MASTER

The inventory control of configuration components
Océ wide format printing systems

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Océ Wide Format Printing Systems

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Océ WFPS

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Management Summary

This report contains the main results of the research of the inventory control of the configuration components at the assembly unit Wide Format Printing Systems, Océ Venlo. The result of the research is a redesign for the inventory control. This redesign consists of another lot sizing method and a method to calculate the safety stock, taking into account the forecast error of the undershoot and of the demand during the lead-time of the supplier and the variance of the lead-time. Not all configuration components are taken into account. A selection has been made based on several criteria. The inventory value per component is calculated when this redesign should be implemented. Beside that, two options to reduce the inventory level are proposed: not stocking certain components any longer and reducing the amount of configuration components that are offered.

In the current situation, the following issues related to the inventory control are:

- The current lot sizing methods are the Economic Order Quantity and the Periodic Order Quantity. These methods do not react very well to dynamic demand;
- There does not exist a clear insight into the level of the safety stock. The safety stock that is reported in SAP R/2 does not correspond with the actual safety stock level. The actual safety stock is higher because a lot of safety *time* is included;
- The safety stock is fixed and based on the average two or three weeks demand;
- The target for the service level for end products is defined at 97.5%. But four of the five different end products do not achieve this level.

Another lot sizing method is proposed in the redesign: the Silver-Meal heuristic. The advantages of this heuristic are:

- This heuristic is designed for situations in which the demand pattern varies with time; the heuristic follows the dynamic demand of the configuration components;
- Based on performance analyses the Silver-Meal heuristic outperforms the Periodic Order Quantity and Economic Order Quantity method;
- The Silver-Meal heuristic is less sensitive for variations in the inventory and set-up costs.

On average, the lot size increases in the redesign, but this is also caused by the fact that in the redesign the minimum order quantity and packing quantity are taken into account. In the current situation, these are left out of consideration. Because of this reason, the lot sizes in the current situation and in the redesign cannot be compared one-to-one.

A method to calculate the safety stock is determined. In this method, the forecast error of the undershoot and of the demand during the lead-time and the variance of the lead-time are taken into account. The results of this method are:

- Cheap components (with a price lower than € 50) need to receive a service level of 100%, otherwise it is impossible to achieve the target of 97.5% for the end products. The method cannot be used in this case. That is why the safety stock is set equal to the maximum demand during the lead-time of the supplier and the review period;
- The safety stock for the expensive components is calculated with the method. The service level at component level that is needed to calculate the safety stock cannot be determined. A mathematical approach is not possible, because the end products are customer-specific. The literature does not provide a solution for this problem either at this moment. That is why the service level for components has to be determined empirically. The optimal service level for expensive components is 99.5% and the overall service level for end products increases.
  When the impact of the action of MRP-controllers are known and their actions lead to a service level of 97.5% with a lower P_2-value, the P_2-value may be defined at a lower level which will lead to lower safety stock values.

The results in inventory value in the redesign are:

- The inventory value in the redesign with a service level of 99.5% at components level is slightly higher but the overall service level for end products increases;
- not stocking certain components may cause a saving of X % of the total inventory value;
- not offering all components anymore may cause a saving of X % of all logistics costs that have to be made.

These last two options need further investigation.

Preface

This report is the result of my graduation project at Océ-Technologies B.V. in Venlo. This project has been carried out from the end of April 2003 until January 2004 and is the final project of the study Industrial Engineering and Management Science at the University of Technology in Eindhoven.

The focus of the project is the inventory control of configuration components. Another lot sizing method is proposed and a method to calculate the safety stock is determined. Beside that, options to reduce the inventory costs are recommended.
The methods that are proposed in this project will hopefully be used in the future by the Logistics department of WFPS. Even a better result would be if these methods would be implemented in SAP R/3 and the new insights about the control of the inventory would be shared with the other assembly units.

The project could not have been carried out without the help of a lot of people. Not only the employees of the Logistics department were always willing to help me but also people from the other units were very helpful and interested in the project. The different opinions and data that were provided by all these people were very valuable.

Especially I would like to thank Corien Wallace, Leon Claassen, Dhr. Fransoo and Dhr. Van der Veeken. Corien always provided me with critical comments about my project and motivated me during the project. Leon was always there when I needed help and his speed of gathering the necessary data was amazing. Dhr. Fransoo was a great help on the theoretical area but he also monitored the progress of my project. He always had a critical view on my project and pushed me a little bit further every time. Dhr. Van der Veeken provided me with more background about the cost aspect of my project and had worthful comments about my report. Without their help, I would never have achieved this result in nine months.

But I have also to express my thanks to some (ex)-students. I would like to thank Pieter Bouwmans, Koen Cremers, Jérôme Delnooz and Christiaan Simons for all their help and support.

Francine van Venrooij
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Abstract

In this report, the main results of the research of the inventory control of the configuration components at WFPS, Océ Venlo are described. The redesign consists of another lot sizing method and a method to calculate the safety stock, taking into account the forecast error of the undershoot and of the demand during the lead-time and the variance of the lead-time. The inventory value per component has been calculated when this redesign should be implemented.

Summary

This report contains the main results of the research of the inventory control of the configuration components at WFPS, Océ Venlo. This research is the final project of the study Industrial Engineering and Management Science at the University of Technology in Eindhoven. A redesign has been made in which a method to calculate the safety stock is designed and another lot sizing method is proposed. Beside that, a first-order-analysis has been carried out what savings could be achieved when certain components would not be offered anymore or are not stocked anymore.

Production process at WFPS
At WFPS printers for the graphical market are assembled. This assembly process consists of two stages: first, the standard product (engine) is assembled. Five different standard products can be assembled at three assembly lines. Then, the engines are stocked in the buffer. This buffer functions as Customer Order Decoupling Point. In the next stage, the configuration process, the product is made customer-specific by adding subassemblies, the configuration *items*, to the standard product. Configuration *components* are used to assemble the configuration *items*. The focus of the assignment is the inventory control of the configuration components.

Motivation of the assignment
Two factors gave rise to this assignment:
- The demand for printers strongly fluctuates per week and is difficult to forecast. As a consequence, this fluctuating demand can lead to large, unexpected orders, which cause a lot of variation in the production. The difficulty of forecasting the demand and receiving large orders leads to uncertainty in the reordering of a right amount of configuration components;
- Because the end product is customer-specific, the demand per configuration component may be very low. This makes it more difficult to forecast the amount of components that have to be replenished.

Based on these two factors, the starting-point of the assignment is formulated:
Analyze the inventory control of the configuration components and define possible research areas. An improvement plan will be designed for one research area, based on scholarly methods.

Many aspects influence the inventory control of the configuration components. The starting-point is the forecast of the sales offices. These offices give forecasts about the amount of products that they expect to order. This forecast is translated into a planning for the configuration process. The forecast of the OpCo's is not directly translated but other factors, like the recent assembly and configuration and available capacity are taken into account too. This planning again is used as input for the configuration matrix. This matrix calculates, based on the planning and a percentage the amount of components that have to be reordered. The percentage that is used as input indicates how many times a certain configuration item is delivered together with a particular engine and is based on historical information.
The forecast of the sales offices contains a forecast error (the difference between the forecast and the actual demand). This forecast error determines the unreliability of the forecast. The configuration matrix also causes a forecast error. This last forecast error determines the unreliability of the configuration matrix and has to be absorbed with safety stock.
The order policy determines in what way components have to be reordered. The forecast calculated by the configuration matrix determines the lot size of the components. The safety stock and the lot size together determine the inventory level.

Four research areas can be defined which are all related to the topic inventory control. The research areas and the main issues in these areas are:
- Forecast of the sales offices:
  The forecast is regarded as unreliable.
- Logistics costs of a configuration item:
  WFPS offers about 600 configuration items. But should all these items be offered to the market? And what are the logistics costs to offer a configuration item to the market?

- Configuration matrix:
  This is a tool which is used to calculate the amount of components that has to be reordered. The reliability of this tool has never been calculated.
- Inventory control:
  - Inventory level: the idea exists that this is unbalanced;
  - Safety stock: there is no unambiguous way of determining the safety stock;
  - There is no differentiated way of reordering configuration components; cheap or expensive, critical or non-critical components are treated in the same way;
  - When determining the optimal order quantity, only the inventory costs are taken into account.

Each research area is further investigated:

The forecast reliability of the sales offices
At this moment, Océ measures the forecast reliability in the following way:

$$1-\left|\frac{(O_t - F_{t-1})}{F_{t-1}}\right| \times 100\,\%$$

O_t the order intake at time-period t

F_{t-1} the forecast made at time-period t-1 for time-period t

Two disadvantages can be mentioned when using this method:

- The amount of orders is not taken into account;
- It is not visible if the order intake is generally higher or lower than the forecast.

Because of these disadvantages, another method to measure the reliability is proposed, using the standard deviation of the forecast error:

$$\sigma = \sqrt{\frac{\sum_{i=1}^{n}(e_i - \bar{e})^2}{n-1}}$$

e_i (the order intake at time i – forecast at time i); this is the forecast error at time i;

$\bar{e}$ the structural forecast error, also mentioned as the bias. When this error is negative, the forecast will be higher than the actual order intake in general;

n the amount of periods that is included in the measurement.

To be able to compare the forecast reliability of the different products taking into account the order intake per end product, the variation coefficient is introduced. The variation coefficient can be defined as:

$$VC = \frac{\sigma}{\sum_{t=1}^{n} O_t \big/ n}$$

A guide-line to interpret the value of the variation coefficient is that when this value is below one, the forecast error can reasonably be absorbed by safety stock.

The forecast reliability of the sales offices as well as the forecast reliability of the configuration planning is measured with this method. The forecast of the sales offices contains considerable structural forecast errors; in general the forecast is higher than the order intake. The structural forecast error of the configuration planning is also measured to see if the structural forecast error of the sales offices is directly translated into this planning. When calculating the structural forecast error of the planning, this error is very small and varies around zero. This means that the forecast that is used for the configuration planning is already for the greater part corrected for this error.

Conclusions about the forecast made by the sales offices are:

- The forecast reliability at engine-level and per order flow (orders from Europe, USA and Asia) is important; measuring the reliability at a lower level is not very useful because these quantities are very small and difficult to forecast. Forecasting configuration items is not very useful either, because of the same reason. Only when growth-trends can be monitored, forecasting may be useful;
- The results of the measurement of the forecast reliability do not indicate that the forecast is very unreliable. But there is a bias in the forecast of the sales offices. When taking into account this bias, the reliability will improve;
- To measure the reliability of the forecast, the method of using the standard deviation is recommended. This approach will lead to better usage of the forecast as input for the planning and the method is more objective than the current method.

Logistics costs of a configuration item:
The logistics costs of offering a configuration item can be split up in four cost modules:

- Materials handling & storage;
- Inventory holding;
- Order processing;
- Transport

The reliability of the configuration matrix
The reliability of the configuration matrix is measured with the same method which is used to measure the forecast reliability of the sales offices. The forecast error can be caused by the configuration planning which is used as input for the configuration matrix as well as the configuration matrix itself. The results of the measurement show that the forecast error is caused by both factors. Two possibilities are available to continue this research area: absorbing the forecast error of the configuration matrix by safety stock or decreasing the forecast error of the configuration matrix itself by changing the functioning of the matrix.

The inventory control
The current inventory level is calculated. At this moment the lot sizing methods that are used to reorder the components are the Economic Order Quantity method and the Periodic Order Quantity method.
It is difficult to calculate what the safety stock should be at this moment because of four reasons:

- The forecast error is measured per month and has to be measured during the lead-time of a component;
- It is not known if the lead-time of a supplier is deterministic or stochastic;
- The service level of components is not known; because the end product is customer-specific and there is not a standard amount of configuration components that is used, it is not possible to calculate the service level is a mathematical way;
- The forecast error of the undershoot (the undershoot is the amount that the inventory level is below the order point when a new order is sent to the supplier) should be taken into account when calculating the safety stock.

Based on this analysis, the choice is made to focus on this last research direction. The forecast error of the configuration matrix should be absorbed by safety stock. When the functioning of the configuration matrix is changed, still an error exists, caused by the configuration planning. Safety stock will be needed whether the functioning of the matrix is changed or not. Of the logistics costs, the inventory costs will be taken into account.

Based on the analysis of the research directions, the final assignment is formulated:

> Analyze the current inventory control for configuration components with the focus on two aspects:
> - the order policy
> - the safety stock
>
> Determine the optimal order policy and the level of the safety stock per component with the purpose to minimize the inventory costs while taking into account the desired service level of 97.5% at end product level.

The goal of the project will be to determine the expected inventory level when the redesign is implemented and to determine the inventory value per component in this situation. Beside that, the service level at end product level is calculated when the redesign would be implemented and compared with the current service level.
Based on the logistics costs of offering a configuration component, a first-order-analysis will be made if it is remunerative not to offer certain components any longer.

Lot sizing method and safety stock formulas
Based on scholarly literature, another lot sizing method is proposed: the Silver-Meal heuristic. In comparison with the current methods, the Economic Order Quantity method and the Periodic Order Quantity method, the advantages of this heuristic are:

- This heuristic is designed for situations in which the demand pattern varies with time; this heuristic follows the dynamic demand of the configuration components;
- Based on performance analyses the Silver-Meal heuristic outperforms the Periodic Order Quantity and Economic Order Quantity methods;
- The Silver-Meal heuristic is less sensitive for variations in the holding and set-up costs than the other two methods.

The formula to calculate the lot size with the Silver-Meal heuristic is:

$$TRCUT(T) = \frac{TRC(T)}{T} = \frac{A + F(2)vr + 2\times F(3)vr + ... + (T-1)\times F(T)vr}{T}$$

TRCUT(T)	total relevant costs per unit time
TRC(T)	total relevant costs
v	unit variable cost of the component. This is the value of the component;
F	forecast of the component;
r	the carrying charge; Océ uses an r of 20% per year;
T	period;
A	fixed cost component, independent of the replenishment quantity.

The safety stock formulas, while taking into account the forecast error of the demand during the lead-time of the supplier, the forecast error of the undershoot and the variance of the lead-time of the supplier are:

$k\times\sigma_{fe,D_L+U} = k\times[(R+L)^{0,75}\sigma_{fe,D_1}]$ with deterministic lead-time;

$k\times\sigma_{fe,D_L+U} = k\times\left\{(E(R+L)^{0,75}\times\sigma_{fe,D_1,L\det})^2+\sigma^2[L]E^2[D_1]\right\}^{0,5}$ with stochastic lead-time

k	safety factor;
σ_{fe,D_L+U}	standard deviation of the forecast error of the demand during lead-time and of the undershoot;
R	review period
L	lead-time of the supplier
σ_{fe,D_1}	standard deviation of the forecast error of the demand during the forecast update interval

Results
First, the current situation is analyzed: the safety stock value according to SAP R/2 is not equal to (the inventory level – ½ Q). The conclusion can be drawn that a lot of safety time is included in the process.

