betekent dat de originele bestelling niet gewijzigd wordt! De niet-originele hoeveelheid krijgt de status ***Extra gefactureerd*** in plaats van de status ***Uitgevoerd***.
- Onderaan in het veld ***Saldo nog te boeken*** zie je het ***bedrag exclusief btw*** dat nog open staat op de factuur nadat je bestellijnen geselecteerd en naar onder verplaatst hebt (positief bedrag) of het bedrag dat hoger is dan het in stap 3 ingegeven bedrag (negatief bedrag). Afwijkingen (geen 0 bedrag) ontstaan bijvoorbeeld door prijsverschillen, koersverschillen, kortingen, op de bestelling ontbrekende transportkosten, etc.

  Saldo nog te boeken: 17,13 EUR.

  → Als het ***Saldo nog te boeken*** positief is, en er dus nog extra kosten op de factuur staan die niet op de originele bestelling staan, heb je 2 mogelijkheden om deze extra kosten te registreren:

  1. De eerste mogelijkheid is door een extra ***logistieke bestellijn*** aan te maken via de knop ***Nieuw***. De hoeveelheid die extra gefactureerd wordt, krijgt een rode kleur en de status ***Extra gefactureerd***.

     Extra transportkosten -> Object: 120976, Transportkosten.
     Aantal: 1 stuks.
     Eenheidsprijs: 17,13 EUR.
     Leveringsdocument: 987.



Klik op ***OK*** en in het volgende venster zie je de extra toegevoegde logistieke bestellijn.
Objectnaam: Transportkosten.

Status: *Extra gefactureerd.*
Saldo nog te boeken: 0 EUR.

selecteerde bestellijnen

Splitsen

Objectnaam	Kostenplaats	Initieel	Hoeveelheid	Extra te factureren	Eenh.	EH-prijs	Korting(%)	Totaal bedrag	Munt	Btw	Btw	Rekening Leverancier
2207 E-2RS1TN9 tbv zaagmachi	280	2	2	0	ST	79,37	64	57,15	EUR	21%	21	440000
2207 E-2RS1TN9 tbv zaagmachi	280	3	3	0	ST	79,37	64	85,72	EUR	21%	21	440000
Transportkosten	280	0	1	1	ST	17,13	0	17,13	EUR	21%	21	440000

De ***btw-code*** kun je ***zelf*** invullen, of de ***standaard*** btw-code wordt overgenomen van stap 3, of de btw-code wordt ***automatisch*** ingevuld op basis van de btw-matrix die is opgesteld.
Btw: 21%.

2. De tweede mogelijkheid wordt behandeld in stap 5, waarbij de extra kosten ***rechtsreeks op de gewenste rekening*** worden geboekt via de knop ***Nieuw*** . Hierdoor gaat de informatie over de extra kosten echter verloren voor de rapportage, waardoor de eerste mogelijkheid over het algemeen de voorkeur heeft.

5. Wanneer je alle benodigde bestellijnen geselecteerd hebt, klik je op ***Volgende*** om verder te gaan naar stap 5. In dit venster wordt de boeking van de factuur voorgesteld, zoals ze uiteindelijk in de boekhouding terecht komt. Er zijn minstens 3 boekingslijnen:
   - Een boeking naar een leveranciersrekening
     Rekening: 440000, Bedrag: -193,6 EUR.
   - Een boeking naar een btw-rekening
     Rekening: 999996, Bedrag: 33,6 EUR.
   - Boekingen naar andere rekeningen (voorraadrekening, kostenrekening, etc)
     Rekening: 999996, Bedrag: 160 EUR.