In the current situation, the lot size value is lower than when the lot size is calculated with the Silver-Meal heuristic. This difference is caused by the minimum order quantity and packing quantity. When calculating the current lot size, these factors are not taken into account.
The safety stock value is calculated with different values for P_2. The literature does not provide a suitable method for determining the P_2-value at component level, so this value can only be determined empirically. The only restriction is that the value has to be higher than 97.5%,

otherwise it is not possible to achieve the required service level for the end products. The P_2-value is varied from 0.995% till 0.980%. The most appropriate situation is when the P_2-value is equal to 0.995. Because it is not known what the influence is of the corrective actions of the MRP-controllers, this is the safest situation.
A way to reduce the inventory value is not stocking any longer unique and expensive components belonging to the TDS800 which are reordered by Requirement Summary. The TDS800 has a lead-time of 28 days and the lead-time of the components included into the analysis, when reordered by Requirement Summary, is equal to 21 days. Not stocking these components would lead to a saving of X % of the total inventory value. Beside that, a few expensive and unique components for the TDS800 are not reordered by Requirement Summary. When this would change, these would not have to be stocked too anymore and this would lead to savings again. But when components are reordered by Requirement Summary, a commitment is given to the supplier that the supplier is allowed to stock raw materials or subassemblies to be able to shorten the lead-time of the component. A trade-off should be made between the savings that can be made when not stocking these components and the commitment that has to be given to the supplier.

Components that should be considered for not offering anymore are components with a low turnover and high logistics costs. When not offering these components anymore, this could lead to a saving of X % of all logistics costs per year. When the turnover of components is compared to the inventory value, this percentage could even be higher, because for a lot of components, the inventory value is higher than the turnover of the components.

Conclusions & recommendations
The main conclusions are:
- The standard deviation method should be used when measuring the forecast reliability;
- Another lot sizing method should be used, which better anticipates on the dynamic demand of the configuration components: the Silver-Meal heuristic;
- The safety stock should be calculated according to the safety stock formulas.

The main recommendations are:
- The redesign should be implemented in SAP R/3;
- The option of not stocking unique and expensiveTDS-800 components needs further investigation;
- The option of not offering all components anymore needs further investigation too;
- The service level at end product level should be measured; then the actions of the MRP-controllers can be quantified and it may be possible to lower the P_2-value which results in a lower safety stock value.

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Chapter 1 The assignment

This report is the result of the research of the inventory control of configuration components at Océ-Technologies B.V. in Venlo. This report represents the results of this research and the different stages that are completed to achieve the goal of the project.
In this first chapter, the assignment of this graduation project will be described. First, the motivation of the assignment is described in section 1.1. In section 1.2 the starting-point of the assignment is formulated. This assignment is defined based on the central question, which is also represented in this section. During the project, a final assignment is formulated and research questions, which need to be answered during the project, are drawn up. These are also described in section 1.2. In section 1.3, the approach of the assignment is explained. The structure of the report is based on this approach.

1.1 The motivation of the assignment

The supervisor of the assignment is the Logistics manager of the assembly unit Wide Format Printing Systems (WPFS) of Océ-Technologies B.V. In this unit, printers for the graphical market are assembled and sold to more than 80 countries worldwide. The printers are assembled-to-order in two stages. First, the basic part, the engine, is assembled. This engine is the input for the second stage: the configuration process. Printers are made customer-specific during this stage.
The scope of the assignment focuses on the inventory control of the components, which are used in the configuration process. At this moment, two factors give rise to the assignment:

1. The demand for printers strongly fluctuates per week and is difficult to forecast. As a consequence, this fluctuating demand can lead to large, unexpected orders, which cause a lot of variation in the assembly process. The difficulty of forecasting the demand and receiving unexpected large orders leads to uncertainty in the reordering of a right amount of configuration components;
2. Because the end product is customer-specific, the demand per configuration component may be very low. This makes it more difficult to forecast the amount of components that have to be replenished.

1.2 The assignment

Based on the interviews with the Logistics manager and the employees of the Logistics department, the central question is formulated:
"In what way does the inventory of the configuration components have to be controlled?"

WFPS would like to know if the components which are used during the configuration process, are controlled in an optimal way. The need exists to analyze the current inventory control and investigate if improvements are possible.
The starting-point of the assignment can be defined as follows:
Analyze the inventory control of the configuration components and define possible research areas. An improvement plan will be designed for one research area, based on scholarly methods.

After determining for which research area an improvement plan will be designed, the final assignment has been formulated:

Analyze the current inventory control for configuration components with the focus on two aspects:
- the order policy;
- the safety stock.

Determine the optimal lot sizing method and the level of the safety stock per component with the purpose to minimize the inventory costs while taking into account the desired service level of 97.5% at end product level.

Beside the fact that an optimal order policy will be determined and a method to calculate the safety stock will be offered, another goal of the project will be to determine the expected inventory level and the service level for the end products when the redesign is implemented and to determine the inventory value per component in this situation.
Based on the logistics costs that have to be made when offering configuration components, a first-order-analysis will be carried out if it is remunerative not to offer certain components any longer. The inventory value in the redesign will also be compared with the turnover of each component. The turn frequency is calculated. With turn frequency is meant the number of times the inventory in total is used per year. Based on the first-order-analysis and the turn frequency, a conclusion is drawn if all configuration components should still be offered.

1.3 The approach of the assignment

The approach of the assignment is based on 'Het Tien-Stappen-Plan' written by Kempen en Keizer [1]. This approach consists of three main stages: orientation stage, analysis stage and solution-oriented & implementation stage and each stage consists of several steps. The three main stages of this approach are followed during the assignment.
This approach is specifically developed for internships of students and provides a structure for the assignment. Not every step of this approach is exactly followed during this assignment. For example the last two steps mainly focus on the implementation of the redesign. In this report, guide-lines for the implementation will be given but the actual implementation has to be done by WFPS.
The structure of the report is also based on the approach of Kempen en Keizer. There is often referred to the three main stages in the report. The structure of the report will be represented now per chapter:

Chapter 1 functions as the introduction of the report. The motive of the assignment and the tentative assignment description will be provided in this chapter. Also, the demarcated assignment and the goal of the assignment are explained.
Chapter 2 and 3 are part of the orientation stage. In chapter 2 a company description is given to provide the reader with a background about the organization and the assembly unit WFPS. A description of the business process is provided in chapter 3. Special attention in this description is paid to the planning of the assembly and configuration center and the reordering of configuration components because these parts are most important for the assignment.

Chapter 4 functions as a transition between the orientation and analysis stage. In chapter 4 the research areas, related to the topic inventory control, are described which were noticed during the orientation stage. The demarcation of the project is provided and research questions, which will serve as a guide-line during the analysis stage, are drawn up. In this chapter, the tentative assignment is described too which will serve as a starting-point for the analysis of the research areas.

In chapter 5 the analysis stage is described. The research areas are further analyzed and conclusions are drawn about the influence of these directions. Then a proposal is made how to continue the assignment and the final assignment is formulated. Also, research questions are drawn up that need to be answered in the solution-oriented stage.

In chapter 6 theory about the current lot sizing methods is provided and a new lot sizing method is proposed. Further, theory about the safety stock is provided and a method to calculate the safety stock is formulated. The redesign is described in chapter 7 and assumptions that have to be made when calculating the new lot size and safety stock per component are discussed. In chapter 8, the financial results of the redesign are represented and compared with the current situation. Beside that, two options to reduce the inventory level, not stocking certain components and not offering some components are discussed. In chapter 9, conclusions are drawn and recommendations are given for the implementation of the redesign.
After the chapters, a literature review is provided and the appendices are shown. In appendix 1, a list with abbreviations, used in the report, is represented.

Chapter 2 Company description [2]

In this chapter, general information about Océ will be given to provide the reader with a background of the company. An organization structure is represented and the assembly unit WFPS, where the assignment is carried out, is described.

2.1 Vision of Océ

The head-office of Océ N.V. is located in Venlo. The company was founded here in 1877 and is active now in more than 80 countries, has own sales offices in more than 30 countries and employs about 22,000 people worldwide. The turnover in 2002 was 3,176 million euro which was a 1.8% decrease from 2001. Océ-Technologies B.V., founded in 1972, is a holding and has almost 4000 employees. The departments Research & Development (R&D) and Manufacturing and Logistics (M&L) belong to Océ-Technologies B.V.

The vision of Océ is:
"In the strategically relevant market segments Océ aims to be one of the top three suppliers of innovative and high-quality products and services for the printing and management of documents in professional environments".

2.2 Organization of Océ

Océ N.V. consists of several departments. The organization diagram is shown in appendix 2. The Strategic Business Units (SBU) belong to 'Group departments'. The SBU's determine the long-term strategy of the company and the different products. Beside that, the sales activities of the company are coordinated by the SBU's. The SBU WFPS is divided according to the different products this unit provides. Products are grouped into technical documentation systems, display graphics systems and software. See appendix 3 for the products WFPS provides. The Océ Operating Companies (OpCo's) are the sales offices of Océ, responsible for the sales in different countries. R&D Venlo belongs to Océ-Technologies B.V. and is responsible for the research and development of new products. M&L Venlo consists of industrialization, manufacturing, distributing and recycling of products for the repro-graphical market.

M&L Venlo consists of M&L Consumables, Logistics Service Parts, Asset Recovery, Imaging Supplies and M&L Machines. M&L Consumables produces strategic products (for example drums and toners). The department Logistics Service Parts purchases service parts and delivers them to service technicians, working for the OpCo's in different countries. Asset Recovery takes care of the recycling of products and paper is delivered by Imaging Supplies. M&L Machines purchases parts for the assembly and configuration and is responsible for the assembly, configuration and distribution of products.
M&L Machines consists of four assembly units: Digital Document Systems 1 (DDS-1), Digital Document Systems 2 (DDS-2), Wide Format Printing Systems (WFPS) and Remanufacturing. The structure of M&L Machines is product-oriented. Low and mid volume copiers/printers are assembled by DDS-1 and DDS-2. Printers for the graphical market are assembled by WFPS and in the unit Remanufacturing, products are repaired or provided with new parts. Each assembly unit consists of the same departments: Logistics, Manufacturing engineering and Quality assurance (MQ), Assembly and Configuration.

The assignment will be carried out in the Logistics department of WFPS. This department consists of two sub-departments: Inbound and Customer Service. Inbound makes sure that there is enough inventory of the assembly and configuration components. They also do the planning for the assembly. Customer Service is responsible for the delivery of orders and the inventory level of components in the configuration centers in Asia and the USA. These configuration centers will be further described in section 3.2. They also plan the orders for the configuration process and maintain the contact with the OpCo's.

Chapter 3 The business process

After the organization description in chapter 2, the business process will be described in this chapter. A graphical representation of this process is shown in figure 3.1.

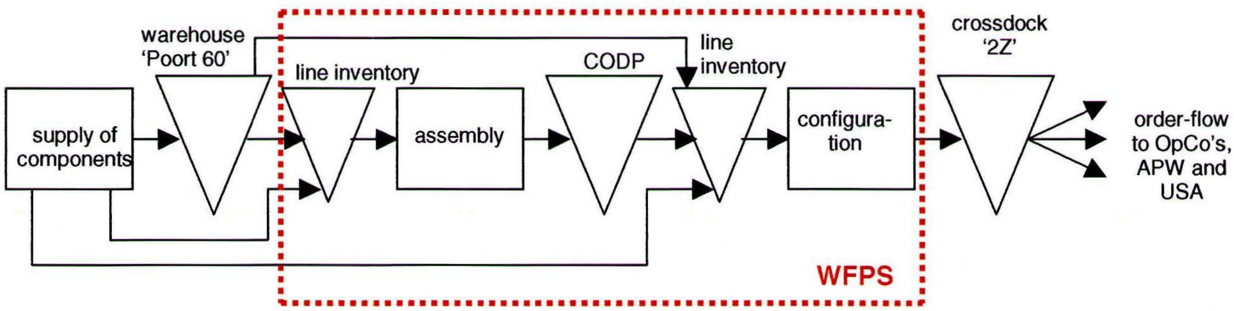

Figure 3.1 *Business process WFPS*

In section 3.1, the supply and transport of components and end products will be described. This is the first and the last part of the figure; from the supplier until the components arrive in the assembly or configuration center and from the configuration center to the OpCo's. Then, the order intake will be explained in section 3.2. After entering the order into the planning system, the product will (partly) be configured and finally delivered to the OpCo's and the configuration centers in Asia and the USA. In section 3.3 the assembly process will be explained. This is the part of the process between the red lines in figure 3.1. Successively, the assembly process, the Customer Order Decoupling Point (CODP) and the configuration process will be described. Finally, the production planning of the assembly and configuration and the reordering of configuration components will be discussed. These last two parts will get more attention because these parts are most important for the assignment.

3.1 Supply and transport of components and end products

At the start of the process, the components that are needed to assemble and configure the printers are reordered from suppliers. M&L Consumables, Imaging Supplies and Asset Recovery are internal suppliers. But most components are reordered from external suppliers. There are about 200-300 suppliers and about 85% of these suppliers deliver from Europe. Transportation of these components is either the responsibility of the supplier or of Océ, depending on the agreements between the supplier and Océ.
In general, the components arrive at 'Poort 60' (P60), a warehouse of Frans Maas Logistiek (FML), the logistics service provider of Océ. In urgent cases, the components can be delivered directly to the assembly or the configuration center. When the customer order is completed in the configuration center, it is transported by FML from the configuration center to 2Z, a cross dock from Océ where final products from DDS-1, DDS-2 and WFPS are collected. From 2Z, the order is transported to the OpCo's.
Almost all components are stocked in P60. In the line inventory, there are only enough components to fulfill the demand for the next few days. It is not possible to stock more components in the line inventory because of capacity constraints.
Large configuration components, like scanners, are not stocked at all in the configuration center. These components are transport from P60 to the configuration line when these components are needed.

3.2 Order intake

OpCo's order products from WFPS and the end-users order again their requested products from the OpCo's. So, WFPS does not have direct contact with end-users. Beside complete printers, an OpCo can require separate orders. A separate order consists of configuration parts like a scanner or folder or software. Most OpCo's make forecasts of the expected order intake for the next time-period, often 2 – 3 months.
The standard delivery time is the time that elapses between receiving an order by Customer Service and scanning the customer order in the warehouse 2Z. The transport time from 2Z to the OpCo is *not* included. The standard delivery times (in working-days) are represented in table 3.1.
The three main order flows, respectively to Europe, the USA and to Asia will be highlighted in subsections 3.1 – 3.3. For some printers, (a part of) the configuration does not take place in Venlo but in the USA or Asia. In appendix 4, an overview of the order flow to the USA and Asia is shown. Also, because the order flow to the USA consists of 50% of the turnover, special attention will be paid to these orders. The order flow to Europe receives special attention because the delivery to most OpCo's in Europe differs from the deliveries to other OpCo's. As a result, other delivery times are used.

Table 3.1 *Standard delivery times*

product	Europe/DMD	rest of the world
Océ 705X (7050/7055)	5 days	15 days
Océ 9300	5 days	15 days
Océ TDS400	10 days	15 days
Océ TDS600	10 days	15 days
Océ TDS800	20 days	20 days

3.2.1 Direct Machine Delivery (DMD)

The goal of DMD is to eliminate/reduce the local inventories and costs and to gain a better insight in the actual customer orders. The mission of DMD is to deliver configured machines, pré-installed, on customer order, directly to the end-customer (or via a cross-dock) within X days (see table 3.1), within a Standard Logistics Item Performance (SLIP) of 95%. The SLIP is defined as a logistics performance indicator for the number of configurations that has been delivered within the standard delivery time. Most OpCo's in Europe are delivered by DMD and function as a cross-dock.

3.2.2 Océ USA

The USA has different ways to distribute products. There is one OpCo, called Océ USA with four warehouses and a configuration center in Itasca. This configuration center has been established to shorten the lead-times to the USA. The configuration center in Itasca is not as extensive as the configuration center in Venlo. Which products are configured in this configuration center is shown in appendix 4. The inventory of Itasca is owned and controlled by WFPS Venlo. When the inventory is below a certain level, an amount of components is shipped to Itasca. These replenishments are based on forecasts of Océ USA. Océ USA reorders products that can be configured at Itasca from there. The other products are reordered from Venlo.

3.2.3 Asian Pacific Warehouse (APW)

APW was established 1.5 year ago. It delivers products to OpCo's in Asia and Australia and Direct Export countries. Direct Export countries do not have an OpCo, but dealers reorder products and sell them to end-users. APW is in a transition: more and more configuration tasks will be done by this configuration center.
The inventory at APW is controlled by the forecast of the OpCo's, the actual inventory and the actual customer orders. Every week, an update with orders is sent to Venlo. In this way, Venlo has a clear insight in the orders that will be required every week. The inventory is controlled by Venlo in consultation with APW.

3.3 Assembly and configuration process

The structure of the assembly and configuration process is represented in figure 3.2. According to Hoekstra and Romme, this situation can be defined as an assembly-to-order process [3].

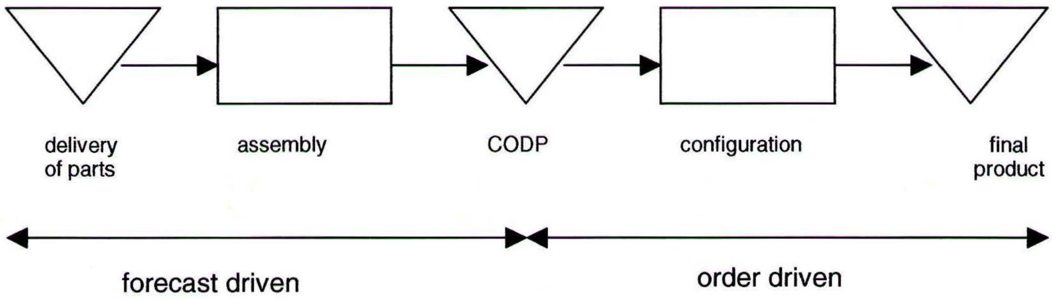

Figure 3.2 *Structure of the assembly-to-order process*

Successively, the assembly process, the Customer Order Decoupling Point (CODP) and the configuration process will be described.

3.3.1 The assembly process

The assembly consists of three product lines: the low volume (LV) line, the mid volume (MV) line and the high volume (HV) line. Assembled products are called engines. In table 3.2 information about the lines is represented. Variants of engines can be produced. This means that during the assembly the printer is already made power-specific (for example 230V versus 110V).

Table 3.2 *The assembly lines*

assembly line	engine	variants	amount assembled per week[1]	hours needed for assembling
LV-line	Océ 705X (7050 and 7055)	8	150	between 4 and 5 hours with 24 employees
	Océ 9300	4		
	Océ TDS400	4		
MV-line	Océ TDS600	1	25	9 hours with 11 employees
HV-line	Océ TDS800	1	4	38 hours with 10 employees

3.3.2 The CODP

After assembly, the engines are stocked. This inventory is the transition from forecast driven manufacturing to order driven manufacturing. The inventory is a buffer. Fluctuations in the demand for final products can be absorbed by the buffer and will not influence the assembly. Also fluctuations in delivery performance from the assembly to the configuration can be absorbed. The inventory level varies between one week and three weeks average demand for final products.

[1] These amounts are based on data in April 2003. During the year, the amounts may vary.

3.3.3 The configuration process
There are between 250 – 300 possible configurations a customer can order. The engine, made in the assembly, is just a part of the final product. Also several configuration items, like controllers, scanners and software can be needed to complete the product. In total, 500 – 600 configuration items are available to be used. These items are assembled in the configuration process. Each item consists of several components. One component can be used in more configuration items. Not all configuration items are available for every engine. See figure 3.3 for the structure of an end-product, based on the "hourglass" of Erens and Hegge [4]. The products are divided into product-families. The kind of engine that is used for the product determines to which product-family a product belongs. In a certain family, the customer can choose a certain configuration.

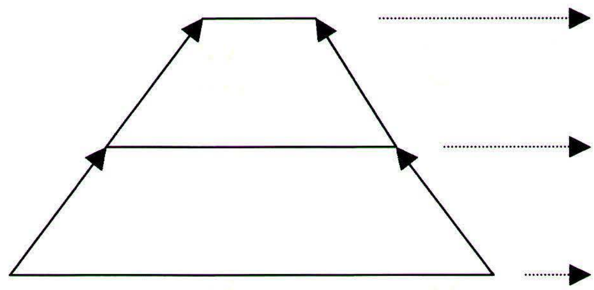

Figure 3.3 Levels in product structure

The configuration process is also an assembly process where the product is made customer-specific. The lead-time is about one day. The lead-time is relatively short because several configuration tasks can be carried out in parallel. At the end of the configuration process, all items of one customer order are collected and sent as one product to 2Z.

3.4 Planning

In this section, the logistics control structure will be described. The structure consists of several levels, as is shown in appendix 5. The actual planning system that is used, is SAP R/2, that is based on Materials Requirements Planning (MRP). MRP can be defined as: "determine when an end product has to be produced and calculate when semi-manufactured articles have to be produced and materials and components have to be reordered" [5]. In December 2003, SAP R/3 will be implemented. Only the planning that is used in the regular life of a product will be explained because this planning is relevant for the assignment.

3.4.1 Manufacturing and delivery plan
Every year, OpCo's provide a sales forecast for the next year. This forecast is made on product-family level. Based on these forecasts, a target for the amount of inventory is set and a placement budget is made for each OpCo. This budget will be converted into an amount of products that has to be delivered to the end-user by the OpCo. Based on this placement budget, the Strategic Business Unit will make a delivery plan for all products WPFS can deliver. The delivery plan changes during the year and influences the manufacturing plan. The placement budget does not change during the year.
Based on this delivery plan, a manufacturing plan is made every quarter with a duration of one year, divided into months. This plan is made by the planning group, consisting of employees of the SBU and the assembly unit WFPS. The actual inventory in Venlo, USA and APW, the pipeline inventory between Venlo and USA/APW, the order intake of last year, latest estimates from the OpCo's about the sales forecast and the capacity availability are taken into account. In the manufacturing plan, the amount of configured products that has to be delivered to OpCo's, is determined. This plan is made on assembly line level. No distinction is made between variants of an engine.

3.4.2 Configuration and assembly plan

The configuration plan is made, based on the first three months of the manufacturing plan, the decisions of the planning group, recent assembly and configuration, short-term forecasts of OpCo's and available capacity. This plan is divided into weeks for the first month. Based on the configuration plan and the configuration matrix (for explanation see 3.4.3) components are reordered from suppliers. The amount of products that will be configured per month is split into equal amounts per week, taking holidays into account. The amount reordered from suppliers is also equally divided. When the lead-time of a component is longer than 3 months, the reordering is based on the manufacturing plan and the configuration matrix.
The assembly planning is based on the manufacturing plan, the configuration planning, recent assembly and configuration, available capacity and decisions of the planning group. The duration is also 3 months and the plan is split into weeks. Both plans are updated every month.

3.4.3 The configuration matrix

The configuration matrix is a tool that is used to predict the expected sales volume of configuration items for next year. The forecast is *not* made at component level, but at the configuration-item level.
The consumption of the items during the last nine months is used as input for the matrix. A percentage is calculated, based on the consumption per item, related to the consumption of the end product the item is used for. Per item, a three-month average and nine-month average is calculated. Based on these averages and the consumption in the last months, the final percentage is determined. When the percentage is doubtful, the sales planner is consulted for further information. This percentage is multiplied with the expected sales according to the configuration plan to calculate the need for configuration items in the configuration center. This expected need is put into SAP. Based on the bill-of-material, the system calculates the needed amount of components. Monthly, a new percentage is calculated.

3.4.4 Detailed configuration and assembly planning

Weekly a planning is sent to assembly, based on the assembly planning, the configuration planning, the available capacity and the stock in the CODP. In this weekly assembly planning, the variants per engine that have to be assembled can be changed. Daily a planning based on actual customer orders and available capacity is made by Customer Service in consultation with the manager of the configuration center.

3.5 The order policy for configuration components

In this section, the current order policy for configuration components will be described. Because the assignment is focused on the configuration components, only these components will be taken into account. An order policy describes which components with a certain order frequency and in a certain order amount have to be reordered according to a certain order method. The description will be done according to the PBI-model of Bemelmans [6]. The P stands for 'Proces' (process), The B for 'Besturing' (control) and the I for 'Informatie' (information). The underlying idea is: not every control concept suits the structure of the process that has to be controlled. The 'B' needs to be adjusted to the 'P' and the 'I' is dependent on the 'P' and on the 'B'.

3.5.1 Order process

The order process can be described as all activities that take place in the supply chain from an external (or internal) supplier until the component is used in the configuration line. The supply of components to P60, the external order process, is already described in section 3.1. When the inventory level of a component in the configuration line drops below a certain level, called trigger, replenishment from P60 takes place. The level of the trigger depends on the average consumption of a component and the space available in the line. This is the internal order process.

3.5.2 Control

To control the reordering of components, MRP and the configuration matrix are used. The use of the configuration matrix is already explained in 3.4.3.
In the order policy, choices are made per component in the following five aspects:

- Contract: single order, single order with forecast (PLX) or a Requirement Summary (contract with forecast);
- Order frequency and order method;
- Logistics concept: delivery to P60 or to the configuration center. This last option is not used at WFPS in the regular delivery of components;
- Responsibility inventory: Océ or supplier is responsible. The components wherefore the supplier is responsible are left out of consideration in this assignment (see for more explanation section 4.3);
- Inventory control: control based on plan or actual usage.

The different contracts are described in subsection 3.5.3. In subsection 3.5.4 the inventory control is described and the order methods are explained in 3.5.5. In subsection 3.5.6 the “I” (information) of the PBI-model is described.

3.5.3 Single order, PLX and Requirement Summary

There are several ways the contact with the supplier is established.
When a component is reordered according to the single order method, there is no contract with the supplier. Single order is often used for components with a low order frequency and/or value. C-items are reordered according to this method.
PLX is an intermediate form between single order and Requirement Summary. The supplier receives forecasts about the amounts that may be reordered but WFPS is not obliged to reorder this amount of components. When the total purchase value is below € 8,000, PLX is considered, but this is also dependent on the order frequency. When SAP R/3 is implemented, PLX orders will not be used anymore.
When Requirement Summaries are used, a ‘commitment’ and a forecast are given to the supplier. This commitment means that a supplier is allowed to stock a certain amount of finished products and/or semi-manufactured products. WFPS is obliged to reorder a minimum amount of these products or has to pay a compensation when a smaller amount is reordered. Requirement Summaries are often used when the total purchase value is higher than € 8,000. Weekly, forecasts, deduced from the planning for the engines and calculated with the percentage from the configuration matrix, are provided to the supplier with a ‘frozen’ period, often 2 or 3 weeks. The forecasts provided to the supplier cover one year. In the frozen period, the orders cannot be changed anymore and this period can be seen as the lead-time of the component. The frozen period, the packing quantity and the minimum order quantity are recorded in the contract with the supplier. The components are delivered once a week to P60. Most A-items are reordered based on a Requirement Summary.
A special way of delivering components which are reordered by a Requirement Summary is Just-In-Time (JIT). The goal of JIT is defined by Silver, Pyke and Peterson [7] as: “ to remove all waste from the manufacturing environment, so that the right quantity of products are produced in the highest quality, at exactly the right time with zero inventory, zero lead time and no queues”. According to this definition, the way components are reordered at WFPS does not conform to the official ‘JIT’ approach. But because JIT is a common used term at WFPS, this term will also be used in this report. JIT can be seen as an additional step beside the Requirement Summary, by sending a call-of scheme to the supplier. In this scheme, the amount needed per day or a few days is shown. The supplier delivers the required amount on the indicated days. The purpose of JIT is to increase the flexibility and to lower the inventory level and used space.

3.5.4. Inventory control

Every week, a MRP-run is done and the consumed components are deducted from the inventory. The amount of consumed components is determined by the back flush; every day, the configured products are scanned and per component the consumption is calculated, based on the bill-of-material.
Cycle stock can be defined as the amount of inventory on hand at any point minus the safety stock. Safety stock (ss) is the amount of inventory, on the average, to allow for the uncertainty of demand and the uncertainty of supply in the short run [7]. When the inventory level is equal

to or below the safety stock level, the cycle stock has been consumed. Forecasted demand has to be delivered from the cycle stock, which is determined by the order quantity. The forecast is used to determine when the cycle stock will drop below zero, regarding the current inventory level. The expected deliveries are subtracted from the current inventory level. In this way, the expected date can be calculated on which the inventory will be equal or below the safety stock. At this time X, a new order should arrive.
The expected demand is calculated by SAP and when a Requirement Summary is concluded with the supplier, these forecasts are sent to this supplier. When a component has to arrive in week X and the current week is X – L (given a deterministic delivery time L of an order), a 'purchase requisition' is generated and the order is sent to the supplier. In a Requirement Summary, L is equal to the frozen period. So, the order point is the moment the purchase requisition is generated and the inventory position is at level s where level s is sufficient to fulfil the expected demand during the lead-time of the supplier.
The total delivery time L exists of:

- the delivery time (the time between reordering and the arrival at P60 or the configuration center)
- the time it takes to receive the order at P60 or the configuration center.

This way of control can be described as time-phased order point [8].

3.5.5 Order methods

There are three possibilities to reorder components, dependent on the order quantity and order frequency.

1. The order frequency is fixed but the order quantity (Q) is not fixed. The order quantity depends on the following factors: packing quantity, minimum order quantity and the order frequency. The packing quantity and minimum order quantity are determined in the Requirement Summary or in case of a single order, dependent on the supplier. The order frequency is determined by the lot sizing method Periodic Order Quantity (POQ). The method calculates the optimal frequency of reordering components. This frequency is calculated when a new component is used. Normally, this frequency is not changed anymore during the life cycle of the component. In subsection 6.1.2 more theoretical background about this method is provided. When the order frequency indicates that every three weeks components have to be reordered from the supplier, this means that the demand for the next three weeks has to be covered with the amount reordered. The order frequency varies between 1, 2, 4 or 8 weeks forecasted demand.
2. The order frequency is not fixed but the order quantity is fixed. The order quantity determines when the next order has to be delivered. Dependent on the demand in the next weeks, the system calculates the new order point. The order frequency varies and depends on the order quantity and the demand during the time-period. The order quantity is determined by the Economic Order Quantity (EOQ) method. When a new component will be used, the EOQ method is used to determine the optimal order quantity (Q). More information about the EOQ method is provided in subsection 6.1.1.
3. For some components, the order point is set by the MRP-controller. These components are used during testing a product. The amount of the component that is used cannot be calculated per product. The inventory level is determined by calculating the physical inventory and the open orders. If this level is lower than the order point, a certain amount is reordered until the inventory is equal to a determined level.

3.5.6 Information

To manage the supply process, the right information is needed. This information comes from MRP and 'Automatische Lijn Bevoorrading (ALB) and the configuration matrix. MRP calculates the needed parts in the future period. Based on the configuration matrix and the needed engines, the amount of configuration components that has to be reordered, is determined.
ALB is used to replenish the line inventory from P60: the internal replenishment process. This replenishment method is consumption-oriented. Every night a back flush is done and when the inventory level comes under the trigger, a replenishment from P60 takes place. A fixed quantity Q is reordered whenever the inventory position drops to the order point or lower. Large configuration components are not stocked at all in the configuration center, but are delivered from P60 during the configuration of a product by FML.