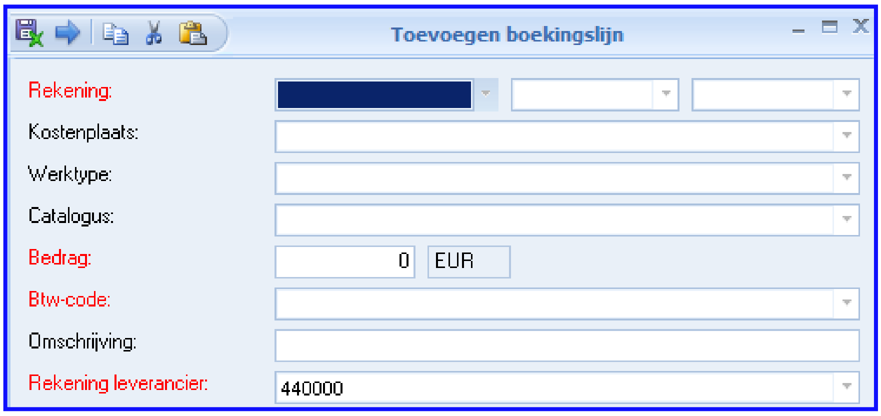
Leverancier: Eriks Servicecenter Almelo — Factuurnr. Lev: 123456 — Totaal factuur: 193,6 EUR

Ingave/Wijzigen boekingslijn

Detail

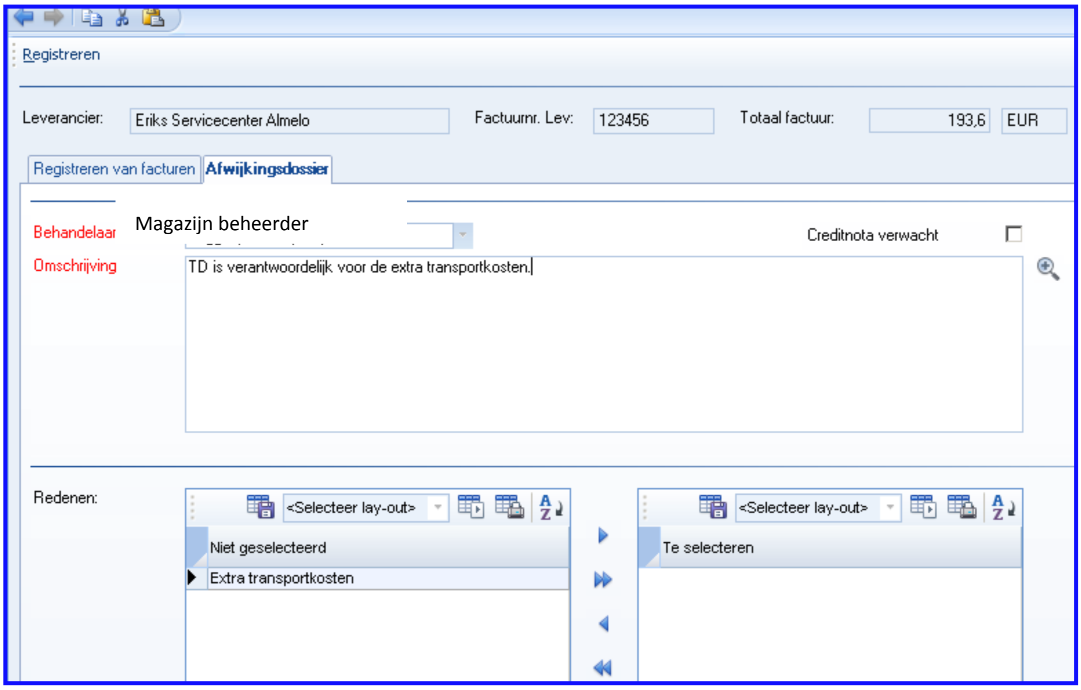
+	Rekening	Rekeningnaam	Sub rekening	2de as	Bedrag firmamunt	Bedrag	Munt	Kostenplaats	Kostenplaats naam
	440000				-193,6	-193,6	EUR		
	999996				33,6	33,6	EUR		
+	999996				160	160	EUR	280	Technische dienst

Wanneer je hebt gekozen om extra kosten in deze stap te registreren, klik dan op de knop ***Nieuw***. Vul in het venster ***Toevoegen boekingslijn*** de benodigde gegevens in. Klik vervolgens op ***OK***.

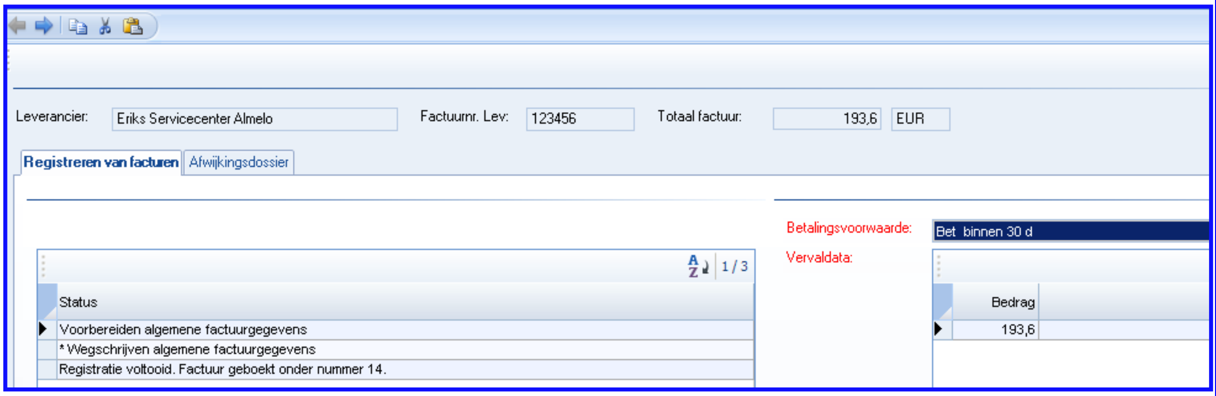


Klik op ***Volgende*** zodra de boeking in evenwicht is (bedrag = 0 EUR). Een boeking die niet in evenwicht is, kun je niet registreren!

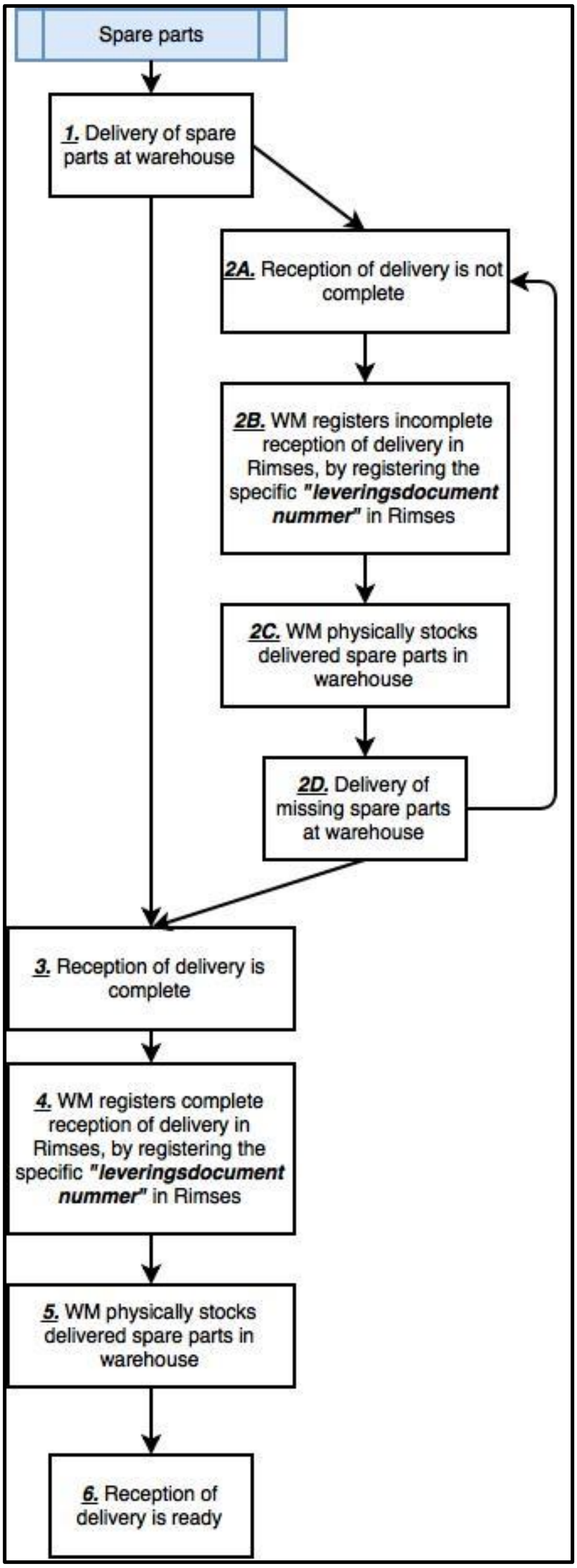
6. In dit venster kun je de factuurgegevens effectief registreren. Als er een prijsverschil was tussen de oorspronkelijke bestelling en de factuur, krijg je automatisch een tabblad ***Afwijkingsdossie***. De verantwoordelijke voor dit dossier kan zo beslissen wie de kosten (positief of negatief) voor het verschil moet dragen.
   Behandelaar: Magazijn beheerder.
   Omschrijving: TD is verantwoordelijk voor de extra transportkosten.