Chapter 4 Research areas

This chapter functions as the transition from the orientation stage to the analysis stage and will represent the research areas related to the assignment that were noticed during the orientation stage and which will be used as input for the next stage, the analysis stage.
The assignment at the start of the project was defined as:
Analyze the inventory control of the configuration components and define possible research areas. An improvement plan will be designed for one research area, based on scholarly methods.
Several issues influence the inventory control of the configuration components. These issues and the relation between these issues will be described. Based on the interviews with the employees of the Logistics and other departments, research areas are indicated. Section 4.1. provides the description and the research areas. Then, the demarcation of the project for the analysis stage is discussed in section 4.2. Research questions, that will provide guide-lines for the analysis, are drawn up in section 4.3.

4.1 Possible research areas

Several aspects influence the inventory control of the configuration components. A description will be given of the area inventory control.
Based on interviews with the employees of the Logistics and other departments, several research areas will be indicated which have to be investigated further.

4.1.1 Description of the area inventory control

The first aspect that influences the inventory control of the components is the forecast made by the OpCo's. This forecast is made at engine-level and used as input for the configuration planning. The idea exists that the forecast of the OpCo's is not reliable and the question exists in what way the forecast error made by the OpCo's is translated to the configuration planning. Large and unexpected orders of OpCo's may increase the forecast error.
The configuration planning is used again as input for the configuration matrix. This matrix calculates, based on the percentages of the matrix itself and the planning the expected amount of configuration components that will be needed. Because this matrix produces again a forecast, again a forecast error will be present. This error can be caused by two factors:

1) The configuration matrix itself, this means the percentages that are used, may cause an error;
2) The configuration planning may contain a forecast error.

In the current situation, the error which is caused by the configuration matrix is not known. The forecast error of the configuration planning as well the error of the matrix itself have never been calculated.
Based on the forecast of the configuration matrix, the configuration components are reordered based on the Economic Order Quantity and the Periodic Order Quantity. This forecast contains an error which needs to be absorbed by safety stock. In the current situation, the safety stock is fixed and based on two or three weeks average demand.
The idea exists that the inventory level is unbalanced: the inventory is too high or too low. This means that the order policy may not be correct and / or the way of determining the safety stock.
Beside an unbalanced inventory level, the question exists if it is necessary to offer that amount of configuration items. At this moment, about 600 configuration items are offered and the configuration matrix needs to calculate a forecast for each of these items. This last aspect is more focused on the marketing aspects, whereas the other aspects are more logistics issues.

Based the interviews during the orientation stage, five areas have been defined for further investigation:

- Forecast of the OpCo's;
- Configuration matrix;
- Inventory control;
- Large, unexpected orders;
- Logistics costs of a configuration item.

The main issues in these areas are already indicated in this subsection. For the sake of clarity, an explanation per issue will be given in the next subsections.

4.1.2 Forecast

The forecast of the OpCo's is regarded as unreliable. Especially, the forecast of Océ USA is considered very important, because this OpCo determines about 50% of the turnover, but this forecast is considered unreliable too. The reliability is measured but the relative reliability is measured instead of the absolute reliability of the OpCo's. The difference between the relative reliability and the absolute reliability will be further explained in subsection 5.1.1.

4.1.3 Configuration matrix

- To calculate the percentages of the configuration matrix, only historical information is taken into account. Information about the future that might be available already is not included in the calculation;
- It is not registered how many configuration items are used per engine. It is only visible how many configuration items in total are used;
- The question exists if the configuration matrix is a reliable tool to predict the sales of configuration items. The reliability has never been calculated.

4.1.4 Inventory control

- Inventory level: the idea exists that the inventory levels are unbalanced; too high or too low but the optimal level is not known;
- Engine-buffer: the inventory level of the engines varies between the one and three weeks demand. This demand is based on the total annual demand. The question is if the level of the engines should be the same for all assembly lines, taking into account the amount of engines assembled per week and the flexibility of the assembly lines;
- Safety stock: there is no unambiguous way to determine the safety stock for the configuration components. The guide-line is the level of the engine-buffer. Also, the relation between the MRP-controller and the supplier influences the amount of safety stock;
- Measurement of supplier reliability: the reliability of the supplier is measured per week. If an order arrives in the planned week, the reliability is 100%. This measurement is not very useful, because the configuration is planned per day. When a supplier delivers a day later than agreed upon, this can cause a work center stop or even a line stop;
- There is no differentiated way of reordering configuration components. Cheap or expensive, critical or non-critical components are treated in the same way; Océ uses the ABC-analysis, but this analysis has not been updated recently and is not valid anymore to classify the components;
- When determining the optimal order quantity, only the inventory costs are taken into account. Transportation costs are left out of consideration.

4.1.5 Large, unexpected orders

Large orders can lead to a bull-whip effect. This effect refers to an increasing variability of demand further upstream in the supply chain [7]. Large orders are often received from the USA and APW.

4.1.6 Logistics costs of a configuration item

When a certain configuration is offered, the profitability during the lifetime of the configuration is never checked. The profitability per configuration item is determined by the costs made to offer an item and the turnover of this item. A part of these costs are the logistics costs. At this moment, there is no insight in these costs. By gaining insight in these costs, WFPS aims to compose a list of items that should be reconsidered to be offered to the market.
When offering an item to the market, of course not only logistics costs play a role in determining if this item should still be offered or not. Marketing aspects will play a very important role too. A marketing aspect may be filling up a gap in the market by offering a certain configuration to the market. When offering a configuration item, a trade-off has to be made between the logistics costs and the marketing aspects. When not offering a configuration item to the market anymore, the logistics costs are not made anymore but the marketing consequences like loosing customers should be taken into account.

In appendix 6, a scheme is represented in which the relations between the research areas are shown. The research areas that are further investigated in the analysis stage are indicated with a red circle.

4.2 Demarcation of the project

In this section aspects that are not taken into account in the remainder of the project will be mentioned and the reason of the demarcation will be given. The aspects are:

- Projects are left out of consideration. Only configuration components in the regular phase of the life cycle are taken into account. In this phase, the situation is stable and history about the components is available. In the phases before and after the regular phase, the situation is much more unstable and more human intervention is needed with a lot of improvisation and judgment;
- Acquisition and software configuration components are left out of consideration. This is a special group of components and is treated differently than the other 'regular' configuration components;
- Components controlled by Vendor Managed Inventory: these components are not visible in SAP R/2 and the supplier is responsible for the inventory of these components;
- Assembly components; a research has been done to the order policy of these components recently;
- The engines are left out of consideration. Engines can be seen as configuration components but because they are assembled internally, other factors like the flexibility of the assembly line may influence the inventory level too;
- The marketing aspects when offering a configuration item are not taken into account. The assignment is carried out in the Logistics department of WFPS. This department is particularly interested in the logistics aspects. Beside that, the logistics costs are easier to quantify than the marketing aspects;
- The research direction 'the bull-whip' effect will be left out of consideration. Taking into account the time aspect and the amount of data that has to be collected to investigate the bull-whip effect thoroughly, the choice is made to focus on the other directions.

4.3 Research questions

The research questions that need to be answered during the analysis stage can be split up according to the research areas. The research questions are:

- Which order methods are used? This question is already answered in section 3.5.;
- What is the average inventory level? What is the inventory level when the safety stock is calculated, based on the forecast error caused by the configuration matrix?
- How reliable is the configuration matrix? The reliability of the 'process step' is measured, not the tool itself;
- How reliable is the forecast, made by OpCo's? What influence has the forecast on the reordering of configuration components?
- Which logistics costs are incurred to offer a configuration item?

The research questions will be answered in chapter 5.

Chapter 5 Analysis

In this chapter, the four research directions which are explained in chapter 4, will be further analyzed. The research directions can be split up into three logistics research directions and a more marketing-oriented research direction. First, the logistics research directions will be analyzed and the results will be quantified as much as possible. This is described in section 5.1 – 5.3. Then the more marketing-oriented research direction is analysed in section 5.4. When a research direction cannot be analyzed or quantified any further, the reason for this will be given and steps that need to be taken for a more in-depth analysis will be explained. Then, a proposal will be made which research direction will be most important. This proposal is described in section 5.5. For this research direction, a final assignment will be formulated in section 5.6.

5.1 The forecast error

At this moment, OpCo's send every time-period a forecast for the next X time-periods to Océ Venlo. This time-period is in most cases equal to one month and the forecasted time-period is 3 months. The forecast is made at product-family level. Some OpCo's also give forecasts for large configuration items like controllers or scanners. The forecast is an input for the configuration planning. The data of the configuration planning are then the input for the configuration matrix which calculates the expected amount of configuration items that will be required. Based on the amounts of configuration items that will be needed, the required amounts of components can be calculated. In this way, the forecast influences the reordering of configuration components.

5.1.1 Forecast reliability measurement at Océ

The forecast reliability is determined with the purpose to give an indication of the reliability of the forecast. The reliability is determined per end product and then the average is calculated per OpCo.

The forecast reliability measurement can be defined as: $1-\left|\frac{(O_t - F_{t-1})}{F_{t-1}}\right| \times 100\%$

O_t the order intake during time-period t

F_{t-1} the forecast made at the beginning of time-period t-1 for time-period t

This method has two disadvantages. First, the amount of orders is not taken into account. When an OpCo forecasts 2 TDS600 and orders 1, the forecast reliability is 50%, while the difference is only one product. Whereas when an OpCo forecasts 80 TDS600 and orders 40 TDS600, the forecast reliability is 50% too, but the forecast error will be larger. With this example is demonstrated that the forecast reliability cannot simply be compared. The relative reliability is the same but the absolute reliability differs. The second disadvantage is that it is not visible if the order intake is generally higher or lower than the forecast. Because it is not possible to draw conclusions about the forecast based on the method used by Océ, another approach is proposed.

5.1.2 Variability in the forecast error

There are several ways to calculate the variability in the forecast error. The forecast error can be defined as (the actual order intake – the forecast). The purpose of calculating the variability is to see if there is a large variability and if this is the case, to seek the underlying causes and take corrective actions.

The choice is made to calculate the variability by determining the standard deviation (σ) of the forecast error. There are two reasons to choose this method:

1. The standard deviation is used for setting the safety stock levels. The standard deviation for the engines cannot simply be used to calculate the safety stock because this forecast on engine-level is translated a few levels lower to component-level. During this translation, also adjustments and changes in this forecast take place, based on other factors. Beside that, this forecast does not include all OpCo's, because not every OpCo gives a forecast every month.
2. The variability of the forecast error of the configuration matrix will also be calculated, using the standard deviation, because these deviations can be used to calculate the safety stock. It is clearer to use one method to calculate the variability than using different approaches.

The standard deviation can be defined as [7]:

$$\sigma = \sqrt{\frac{\sum_{i=1}^{n}(e_i - \overline{e})^2}{n-1}}$$

e_i (the order intake at time i – forecast at time i); this is the forecast error at time i;
$\overline{e}$ the structural forecast error, also mentioned as the bias. When this error is negative, the forecast is structurally higher than the actual order intake;
n the amount of periods that is included in the measurement.

In this formula, the forecast error is corrected for the bias. The bias indicates that, on average, the forecast is substantially above or below the actual demand. As can be seen in table 5.1, the structural forecast error does not fluctuate around zero which indicates that there is a bias in the forecast error. Two choices can be made: calculating the standard deviation without correction or, as is done in the formula, first correcting the forecast error for the bias and then calculating the standard deviation for the corrected forecast error. This last option is chosen for two reasons:

1) Because the structural forecast error does not fluctuate around zero, this error should be taken into account when making the configuration planning. The forecast will be changed, based on the structural forecast error (the forecast will be changed to a higher or lower level, dependent on the value of the structural forecast error). This changed forecast will function as an input for the configuration planning. The planner will be interested in the standard deviation of the 'new' forecast error. This error is the forecast error, based on the forecast of the OpCo's minus the bias. This is a different approach of using the forecast than is done in the current situation;
2) The standard deviation of the forecast error for components will be used for calculating the safety stock. This forecast error is the result of the calculation of the configuration matrix. When the forecast of the OpCo's is not corrected for the structural forecast error and the actual forecast is used as input for the configuration planning, this would lead to unnecessary high levels of the safety stock when the structural forecast error is negative, as is shown in figure 5.1. If the structural forecast error is positive, the opposite will occur.

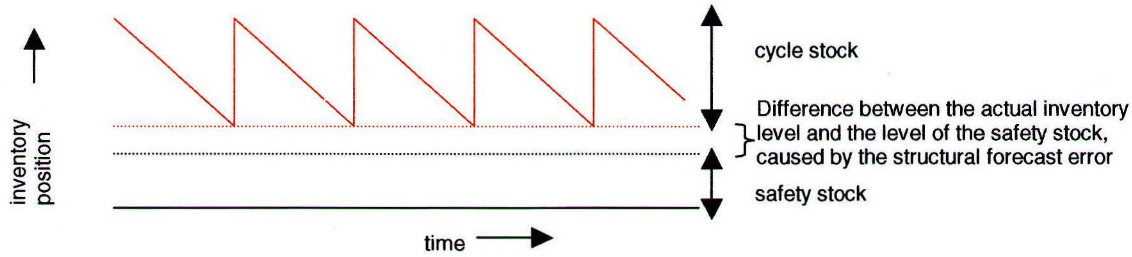

Figure 5.1 Inventory level without correcting the forecast of the OpCo's for the structural forecast error

As can be seen in this figure, the average level of the cycle stock is not the same as the 'normal' safety stock level at the moment a new order arrives. This leads to a higher inventory level than would be necessary. Because the structural forecast error would affect the configuration planning and the inventory level, the forecast of the OpCo's should first be corrected.

However, when calculating the standard deviation, the problem still exists that the order intake is not taken into account and the results are not comparable. That is why, after calculating the standard deviation, a variation coefficient (VC) is calculated. This variation coefficient is the standard deviation divided by the average order intake per month:

$$VC = \frac{\sigma}{\sum_{t=1}^{n} O_t \Big/ n}$$

By calculating this coefficient, the results can be compared. A guide-line to interpret the value of the variation coefficient is that when this value is below one, the forecast error can reasonably be absorbed by safety stock.

5.1.3 The results of the calculations

The forecast error can be calculated at different levels:

- the total forecast error per product-family;
- the forecast error per product-family, divided per order flow (DMD, Océ USA and APW);
- the forecast error per DMD-country and the forecast error per OpCo, delivered by APW.

The total forecast error per product-family is most important, because this forecast is used as input for the configuration planning. The forecast error per order flow will be calculated too to see if deviations are caused by a particular order flow.

The results at product-family level are shown in table 5.1. The forecast and the order intake were recorded over the time-period June 2002 – April 2003. The time-period used to calculate the standard deviation is one month. All forecast and order intake data are given in appendix 7.

Table 5.1 Standard deviation and variation coefficient of the forecast error on engine-level

product-family	total forecast	total order intake	structural forecast error	standard deviation	variation coefficient
9300	484	366	-10.72	14.74	0.44
705X	3079	2573	-46.00	50.98	0.22
TDS400	3193	2976	-19.45	57.37	0.21
TDS600	1428	1209	-19.91	27.29	0.25
TDS800	352	255	-8.81	9.05	0.39

Table 5.1 shows the results at the highest level: product-family level. The forecast error can also be calculated per order flow. The variation coefficient per order flow is important too, because not every order flow has the same influence on the configuration planning. The forecast of Océ USA always receives special attention, because this OpCo is responsible for 50% of the turnover. This forecast has a larger influence on the planning than for example the forecast of APW –OpCo's but the influence also depends on the subjectivity of the planning group. This is the reason why the forecast error per order flow is calculated too. These results are shown in appendix 8. Océ USA and APW do not give one forecast per product-family but a division is made. A forecast is made per 1- or 2-rolls printer and APW also makes a difference in the kind of power that will be needed (50 Hz or 60 Hz). These forecasts are taken together to be able to compare the results with the DMD-countries. Beside that, the configuration planning is only made at product-family level and does not take into account different variants of the engine.

5.1.4 The forecast of the configuration planning

As already indicated, the forecast that is made in the configuration planning is not the same as the forecast made by the OpCo's. Because the forecast of the configuration planning is used as input for the calculation of the configuration matrix, the forecast error of the configuration planning is calculated too. The same way of calculating is used. The results are shown in table 5.2. This forecast error is calculated per week, measured from week 49 in 2002 until week 31 in 2003. The order intake and forecasted amount per week is shown in appendix 9. Attention should be paid to the time-periods of table 5.1 and 5.2. These are not the same, so the results are not one-to-one related.

Table 5.2 Standard deviation and variation coefficient of the configuration planning

product-family	total forecast	total order intake	structural forecast error	standard deviation	variation coefficient
9300	375	401	0.76	5.81	0.49
705X	2160	2085	-2.20	16.44	0.27
TDS400	2195	2159	-1.06	14.01	0.22
TDS600	929	934	0.15	8.96	0.33
TDS800	154	127	-0.79	2.28	0.61

To compare the data in table 5.2 and table 5.1 the structural forecast error in table 5.2 has to be multiplied with 4 to be able to compare the values with the structural forecast errors in table 5.1. To be able to compare the standard deviations, the standard deviation of table 5.2. has to be multiplied with $\sqrt{4}$ (=2). When this is done, the conclusion can be drawn that the structural forecast error and the standard deviation of the configuration planning are lower. The planning group already functions as a filter and corrects the forecast for the structural forecast error.

5.1.5 Conclusions & recommendations

In this subsection, three aspects will be mentioned. At first, the level at which forecasts are made by the OpCo's, will be evaluated and a recommendation will be made. In the second place the results of the forecast reliability of the OpCo's will be discussed and compared with the results of the configuration planning. At last, a proposal for determining the forecast reliability will be made. In this subsection the assumption is made that the forecast is only used to give expectations about the amount of products that will be reordered. The forecast can also be used for other aspects, like replenishments for APW, but this is not taken into account.

Level of the forecast

Only the forecasts on product-family level and per order flow are analyzed. Most OpCo's send forecasts to Océ but not every forecast is evaluated in the analysis. The total forecast is important and is used as input for the configuration planning and not the separate forecasts. Beside that, often the forecasted amount of a product is small. Smaller amounts are more difficult to forecast and the probability of a more unreliable forecast will be higher.
Some OpCo's, especially the OpCo's delivered by APW, give forecasts on variant level. It is questionable if forecasting variants is useful if the forecast is only used for forecasting the order intake, when the amounts of products are taken into account. These amounts are very small and difficult to forecast. One level higher, the product-family level, it will be easier to forecast the amounts more accurately. If Océ Venlo expects that the amounts will grow in the future, the forecasts can be useful to monitor the growth-trend. The forecasting of configuration items that are reordered in small amounts is not very useful either. The reliability of these forecasts can be questioned and the usefulness of these forecasts is low. The same advice applies in this case: The growth-trend can be monitored by expected increasing demand.

Results of the forecast variability
As can be seen in table 5.1, the standard deviation cannot simply be compared. The variation coefficient gives a more realistic view of the reliability among different products. These coefficients are not extremely high and fluctuate around 0,35. When the results of the different order flows are evaluated, the variation coefficient fluctuates around one (see appendix 8). These data do not give an immediate reason to conclude that the forecast is unreliable.
The structural forecast error does not fluctuate around zero, an assumption that is often made in literature. The structural forecast error is in all measurements, in the total order flow as well as in the separate order flows, negative. This means a structurally higher forecast than actual order intake. The deviation is not caused by one order flow, but all flows give higher forecasts than they actually realize. Especially for the 705X, the structural error deviates largely from zero. This means that when the forecast will be used directly for the configuration planning, the planning will be too high and too many components will be reordered, which finally will result in higher inventory levels than needed. This is shown in figure 5.1.
But the forecast of the OpCo's is only one part of the input for the configuration planning. The history of the order intake and information of the SBU is also used to do the configuration planning. As can be seen in table 5.2 the structural forecast error of the configuration planning is lower than the structural forecast error of the OpCo's and fluctuates around zero. This means that the forecast which is used for the configuration planning is more realistic than the forecasts made by the OpCo's and, on average, is not lower or higher than the actual demand. The structural forecast error of the OpCo's is already taken into account. But to make the measurement more objective and to better anticipate on the results of the measurement, a new proposal is made.

Proposal for the measurement of the forecast
Because the structural forecast error does not fluctuate around zero, this error should be taken into account when making the configuration planning. The structural forecast error, if this error is negative, should be subtracted from the total forecast. If the structural forecast error is positive, the amount has to be added to the total forecast. This corrected forecast has to be used as input for the configuration planning.
To measure the variability of the forecast, the method described in section 5.1.2 is recommended. When the structural forecast error, based on a time-period for a year, is measured every month and the correction of the forecast takes place, the planner will be interested in the standard deviation of the *corrected* forecast error instead of the standard deviation of the actual forecast error. This measurement should be done once a month to monitor the forecast variability and to notice possible trends in the variability.
A marginal note has to be made when using this approach. In the current situation, the forecast error is almost in all months negative and it is justified to correct the forecast. When there is a lot of variation in the forecast error, it may not be advisable to 'just' subtract the structural forecast error. Human judgment is still needed.
This new approach will lead to better usage of the forecast as input for the planning. The adjustment of the forecast can be done *on a more objective basis* than is the case in the current situation. Beside that, the approach gives a better indication which corrective actions need to be taken. Because of the expected results of this approach, it is not necessary to investigate this research direction more thoroughly.
There is a second reason why it would not be very useful to pay more attention to this research direction in the remainder of the project. When SAP R/3 will be implemented the forecast procedure is changed. Forecasts will be made in SAP R/3 and sent to the OpCo's. If they do not agree, the forecast will be adapted in consultation with the OpCo's. The proposal is also useful when the forecast procedure will change.

5.2 The reliability of the configuration matrix

The second research direction is the reliability of the configuration matrix. The reliability of the configuration matrix is measured and the results are shown in appendix 10. In this measurement, the configuration matrix is considered as a step in the process with the goal to determine the amount of components that have to be reordered. The focus will be on the total forecast error that is the output of the configuration matrix, not on the part of the error that is caused by the percentages of the matrix.

5.2.1 Method to calculate the reliability

The method to calculate the forecast reliability of the OpCo's is also used to calculate the reliability of the configuration matrix with one exception. When calculating the standard deviation, the bias is taken into account too. The *total* forecast error, including the bias, has to be absorbed by safety stock. The way of selecting the components that have to be taken into account and the exact way of calculating the reliability of the configuration matrix is described in appendix 11.

5.2.2 Results of the calculation

In appendix 10, the results of the forecast error of the configuration matrix are shown. In this table, the following data are shown: the structural forecast error, the structural forecast error with actual configuration (is equal to the structural forecast error caused by the configuration matrix) the structural forecast error caused by the configuration planning, the average usage per month, the standard deviation of the forecast error and the variation coefficient. As already explained in subsection 4.1.1, the forecast error of the configuration matrix can be caused by two factors: the configuration planning or the configuration matrix itself. That is why the forecast error is calculated twice. In the first calculation, the forecasted amount of engines is used to calculate the expected needed amount of components. The result is the *total* structural forecast error. In the second calculation, the actual amount of engines that is configured is used and the expected needed amount of components is calculated based on these 'actual' data. The result is the structural forecast error caused by the configuration matrix. Both results can be compared to determine the forecast error caused by the configuration planning.
To explain the calculation, the first row of data in appendix 10 is used as an example. The structural forecast error when using the forecasted amount of engines is -446,77. The structural forecast error when using the actual amount is -401,32. The difference is 45,45 and is caused by the configuration planning. This part of the forecast error that is caused by the configuration planning is shown in the appendix too. The 401,32 is caused by the configuration matrix. Because of capacity constraints, only the structural forecast errors are represented in the appendix.

The results show that the configuration planning as well as the configuration matrix itself cause forecast errors. In section 5.1, the forecast error of the forecast made by the OpCo's is calculated and another method to measure the forecast is proposed. This measurement can also be used to measure the forecast error of the configuration matrix while taking into account the bias.
It is not possible to draw conclusions about the functioning of the configuration matrix. Only results *per component* are shown in appendix 10. These results cannot be translated to a higher level because the results differ per component. The error caused by the configuration planning can be larger than the error caused by the configuration matrix itself or vice versa. When the results are evaluated the focus is on the total forecast error and what actions have to be taken to reduce the impact of this error on the reordering of components. If no actions are taken, this will result in stock-outs if there is more used than forecasted or higher inventory levels than needed if more is forecasted. The total forecast error of the configuration matrix, the error caused by the planning as well as the error caused by the matrix, should be absorbed by safety stock. The topic safety stock will be described in section 5.3.
Two options are available to continue this research direction: changing the functioning of the configuration matrix or absorbing the forecast error by safety stock.

5.3 Actual and expected inventory level

Several aspects related to the research direction inventory control were mentioned in subsection 4.1.4. These where related to the following aspects: inventory level, the engine-buffer, the safety stock, the measurement of the reliability of a supplier, the reordering of configuration components and the determination of the lot size. Not all aspects will get attention in this section. The engine-buffer is left out of the scope of this project and the reordering of configuration components and the determining of the lot size in the current situation has been described in section 3.5. This section will mainly focus on the expected inventory level, the safety stock and which aspects should be taken into account when calculating the safety stock level.

5.3.1 Inventory level

In general the average inventory level is the safety stock (ss) and the average cycle stock (½Q). The inventory level of a component follows a path that can be represented as a saw tooth. The path is shown in figure 5.2. In reality, the demand is not linear and the forecast is not unbiased as this figure would suggest. But this figure is only meant to give an idea of the inventory level.

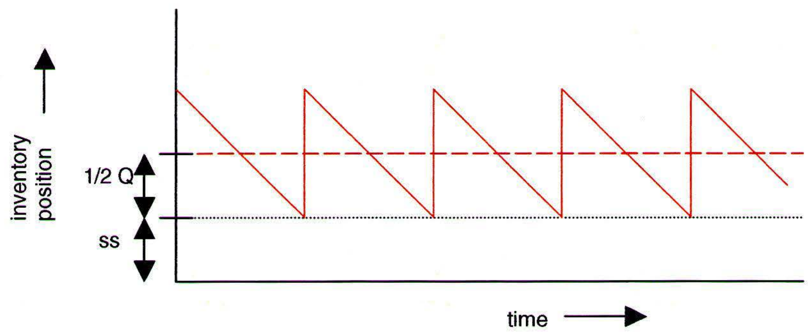

Figure 5.2 The inventory position of a component in time

5.3.2 Calculation of the actual inventory level

To determine if the inventory levels are higher than necessary, the actual average inventory level has to be compared with the expected average inventory level when using the current lot sizing methods. The actual average inventory level is calculated based on the inventory levels of the last seven months (January 2003 – July 2003). The results of the actual inventory level per component are shown in appendix 12. The current safety stock per component, as this is registered in SAP R/2 is mentioned in this appendix too. On average, the inventory value (defined as the amount of stock multiplied by the standard purchase price) is about k€ 2,642 where k€ is equal to €1000. Of course, the inventory level is not constant. The inventory level fluctuates per month. The inventory level of January 2003 – July 2003 is shown in appendix 13.

To compare the actual inventory level with the expected inventory level, the expected average Q has to be determined and compared with the current average Q. Because data of the exact lot sizes that were reordered in the past are not available the current Q is determined by { ½ × (actual inventory level – safety stock)}. The results are shown in appendix 12 in the column 'current average lot size'. The calculation of the expected average Q will be explained in section 5.3.3. The safety stock that is needed in the current situation has to be calculated based on scientific methods. This will be described in section 5.3.4.

5.3.3 Determining the expected average lot size in the current situation

The expected average lot size has to be determined to be able to calculate the expected average inventory level in the current situation. The lot size has to be calculated based on the average annual demand and the order condition. The order condition determines the order quantity. There are several order conditions for the components which are included in this project:

E = a fixed order quantity is reordered;
A = the expected need for a week is reordered;
X = the expected need for two weeks is reordered;
Y = the expected need for four weeks is reordered;
Z = the expected need for eight weeks is reordered.
The underlying idea is the EOQ- and the POQ-method. More information about these lot sizing methods are provided in subsection 6.1.1 and 6.1.2. The order condition is determined when the contract is made. In practice, the order condition is not strictly used. When an order needs to be delivered earlier or later or the expected need changes, the MRP-controller reacts on these changes. The order condition functions more as a guide-line.
Based on the order condition and the annual demand, the expected average Q can be calculated. The results are shown in appendix 12.

As can be seen in this appendix, the expected average lot size is lower than current lot size when using the current lot sizing methods. This leads to a lower expected inventory level than the actual level if the safety stock is kept the same. Several aspects cause this. The supplier can decide that there has to be reordered a minimum quantity, which is in contrary with the order condition. Also, the order quantity has to be rounded up to a packing quantity. The minimum order quantity as well as the packing quantity can be significantly larger than the needed quantity. Reordering larger quantities than needed can also be the result of agreements about discounts between the department Purchasing and the supplier. Beside this, some suppliers are very unreliable which leads to a higher inventory, just to be sure that components will be available. To be sure of this, a lot of safety time is included in the reordering process. This higher level is not included in the 'official' safety stock. At last, because of the ever-changing expected need, the order conditions cannot strictly be used. When the expectations are higher than the actual demand, this can lead to higher inventory. Because the 'ideal' safety stock is not known (see 5.3.4) it is not possible to express the expected average inventory level in euro and to compare this with the current situation at this moment.
All these aspects cannot be taken into account when calculating the expected average inventory level, which causes the differences in the levels.

5.3.4 Safety stock

An order is placed when the inventory level is the same as the safety stock level and the expected demand during the lead-time of the component. The reason for keeping safety stock is to protect against uncertainties.
As already described in 4.1.4, there is no structured way at Océ to determine the level of the safety stock. The theoretical standard formula for calculating the safety stock is [7]:

$$ss = k \times \sigma_{L+R,FE},$$

k	safety factor;
L	deterministic lead-time;
R	review-period (equal to one week);
$\sigma_{L+R,fe}$	standard deviation of the forecast errors (fe) of total demand over a period of duration L + R.

Special attention has to be given to the standard deviation. The standard deviation of the *forecast error* has to be measured instead of the standard deviation of the actual demand. Only when the average of the demand is known and constant, the standard deviation of the forecast error can be replaced by the standard deviation of the demand. This is not the case in this situation. The standard deviation of the forecast errors has to be used.

There are four reasons why it is not possible 'just' to use this formula. These reasons will successively be discussed:

The lead-time of the component
The formula is valid when the lead-time of a component is deterministic. At this moment it is not known per component if the lead-time is stochastic or deterministic.