7. Klik vervolgens op de knop ***Registreren***, zodat de factuurgegevens worden voorbereid en weggeschreven. Noteer het interne factuurnummer in D3.
   Intern factuurnummer: 14.

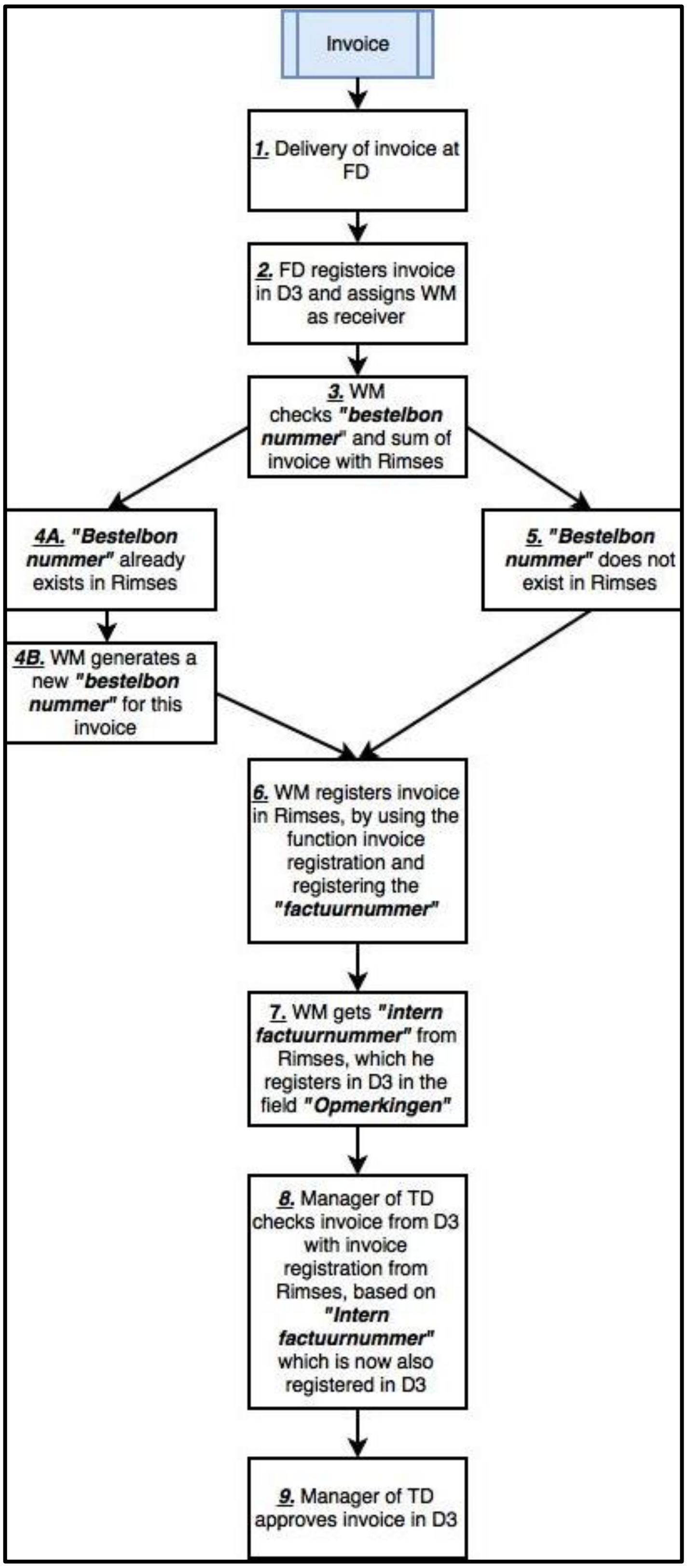

Leverancier:
Eriks Servicecenter Almelo
Factuurnr. Lev:
123456
Totaal factuur:
193,6
EUR
Registreren van facturen
Afwijkingsdossier
Betalingsvoorwaarde:
Bet binnen 30 d
Vervaldata:
1 / 3
Status
Voorbereiden algemene factuurgegevens
* Wegschrijven algemene factuurgegevens
Registratie voltooid. Factuur geboekt onder nummer 14.
Bedrag
193,6

Appendix 7: New process of delivery & reception of spare parts



Explanation of this process:	
1.	The supplier delivers spare parts at the warehouse and the warehouse manager (WM) receives these spare parts.
2A.	The reception of the delivered spare parts is NOT complete.
2B.	The WM registers the incomplete reception of delivery in Rimses, by registering the specific **“leveringsdocument nummer”** in Rimses.
2C.	The WM physically stocks the delivered spare parts in the warehouse.
2D.	The supplier delivers the missing spare parts at the warehouse and the WM receives these spare parts.
3.	The reception of the delivered spare parts is complete.
4.	The WM registers the complete reception of delivery in Rimses, by registering the specific **“leveringsdocument nummer”** in Rimses.
5.	The WM physically stocks the delivered spare parts in the warehouse.