Calculation of the k-factor
The safety factor k can be determined based on the measure for the customer service. The used measure at WFPS is the P_2 –value: the fill-rate. The fill-rate can be defined as the fraction of customer demand that is met routinely, without backorders or lost sales [7]. The fill-rate for a configured product is 97.5%. This value has to be translated to a value for the configuration components. But there is not an easy way to translate this value to component level. The problem is that not every configured product consists of the same components. If for every configuration, the same amount and the same components were used, the P_2 –value could be translated to component level based on the formula: $x^n = 97.5\%$. The variable x would then be the P_2 –value on component level and n is the amount of components. But because n is not a constant value, this formula contains two variables and x can only be determined empirically. Beside this, the service level at component level does not have to be equal for each component but may vary. At this point, the only conclusion that can be drawn is that the P_2-value has to be higher than 97.5%.

The undershoot
In figure 5.2, the assumption is made that a lot size is reordered at the moment that the inventory level is exactly the same as the order point. But a MRP-run is done only once a week and at that moment the inventory level is compared with the order point. In this case it is possible that the inventory level drops below the order point between two review-moments. The amount below the order point is defined as the undershoot [7]. When calculating the safety stock, the undershoot has to be taken into account.

The forecast update interval
The standard deviation of the forecast errors is measured over the lead-time of the components in the formula. But in the current situation the lead-time is not the forecast update interval. A conversion has to take place to be able to use the standard deviation over the forecast update interval.

Because of these four aspects, it is difficult to calculate the required safety stock level at this moment. To calculate the safety stock, further research is necessary.

These first three research directions were all related to logistics aspects. The last research direction is more focused on marketing issues. Anyway, because the assignment is carried out in the Logistics department, the focus is on the logistics aspects of this research direction. But, as already indicated in subsection 4.1.6, marketing aspects should not be neglected when offering certain configuration items to the market.

5.4 The logistics costs of offering a configuration item

To make a product customer-specific, several configuration items are needed. During the development of a product, decisions are made about which configuration items will be offered in combination with this product. To offer the customer the possibility of buying a certain configuration, several costs have to be made to be able to assemble this configuration. These costs are made at component level but the decision which configurations are offered to the market is made at item level.

5.4.1 The framework

To determine the logistics costs of offering a configuration item, a framework, developed by R. Luykx [9] is used as a guide-line. This framework will represent the costs-to-serve. These costs can be defined as the sum of the costs that are made throughout the whole supply chain to serve the customer by offering the required products and service, in this case the required configuration item. The logistics costs from the point the required components are transported to P60 until the configuration item is assembled in the configuration line are taken into account. The framework consists of four cost modules with their contents.

The cost modules are:

- materials handling & storage costs;
- inventory holding costs
- order processing costs;
- transport costs.

Not all costs are known exactly per cost module. Sometimes assumptions have to be made. In appendix 14, a sensitivity analysis is carried out to give an indication of the costs when the assumptions are changed.
In subsection 5.4.2 the difference between the costs for configuration and assembly components is discussed and several assumptions are made. In section 5.4.3 estimations of the costs are given per cost module. In section 5.4.4. a table with the total costs per cost module is shown.

5.4.2 The difference between costs for assembly and configuration components

There is not made a difference between assembly and configuration components for every cost module in the cost reports. Some costs are reported at aggregate level and only the total costs for all components are known. This is the case for the cost module transport and the materials handling costs. To give an indication of the transport costs and the materials handling costs for the configuration components, an estimation has to be made. The total amount of assembly components that is reordered by WFPS is about 2500. The amount of configuration components is about 700; 80 of them are large configuration components. Large configuration components have higher materials handling costs. This is because of the fact that they cannot be stored on a standard pallet and the handling activities demand more capacity than the 'normal' configuration components. The materials handling costs are reported separately for large configuration components. Because of this separate reporting, the assumption that in this cost module 'normal' configuration components can be treated the same as assembly components seems justified.
Transport costs are only known at aggregate level; no distinction is made between large and 'normal' configuration components. The transport costs for configuration components are in general higher than for assembly components, but the frequency of transport for assembly components is higher. This is based on the way configuration and assembly components are reordered. Most configuration components are reordered on 'single order' and are delivered a few times a year. On the contrary, Requirement Summaries are more often used for assembly components, which means that the need for one week is reordered. In general, this will lead to more frequent deliveries. Therefore, the assumption is made that the transport costs for assembly and configuration components are equal.

Per cost module, an estimation of the costs is given. The time-period will be one month. To avoid 'extreme' values by taking a 'high-flyer', the value per month will be the average of several months, dependent on the availability of data. When the costs are reported separately for large and normal configuration components, these will be represented separately; otherwise the costs for all configuration components are given. Per cost module, the costs will be indicated as variable costs or sunk costs. Variable costs are directly influenced by the amount of components that are offered; sunk costs are not influenced on the short-term by the amount of components that are offered.
When the cost module can be split up into several activities, these are shown in appendix 15. In this chapter, only the total costs are mentioned.

5.4.3 Materials handling & storage[2]

The first cost module, materials handling & storage, consists of two aspects: the materials handling costs and the storage costs. Materials handling costs consist of goods-in costs (receiving components at P60 and in the configuration line) and goods-out costs (picking and packing, customization activities). Storage costs consist of location management costs: the overhead costs charged by FML. Materials handling costs are variable costs and the storage costs are sunk costs. The materials handling costs are equal to k€ 23.5 and the storage costs are equal to k€ 18.7. The total costs for this cost module are k€ 42.2.

2 2 The costs that are given in the next sections are based on the reports of the department Controlling

In appendix 15, the costs of this cost module are split up per activity. Pay attention to the fact that the actual storage costs are calculated in the cost module inventory holding. The storage costs is this module indicate the sunk costs.

5.4.4 Inventory holding

The second cost module is the module inventory holding. This module consists of the part warehouse inventory costs and the pipeline inventory costs. The pipeline can be defined as the physical goods flow between a sending and receiving organization [10].This last part is not taken into account by Océ. In this analysis, these costs are left out of consideration too. As already described in section 3.1, about 85% of the suppliers delivers from Europe and the delivery times are at most a few days. In comparison with the warehouse inventory, about 7 weeks safety stock per component (see section 10.1), these few days inventory are negligible.

The inventory costs are calculated by using the value of the inventory and a percentage that covers the three R's: 'rente' (interest costs), 'ruimte' (space) and 'risico' (obsolescence costs). This percentage is defined at management level at 20% per year. The inventory costs can be defined as: inventory value (number of products x standard price) x 20% x time-period (expressed in years). This 20% will be used to calculate the inventory costs. However, a marginal note can be made about the correctness of this percentage. Because of price erosion and a relative high possibility of components becoming obsolete, this percentage may be higher in reality. For example, the percentage for assembly components will probably be higher than for configuration components. After all, more product changes take place in the assembly process and the possibility that components become obsolete is higher. Also, when products will not be assembled anymore, the MRP-controller gives special attention to the configuration components because the configured sub-assemblies are relatively expensive. Despite these considerations, the calculations will be based on the current percentage. In appendix 14, the percentage is changed and the influence on the inventory costs is shown. The average inventory costs of configuration components are k€ 154.3[3]. These costs are variable costs because they are directly influenced by the amount of components that is offered.

5.4.5 Order processing

The data of the third cost module 'order processing', the salary costs of MRP-controllers, are confidential. Anyway, an estimation is made to give an indication of these costs. The annual salary is assumed to be k€ 50. The monthly costs are k€ 16.7 if four MRP-controllers are employed. These MRP-controllers do not only reorder configuration components, but also assembly components. Because the amount of assembly components is about four times the amount of configuration components, not offering certain configuration components any longer will not directly lead to a saving on employees. Because of this reason, these costs are sunk costs on the short-term. Although the system costs could also be included into this cost module it will be considered as part of the cost module materials handling & storage in this analysis as is done already by Océ.

5.4.6 Transport

The fourth cost module, 'transport', consists of transport costs from the supplier to P60 and from P60 to WFPS.

The transport costs from the supplier to Océ are only known for M&L in total. M&L consists of four units, of which one unit is a small unit. Beside that, another unit does not have a lot of configuration components. Because of these facts, the assumption is made that the transport costs can be divided by three to determine the transport costs from the supplier to P60 for WFPS. In that case, the total transport costs for configuration components are k€ 34.2[4]. These costs are variable costs.

[3] These costs are based on the months December 2002 – July 2003

[4] These costs are based on the costs made in 2002

5.4.7 Total costs and conclusions

In table 5.3, the total costs are represented. Per cost module the costs are split up into variable costs and sunk costs. Only the costs in the column 'variable costs' are relevant when certain configuration components are considered for not being offered any longer.

Table 5.3 Costs per cost module in the current situation

cost module	costs per month	variable costs	sunk costs
materials handling & storage	k€ 42.2	k€ 23.5	k€ 18.7
inventory holding	k€ 154.3	k€ 154.3	
order processing	k€ 16.7		k€ 16.7
transport	k€ 34.2	k€ 34.2	
total	**k€ 247.4**		

When the results of the sensitivity analysis, carried out in appendix 14, are evaluated, the conclusion can be drawn that the assumptions influence the total costs. It is important to be sure of the costs and the validity of the assumptions. At this moment, exact information about the costs is not available, so the results in this chapter will be used in the remainder of the report.

Based on this framework, the logistics costs can be determined. There are between 500 and 600 configuration items and the translation in costs from component level to item level has to take place before the costs can be determined. It is not possible to determine all these costs for each component separately. This is very time-consuming and probably the different costs are not known per component. The best way to determine the costs would be to divide the configuration items into categories. These categories could be based on variables, like value or dimensions. To define the categories, further research is necessary. But defining categories will not receive more attention in this project because other aspects are more important and the revenues on short-term will be higher.

5.5 Conclusion

In this section, a conclusion will be drawn which research direction is most important and a proposal will be made for the continuation of the assignment.

The most important research direction, which also relates to the yet unsolved research direction 'the reliability of the configuration matrix' and the direction 'the logistics costs of offering a configuration item' is the inventory control. This direction consists of two parts: the order policy and the safety stock. As already mentioned, both parts need to be investigated further. The reliability of the configuration matrix influences this direction, because the forecast error, caused by the configuration matrix, needs to be absorbed by the safety stock. This indicates that the last option that is proposed in 5.2.2 is chosen for dealing with the forecast error of the configuration matrix. There are two reasons why this option is chosen and not the option of changing the configuration matrix in such a way that the forecast error caused by the matrix will decrease. When forecasting the demand of components, a forecast error will always occur and has to be absorbed. When the forecasting method of the configuration matrix will be changed, still a forecast error exists, caused by the configuration planning and this error needs to be absorbed by safety stock. Because of time-constraints it is not possible to analyze both directions. Because the method of determining the safety stock is also useful when the forecasting method of the matrix will be changed, this direction receives priority. Beside that, the revenues on short term will be higher when redesigning the order policy and the safety stock. A part of the logistics costs is taken into account, namely the inventory costs. In the current lot sizing methods, the focus is only on the inventory costs. But because the demand for configuration components is time-varying, the current lot sizing methods may not appropriate anymore. When proposing another lot sizing method, the focus will be on the inventory costs too. Based on the analysis in section 5.4, the inventory costs are the largest part of the logistics costs, so it seems justified to mainly focus on these costs. But the influence on the other costs, when proposing another lot sizing method, should not be neglected. When the other lot sizing method will be implemented, the ratio between the inventory costs, transport costs and material handling & storage costs may change. For example when the average lot size will be halved, the transport costs will almost double and the materials handling & storage costs will also increase. When implementing the other lot sizing method, these effects have to be taken into account.

In the next section, the final assignment will be defined, specifically focused on this research direction and the final goal of the assignment will be described. Also, research questions for this research direction will be drawn up which need to be answered in the remainder of this project.

5.6 The assignment

5.6.1 Assignment description and restrictions

Based on the conclusion in section 5.5 the assignment can be defined as follows:

Analyze the current inventory control for configuration components with the focus on two aspects:
- the order policy;
- the safety stock.

Determine the optimal order policy and the level of the safety stock per component with the purpose to minimize the inventory costs while taking into account the desired service level of 97.5% at end product level.

The following restrictions are set:

- Only the components which were included in the analysis of the configuration matrix and the inventory level are taken into account;
- The assumption is made that components are unique and not replaceable by each other;
- The average service level for end products in the redesign is not allowed to drop below the average current service level.

The average current service level is defined as: $\overline{P_2} = \dfrac{\sum_{n=1}^{5}(P_{2,n} \times O_n)}{\sum_{n=1}^{5} O_n}$

$P_{2,n}$ service level of an end product n
O_n order intake of end product n

Beside the fact that an optimal order policy will be determined and a method to calculate the safety stock will be offered, another goal of the project will be to determine the expected inventory level and the service level for the end products when the redesign is implemented and to determine the inventory value per component in this situation.
Based on the logistics costs that have to be made when offering configuration components, a first-order-analysis will be carried out whether or not it is remunerative not to offer certain components any longer. The inventory value in the redesign will be compared with the turnover of the components and the turn frequency will be calculated. Based on the first-order-analysis and the turn frequency, a conclusion will be drawn if all configuration components should still be offered.

5.6.2 Research questions

In the analysis stage, research questions were drawn up to provide a guide-line during that stage. The same will be done for this part of the project, in which one research area, the inventory control, will be further analyzed and a redesign will be made. Therefore the following research questions need to be answered:

- Is it justified to focus only on the inventory costs when determining another lot sizing method and to leave the other costs out of consideration?
- At what level should the safety level be set, taking into account the forecast error of the undershoot, the service level for components, the forecast error of the demand during the lead-time of the supplier and the reliability of the supplier?
- Which order policy is optimal for the reordering of configuration components?
- After determining the safety stock level and the optimal order policy, what is the inventory value?
- Is it remunerative to offer all configuration components? What are the savings when some components are not offered anymore?

Chapter 6 Theory about the lot sizing method and safety stock

In section 5.4, an analysis of the logistics costs is carried out and the conclusion is drawn that it is justified to focus on the inventory costs when proposing another lot sizing method, provided that the influence on the other costs when the lot size is changed is taken into account.
The lot size and the safety stock are factors that influence the expected stock level. These factors can be split in sub factors again. In this way, a hierarchical scheme can be built to indicate the factors at different levels that finally influence the expected stock level. This scheme is shown in appendix 16. This scheme will be used to deal with the theory about the order policy and the safety stock.
The lot size influences the safety stock. So, when changing the lot size, the safety stock level will be influenced too. Because of this interaction it is not possible to say that the lowest costs are achieved. Anyway, according to Silver, Pyke and Peterson [7], the cost savings are marginal when compared with the effort that will be needed to find the optimal Q that will lead to the lowest inventory costs overall. That is why the lot sizing method and the safety stock level will be determined independently.

6.1 The lot sizing method

According to Rana the objective of lot sizing is to minimize inventory-related costs [11]. In this section, first the current lot sizing methods will be explained and under what conditions these methods are appropriate. Another lot sizing method will be proposed to replace the current methods that are being used. A simplistic method is proposed because of user acceptance. The MRP-controllers need to understand how and why lot-size quantities are what they are. Complex methods are not likely to be accepted by the MRP-controllers that have to use this method. The proposal will be supported with scholarly literature.
When deciding on a lot sizing method, no attention is paid to coordination of replenishments. However, when reordering components, it may be advantageous to coordinate these replenishments, for example when taking into account transportation costs and reordering costs. There are also possible drawbacks like an increase in the average inventory level and reduced flexibility [7]. Not all components are taken into account and this could interfere with the coordination principle, leading to a non-optimal solution. Therefore coordination of replenishments is not taken into account. However, this does not mean that coordination does not have to be considered in practice.
The current lot sizing methods are the Economic Order Quantity method and the Periodic Order Quantity method. In the next subsections, these methods will be described and a proposal for a new method will be made.

6.1.1 EOQ method

The Economic Order Quantity is a lot sizing method that is appropriate when there is an approximately level demand pattern. The conditions are rather stable (the changes occur rather slowly in time) and there is relatively little uncertainty in the level of demand. The criterion when using the EOQ is minimizing the total relevant costs. These costs can be defined as the basic purchase costs and the inventory carrying costs.

The formula for the EOQ is:

$$EOQ = \sqrt{\frac{2AD}{vr}} \qquad (6.1)$$

A fixed cost component, independent of the replenishment quantity; Océ uses € 45.00 as fixed cost;
v unit variable cost of the component. This is the value of the component;
D demand rate of the component;
r the carrying charge; Océ uses an r of 20%.

It is clear that the conditions when using the EOQ-formula are not valid in the case of reordering configuration components. The most important reason is that there is no level demand pattern. When the demand rate varies with time, the best strategy will not automatically be the EOQ-method. Other heuristics may be more appropriate. The choice when using the EOQ-method or a heuristic depends on the variation coefficient of the demand pattern. As a guide-line may be used that when the variation coefficient of the demand pattern is smaller than 0,2, EOQ is appropriate. Otherwise, a heuristic has to be used. This is the case for the demand pattern of the configuration components so a heuristic has to be used to determine the lot size of the components. This variation coefficient is not the same as the variation coefficient presented in appendix 10. The coefficient in the appendix is the variation coefficient of the *forecast*, in this case the variation coefficient of the *demand* is used.
When using a heuristic, several assumptions are made [12] :

- The value of a component is constant throughout the planning horizon;
- There is a fixed set-up cost for the purchase of a lot and this cost is constant over time;
- There is a linear inventory cost that is also constant over time;
- Every time a lot size needs to be reordered, the fixed cost component has to be charged. The fixed cost component is part of the relevant costs.

6.1.2 POQ method

This method is a heuristic that can be used when the demand rate varies with time. In fact, this heuristic is based on the EOQ and expresses this quantity as a time supply. Then, any replenishment is made large enough to cover exactly the requirements of this integer number of periods. This method can be expressed in a formula:

$$T_{EOQ} = \frac{EOQ}{\overline{D}} = \sqrt{\frac{2A}{\overline{D}vr}} \qquad (6.2)$$

This approach has the advantage that the orders arrive regularly. But just like the EOQ, this method uses the average annual demand. Because the demand of configuration components is rather dynamic, this demand needs to be updated regularly because otherwise the dynamic demand pattern will not be followed anymore. Because this updating does not take place at Océ at a regular base, another method is proposed which will better follow the dynamic pattern.
One of the heuristics that can be used in a time-varying demand pattern is the Silver-Meal heuristic. Based on scholarly literature, this heuristic seems most appropriate to use under the conditions that apply for the configuration components.

6.1.3 The Silver-Meal heuristic

This heuristic tries to minimize the total relevant costs per unit time for the duration of the replenishment quantity. An assumption is that the orders arrive at the beginning of the periods, so the replenishment quantities must last for an integer number of periods. When a replenishment arrives at the beginning of period t and fulfils the demand until period T+1, this criterion function can be written as follows:

$$TRCUT(T) = \frac{TRC(T)}{T} = \frac{A + F(2)vr + 2\times F(3)vr + \ldots + (T-1)\times F(T)vr}{T} \qquad (6.3)$$

TRCUT(T)	total relevant costs per unit time
TRC(T	total relevant costs
F(T)	forecast of the demand for period T

The idea is to evaluate TRCUT(T) for increasing values of T until, for the first time TRCUT(T+1) > TRCUT(T). This means that the total relevant costs per unit time start increasing.
The danger exist that only a local minimum will be found. It is possible that larger values of T would have lower costs per unit time. To protect against this danger, it is advisable to compute the TRCUT for a few more values of T.
This method does not lead to an optimal solution when the demand pattern has a well-defined ending-point. Because only regular components are taken into account, this is not the case. Beside this, components that will not be offered any longer after a certain time-period receive special attention of the MRP-controller. Often, manual intervention takes place when reordering these components.

6.1.4 Results of performance analyses and sensitivity analysis for heuristics

Silver, Pyke and Peterson [7] have carried out a performance analysis for several heuristics. Beside the current lot sizing methods and the Silver-Meal heuristic also other heuristics were included. In this analysis several assumptions are made. The demand is known and the entire requirements of each period must be available at the beginning of that period. There are no discounts and the cost factors do not change with time. Under these assumptions, the Silver-Meal heuristic outperforms other heuristics. The Silver-Meal heuristic outperforms the Periodic Order Quantity by 10% and the EOQ by 28% in total costs in this analysis. K. Zoller and A. Robrade [13] also indicate that this heuristic is an appropriate heuristic when the demand is time-varying and, based on numerical experiments, performs well.

All three methods, EOQ, POQ and Silver-Meal, use the reordering costs and the inventory costs to determine the lot size that has to be reordered. For all components the same reordering costs and carrying charge are used. This assumption is also used in the performance analysis conducted by Silver, Pyke and Peterson [7]. But as already discussed in subsection 5.4.4 the carrying charge should probably not be the same for all components. The same argument is valid for the reordering costs. So, when using these parameters an estimation is made and the exact costs are not used. Beside that, these costs may be changing over time.
To measure the influence of the error in the input parameters, the reordering costs and inventory costs, a sensitivity analysis can be carried out. C.H. Pan [14] has carried out a sensitivity analysis in which only errors in the inventory costs and reordering costs are included. Errors in the forecasted demand are left out of consideration. According to this analysis, the Silver-Meal heuristic is the most insensitive heuristic to uncertainty in parameter estimation. In this analysis, the EOQ and POQ methods were also included but were outperformed by the Silver-Meal heuristic. Beside that, according to H.C. Huang and H.L. Ong [16], the Silver-Meal heuristic is also relatively insensitive to changes in the planning horizon.

Based on these analyses, the Silver-Meal heuristic is the most appropriate heuristic to use in the situation of reordering configuration components. This heuristic follows the dynamic demand of the configuration components and is less sensitive for errors in the reordering costs and the inventory costs than the current methods.

A marginal note needs to be made for all three lot sizing methods which are described in this section. This marginal note refers to the last assumption that is made when using a heuristic. All methods claim to make decisions based on the relevant costs. But it may be questionable if the costs that are evaluated in these methods are all relevant costs. The inventory costs indeed are variable with the amount and frequency of reordering components. The problem refers to the fixed cost component A. In the Silver-Meal heuristic, as well as in the other two current lot sizing methods, the assumption is made that the fixed cost component depends on the order quantity and the frequency of the replenishments. The fixed cost component is included into the total relevant costs. Every time a replenishment is done, the fixed cost component is taken into account.

This fixed cost component consists of the salary costs of the MRP-controller and system costs. The system costs are independent of the amount of replenishments. When increasing the frequency of replenishments, first the salary costs will be fixed, but at a certain moment, these costs will increase because employees will do overtime to finish their work. In more extreme increase, an extra employee will be hired.
When the frequency increases within certain boundaries, the fixed cost component will be the same. Only when the increase is higher than the defined boundary and the salary costs will increase, the cost component will be higher with a higher frequency of replenishments. But the increase in frequency of replenishment and the increase in the fixed cost component is not one-to-one related. Anyway, because the Silver-Meal heuristic as well the current lot sizing methods do not deal with this aspect, this will be left out of consideration. For more information is referred to [15].

6.2 The safety stock

In section 5.3, four aspects were indicated why it is difficult to calculate the safety stock:
- It is not clear whether the lead-time of the supplier is deterministic or stochastic;
- The standard deviation of the forecast error of the demand is calculated per forecast update interval instead of per lead-time of the supplier;
- The service level at component level is not known, only at end product level;
- The forecast error of the undershoot should be taken into account.

The formula to calculate the safety stock is:

$$ss = k \times \sigma_{fe,D_L} \qquad (6.4)$$

The subscription fe, D_L indicates the forecast error of the demand during lead-time. Because of the four mentioned aspects, the formula for the safety stock needs adjustments. In the next subsections the reason of keeping safety stock and the adjustments will be explained. In subsection 6.2.6 the final formulas for calculating the safety stock will be represented.

6.2.1 The reason of keeping safety stock

At the reordering point, the inventory position minus the safety stock is only enough to fulfill the demand during the lead-time of the supplier. The reason why keeping safety stock is to absorb forecast errors of the demand during the lead-time. But the lead-time itself and the undershoot are uncertainties too. The safety stock is influenced by two factors: the k-factor and the standard deviation of the forecast error of 'the uncertainties'. In formula 6.4, only the forecast error of the demand during lead-time is taken into account. Adjustments for this formula have to be made to include the uncertainty in the forecast of the undershoot and the lead-time. These adjustments will be discussed in the next subsections.

The formula is only valid when the forecast errors are normally distributed. But because several factors determine the total forecast error and data of these factors are not available, it is not possible to prove that the normal distribution is valid and an assumption has to be made. In the remainder of the chapter, the assumption is made that the normal distribution is valid.

6.2.2 The standard deviation of the forecast error of the demand

At this moment, the standard deviation of the forecast error of the demand is calculated per forecast update interval, in this case one month. But this standard deviation cannot directly be used as input for calculating the safety stock. For calculating the safety stock, the standard deviation of the forecast error during the lead-time of the supplier is needed. That is why a translation should take place. The following relation exists between the two standard deviations:

$$\sigma_{fe,D_L} = L^c \sigma_{fe,D_1} \quad (6.5)$$

σ_{fe,D_L} the standard deviation of the forecast error during the lead-time;

σ_{fe,D_1} the standard deviation of the forecast error during the forecast update interval (indicated with 1);

L the lead-time of the supplier;
c a coefficient that has to be determined empirically.

The calculation of c will be explained in appendix 17. Based on the results shown in appendix 17, the coefficient c is equal to 0.75 and the relation can be defined as:

$$\sigma_{fe,D_L} = L^{0.75} \sigma_{fe,D_1}$$

Because c is not calculated for every component but 10 components have been chosen at random, the assumption is made that these components are representative for the other components. A sensitivity analysis is carried out for c in appendix 18. This analysis shows the influence on the safety stock value of the expensive components when the value of c is changed.

6.2.3 The undershoot

Two aspects cause undershoot:
1. non-unit sized demand;
2. review period.

When the unit size is not equal to one per demand, the possibility exist that the inventory level 'drops' below the reordering point without having been equal to this point. Because of the review period, the possibility exists that during the last review period the level was above the reordering point and during the period, the level dropped below this point. This can only be observed at the next review moment. This is visualized in figure 6.1. Because at WFPS the situation is periodic review (with R = one week) the remainder of this section will assume a period review situation.

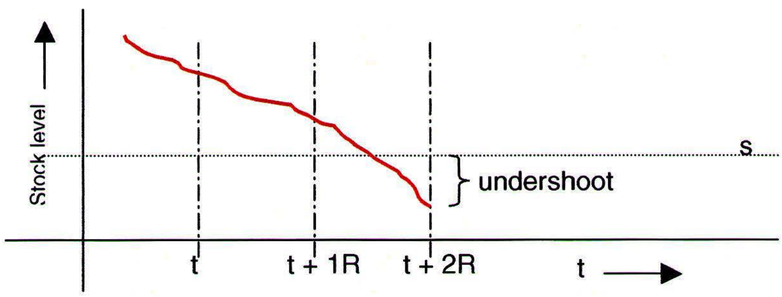

figure 6.1 Undershoot

The reordering point will be higher than in a continuous review situation. The reordering of components takes place if the inventory position minus the safety stock is equal to the expected demand during the lead-time and the expected undershoot. This can be expressed as:

$$s = \hat{D}_L + \hat{U} + ss \quad (6.6)$$

$\hat{D}_L$ expected demand during the lead-time of the supplier

$\hat{U}$ expected undershoot

Based on De Kok [17], the expected undershoot can be defined as:

$$\hat{U} \approx \frac{\sigma^2(D_R) + E^2[D_R]}{2E[D_R]} \tag{6.7}$$

$E(D_R)$ can be defined as the expected demand during the review period.

In case of periodic review, the safety stock should protect against incorrect estimations of the undershoot. The formula of the safety stock needs to be adjusted. The 'new' formula will be:

$$ss = k \times \sigma_{fe,D_L+U} \tag{6.8}$$

Because the actual realisations of the undershoot are not available, this 'new' standard deviation leads to the next question: how should this standard deviation be calculated?

$\hat{U}$ is calculated by use of demand predictions. The forecast error of the undershoot will therefore be caused by the forecast error in demand during R, the review period. So the length of R and the forecast accuracy of demand per period influence the accuracy of forecasting the undershoot. From recent literature no exact formula can be obtained that incorporates the uncertainty regarding the undershoot in the safety stock calculation. However, since R and σ_{fe,D_R} are the influencing factors, the decision is made to incorporate them in the same way as σ_{fe,D_1} and L. Thus, the formula for σ_{fe,D_L+U} can be defined as:

$$\sigma_{fe,D_L+U} = \sigma_{fe,D_{R+L}} = (R+L)^{0.75}\sigma_{fe,D_1} \tag{6.9}$$

6.2.4 Stochastic lead-time of the supplier

In formula 6.4 the assumption is made that the lead-time of the supplier is deterministic. This is not for every component a realistic assumption. When the lead-time of the supplier is not deterministic, the standard deviation of the forecast error needs adjustment again. Based on De Kok [17], the next formula can be found for the standard deviation of the forecast error of the lead-time:

$$\sigma^2_{fe,D_L} = (E[L]) \times \sigma^2(D_L) + \sigma^2[L]E^2[D_1] \tag{6.10}$$

In this formula, the lead-time L equals an *integer* number of periods. This translation has to take place to keep the dimensions correct. The period in the actual situation is one month.

This formula is valid in case the parameter of the distribution, E(D) is known. But in the actual situation, estimations are made by means of forecasting. This implies that instead of calculating with $\sigma^2(D)$, $\sigma^2(fe)$ should be used. This means, instead of using the variance of the actual demand during the period, the variance of the *forecast error* of the demand during the lead-time should be used.
When the formula is corrected, the result is:

$$\sigma^2_{fe,D_L} = (E[L]) \times \sigma_{fe,D_1}^2 + \sigma^2[L]E^2[D_1] \tag{6.11}$$

Now the formula for the standard deviation of the forecast error of the lead-time and the formula for the standard deviation of the forecast error of the demand during lead-time need to be combined into one formula. The first part of the formula needs adjustments.