6.	The physically reception of delivered spare parts in the warehouse and the registration of delivered spare parts in Rimses are now both ready.

Appendix 8: New process of invoice registration



Explanation of this process:	
1.	A supplier sends an invoice to the Financial Department (FD).
2.	When the FD has received an invoice, they scan this invoice into D3, the accounting system of Bolletje. The warehouse manager (WM) is assigned as receiver.
3.	Then this invoice is sent to the WM in D3, so that he can check the sum of the invoice with the sum of the order line in Rimses. If there are any deviations, the WM can change the sum of the order line in Rimses. Besides that, he checks if the **"bestelbon nummer"** of the invoice already exists in Rimses.
4A.	The **"bestelbon nummer"** already exists in Rimses.
4B.	The WM generates a new **"bestelbon nummer"** for this invoice.
5.	If the **"bestelbon nummer"** does not exist in Rimes, there is no problem.
6.	Consequently, the WM registers the invoice in Rimses, by using the function invoice registration and registering the **"factuurnummer".**
7.	The WM get an **"intern factuurnummer"** from Rimses, which he registers in D3 in the field **"Opmerkingen".**
8.	The manager of the TD checks the invoice from D3 with the invoice registration from Rimses, based on the **"Intern factuurnummer"**, which he can find in D3.
9.	Finally, the manager of the TD approves the invoice in D3, so that the FD can see if the invoice is ready for payment.