In fact, σ_{fe,D_L} can be formulated as

$$\sigma_{fe,D_L} = \{(\sigma^2(L) \times E^2[D_1]) + \text{var}(fe, D_{L\text{det}})\}^{0.5} \qquad (6.12)$$

The second term, var(fe, D_{Ldet}) is the variance (σ^2) of the forecast error of the demand during lead-time when the lead-time is deterministic (= det).
The next relations exist:

$$\text{var}(fe, D_{L\text{det}}) = (\sigma_{fe,D_{L\text{det}}})^2 = (E(L)^{0{,}75} \times \sigma_{fe,D_1,L\text{det}})^2 \qquad (6.13)$$

This means that the formula for σ_{fe,D_L} when the lead-time is stochastic can be formulated as:

$$\sigma_{fe,D_L} = \{(E(L)^{0.75} \times \sigma_{fe,D_1,L\text{det}})^2 + \sigma^2[L]E^2[D_1]\}^{0.5} \qquad (6.14)$$

In this formula, the forecast error of the undershoot is not taken into account because this formula is meant for a continuous review situation. The formula will be changed to a periodic review situation:

$$\sigma_{fe,D_L+U} = \{(E(L+R)^{0.75} \times \sigma_{fe,D_1,L\text{det}})^2 + \sigma^2[L]E^2[D_1]\}^{0.5} \qquad (6.15)$$

This is the final formula for calculating the safety stock in case the lead-time of the supplier is stochastic.

In case the lead-time of the supplier is deterministic, the formula for the safety stock is:

$$\sigma_{fe,D_L+U} = (R+L)^{0.75} \sigma_{fe,D_1} \qquad (6.9)$$

6.2.5 The P_2-value

The relation between k and P_2 can be defined as:

$$G_u(k) = \frac{Q}{\sigma}(1 - P_2) \qquad (6.16)$$

$G_u(k)$ is a function of the unit normal variable with mean 0 and standard deviation 1. The values for Gu(k) and k are given in appendix 19. For more information about the function $G_u(k)$ is referred to [7].

Because the configuration process is not a pure assembly process but a customer-specific process, determining the corresponding P_2-value at component level based on a mathematical approach is not possible. The number of components that is used in a configuration is unknown. Only a empirical way can be used to determine the service level. The only restriction that is set for the P_2-value at component level is that the P_2-value is not allowed to drop below the 97.5%, the service level at end product level. The literature does not provide a scholarly method at this moment for determining the P_2-value in this situation. Determining the P_2-value in an empirical way is explained in section 7.2.

6.2.6 The final formulas for determining the safety stock

For the sake of clarity, the formulas for calculating the safety stock will be summarized here again. There are two situations: the lead-time of the supplier is deterministic or this lead-time is stochastic.
When the lead-time is deterministic, the safety stock can be calculated by:

$$\text{Safety stock} = k \times \sigma_{fe,D_L+U} = k \times [(R+L)^{0.75} \sigma_{fe,D_1}] \qquad (6.9)$$

When the lead-time is stochastic, the safety stock can be calculated by:

$$\text{Safety stock} = k \times \sigma_{fe,D_L+U} = k \times \{(E(R+L)^{0.75} \times \sigma_{fe,D_1,L\text{det}})^2 + \sigma^2[L]E^2[D_1]\}^{0.5} \qquad (6.15)$$

Chapter 7 The redesign

In chapter 6, theory, based on scholarly literature, is explained to provide a basis for the redesign. This redesign consists of two aspects: the lot sizing method and the safety stock. In this chapter, the total redesign will be described. Especially the service level at component level, for which the literature does not provide a solution, will receive attention.

7.1 The lot sizing method

In chapter 6 a heuristic is explained which is most appropriate to use for the reordering of configuration components: the Silver-Meal heuristic. First, the advantages and disadvantages of the Silver-Meal heuristic will be mentioned in comparison with the POQ method and the EOQ method. Also, the calculation when using the Silver-Meal heuristic will be described.

7.1.1 Advantages and disadvantages of the Silver-Meal heuristic

Based on literature, the advantages of the Silver-Meal heuristic, in comparison with the current methods that are used for reordering components are (see also chapter 6):

- This heuristic is designed for situations in which the demand pattern varies with time; this is the case when reordering configuration components; the heuristic follows the dynamic demand of the configuration components;
- Based on performance analyses the Silver-Meal heuristic outperforms the Periodic Order Quantity and Economic Order Quantity method;
- The Silver-Meal heuristic is less sensitive for variations in the inventory and set-up costs than the other two methods.

A disadvantage is that the heuristic does not lead to an optimal solution when a well-defined ending point is used. But as already mentioned in chapter 6, this is not the case for regular components.

7.1.2 Calculation of the lot size using the Silver-Meal heuristic

Every time the inventory level drops below the order point, the Silver-Meal heuristic calculates the required Q that has to be reordered. The Q that will be reordered is also influenced by two other factors: the packing quantity (Q_{PACK}) and the minimum order quantity (Q_{MIN}). This is already mentioned in subsection 5.3.3. The Q that is calculated with the Silver-Meal heuristic will be further mentioned as Q_{SM}. The following rules apply:

If $Q_{SM} < Q_{MIN} \rightarrow$ reorder Q_{MIN}

If $Q_{SM} > Q_{MIN} \rightarrow$ reorder Q_{SM}

And Q_{MIN} or $Q_{SM} = xQ_{PACK}$ with $x \in \{1, 2, 3, \ldots\}$

This last equation means that both Q_{MIN} as Q_{SM} need to be rounded up to a packing quantity. If the packing quantity is larger than the minimum order quantity, the packing quantity is the minimum order quantity.

Several choices and assumptions have been made when calculating the lot size with the Silver-Meal heuristic:

- The data of the months October 2002 – June 2003 are used;
- The time-period is chosen to be one week. This means that a lot size can be reordered once a week. This choice is made, because most suppliers only deliver once a week. Exceptions are the JIT-components. These components are reordered once a week, but the delivery takes place several times a week. However, the choice about the delivery frequency can be made afterwards because this does not influence the functioning of the heuristic. The issue is how many times to *reorder*, not how many times components should be *delivered*.

- The assumption is made that the demand and forecast can be divided equally over the weeks in the relevant month. It is necessary to make this assumption, because the demand and forecast data are not available per week, only per month. The influence on the lot size will be marginal. When components are reordered often, the average lot size will be used in the calculations. When components are only reordered once in the nine months that are used for the calculation, it does not matter if the total demand of one month is divided equally per week or if the demand is asked in two weeks of a month. The total amount per month is more important. This amount determines the lot size that has to be reordered. Only when the heuristic indicates that the forecasted demand for X ½ month has to be reordered, variation can exist in this half month. But, when X is large enough, this half month will not influence a lot. Because nine months of data are available the conclusion can be drawn that X is large enough.
- If the lot size covers more than the demand in these months, the horizon is lengthened with the average demand and average forecast. These averages are calculated, based on the data of the nine months that are used.

In appendix 20, an example of calculating the lot size with the Silver-Meal heuristic is described. The results of the calculated Q per component are represented in chapter 8.

7.2 The calculation of the safety stock

The formulas given in chapter 6 have to be used when calculating the safety stock. When using these formulas, assumptions have to be made. These will be mentioned in 7.2.1. The problem of determining the service level at component level will be described in 7.2.2.

7.2.1 Stochastic lead-time

When calculating the safety stock, the forecast error of the undershoot and of the demand during the lead-time of the supplier and the variance of the lead-time should be taken into account. The reliability of the lead-time of the supplier is not measured for every component. For example, the reliability of the lead-time for JIT-components is not measured. When the reliability is not measured, the assumption is made that the lead-time of the supplier is deterministic.
At Océ, the reliability of the lead-time is measured at week-level as already is mentioned in section 4.1.4. To measure this reliability, the requested delivery date is compared with the actual delivery date. However the problem is that the requested delivery date can change during the lead-time. In figure 7.1, the problem is visualized:

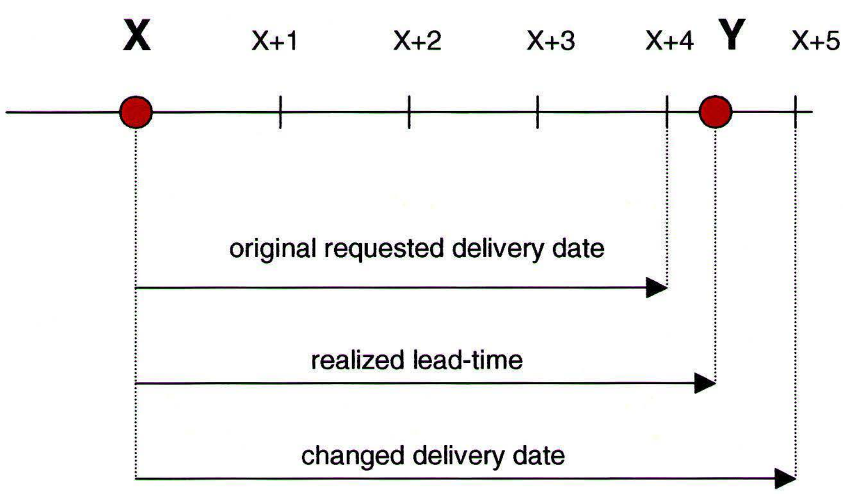

Figure 7.1 Original requested delivery date, realized lead-time and changed delivery date

In this figure, the situation is visualized when the MRP-controller changes the delivery date. This situation can occur when the supplier contacts the MRP-controller with the message that the order cannot be delivered on the requested delivery date. When this is possible, the requested delivery date is changed, indicated with 'changed delivery date'.
When calculating the variance of the lead-time, the data that are used do not indicate if the requested delivery date has been changed or not. That is why the assumption has been made that no changes have been made in the requested delivery date. In reality, the variance of the lead-time will be higher, because the deviation between the original requested delivery date and the realized lead-time will be higher than the deviation between the changed delivery date and the realized lead-time. This would lead to a higher safety stock. But only for 16 components the formula for calculating the safety stock with stochastic lead-time is used. The increase in the total value of the safety stock will be marginal, because the variance of the lead-time will increase for only a few components of the relating 16 components.

7.2.2 The service level of the components

When calculating the safety stock, one parameter is still unknown: the service level of the components. As already mentioned in chapter 6, the literature does not provide a method for determining the service level at component level at this moment. That is why the service level has to be determined empirically.
Rustenburg [18] mentions that, to achieve an overall service level of X percent with the lowest costs, it may be valuable to differentiate between the components. The cheaper components need to receive a higher service level with the purpose to be able to give the more expensive components a lower service level. In the following subsections, an explanation is given in what way is dealt with the service level for components. The concept of Rustenburg is used as a basis to determine the service level.

7.2.3 Grouping of components

To determine the service level per component, the components are divided into categories. Two factors are used to establish this:

- The product-family the component belongs to; it is also possible a component belongs to more than one family;
- The price; this factor is chosen based on the concept of Rustenburg.

In appendix 21, the components are shown with their value versus the total cumulative value. Based on this figure, five categories of components are made. The ranges of these groups are chosen arbitrary. The categories with the amount of components in it are:

1.	€ 2,500 – maximum value	7 components
2.	€ 1,000 - € 2,500	6 components
3.	€ 300 - € 1,000	11 components
4.	€ 50 - € 300	14 components
5.	€ 0 – € 50	252 components

Notable is the amount of cheap components versus the more expensive components: 252 versus 38.

These price categories are again divided per product family. In total, the components are divided into 33 categories. Per category, the amount of components is determined. But when for example 50 components belong to a particular category, this does not mean that all 50 components will always be required. This depends on the kind of configuration that is required. To be able to calculate the service level, the average amount of components that will be required is needed. This average amount of components can be calculated, based on the percentages of the configuration matrix. The configuration matrix gives forecasts at sub-assembly level; so first the percentages at sub-assembly level need to be translated to component level. The components are considered to be equal and the total of all percentages of these components is taken as the average amount of components that will be required in this category. For example, a category consists of 5 components and each component is required with a chance of 20%, the total percentage is 100% and this means that on average 1 component is required. In appendix 22, a visualisation of the categories is given. This model represents 'the average configuration'. The first number indicates the category in value (1 – 5), the second number in parentheses is the actual amount of components belonging to this category and the third number is the average amount of components that is required in this category. When calculating the average amount in a category, the assumption is made that the components are asked independently of each other. This assumption is in some cases violated but there is no way found to model the dependencies of some components.

7.2.4 Cheap components
Based on this model, it is not possible to calculate realistic P_2–values according to the formulas as these are represented in chapter 6. This is because in theory, the service level can never be equal to 100%. But, when looking at the categories, the conclusion can be drawn that the cheap components, the components with a value lower than € 50 should be available anytime. In practice this means that the P_2-value has to be equal to 100%. Because it is not possible to calculate the required level with formula 6.15 or 6.9, the safety stock is set equal to the maximum demand during the lead-time of the supplier and the review period (L+R). As a result, the cheap components are available 100% and left out of consideration. Now, the focus will be on the expensive components.

7.2.5 Expensive components
Because of the fact that the service level of the cheap components is 100% the expensive components can receive a lower service level. However, there is still no scholarly method to determine the service level for these components. Therefore the service level is determined by trial-and-error. To achieve a service level of 97.5% at end product level, the service level of the expensive components needs to be higher than 97.5%. The service levels are set at 99.5% , 99.0% , 98.5% and 98.0%. The safety stock is calculated and the inventory value of the safety stock is determined. Also, the end product service level is calculated per service level at component level. The results are represented in chapter 8.

7.2.6 Marginal note for the average configuration model
When determining the average configuration to be able to calculate the P_2-value for components, the components that are not included in this assignment are not taken into account. However these components influence the service level for end products as well as the other components do. But the components that are not included in the assignment are cheap components or acquisition components. Cheap components need to be available 100% and do not influence the service level at end product level negatively. The acquisition components are not used for the end products so their service level does not influence the service level of the end products either. So the conclusion can be drawn that the demarcation of certain components does not influence the average configuration.

7.3 The redesign

Based on the theory in chapter 6, the following redesign of the current situation has been made:

The lot size:
The heuristic that is appropriate to calculate the lot size is the Silver-Meal heuristic.

The safety stock:
The safety stock should be calculated according to the formulas described in chapter 6; the P_2-value has to be determined empirically.

The next chapter will represent the results when the redesign will be implemented. The results will also be compared with the current situation.

Chapter 8 Results of the redesign

In this chapter, the results of the redesign will be represented. The results will be quantified as much as possible. Beside that, the redesign will be compared with the current situation. Two options will be given to reduce the inventory value: not stocking certain components and not offering all components any longer. For this last option, a first-order-analysis, based on the analysis in section 5.4, is carried out in section 8.5. An estimation will be made which percentage of the components can be considered for not offering anymore.

8.1 Current situation

During the analysis, an attempt has been made to quantify the current inventory level. The results are described in section 5.3. The average inventory value is equal to k€ 2,643.

In general the inventory consists of two parts: ½ Q and ss. It was not possible to determine the exact Q per component, because the history of the exact amounts that were reordered was not available. Because of that, the next approximation has been made: the lot sizing method per component was determined. Based on these methods and on the forecasted usage of the forthcoming year, the average lot sizes have been calculated. In this calculation, the minimum order quantity and packing quantity have not been taken into account. The average lot size is shown in appendix 12 in column 'expected average lot size'.

In SAP R/2, the safety stock is determined. However, this safety stock is not equal to the average inventory level minus the calculated ½ Q. The difference is so enormous, that it is justified to draw the conclusion that the safety stock as this is recorded in SAP is not correct. In reality, the safety stock is higher. A lot of safety time, which in fact is equal to safety stock, is included into the reordering process. A clear example of safety time is the time to receive the goods at P60. This time is equal to 5 days in the system, where in reality this time is at most one day. The rest of the time is safety time and leads to a higher safety stock level. The safety stock value, as mentioned in SAP R/2, is equal to k€ 446 but the safety stock in reality is equal to k€ 2,371. This is about five times higher than is indicated in the system! This is visualized in figure 8.1.

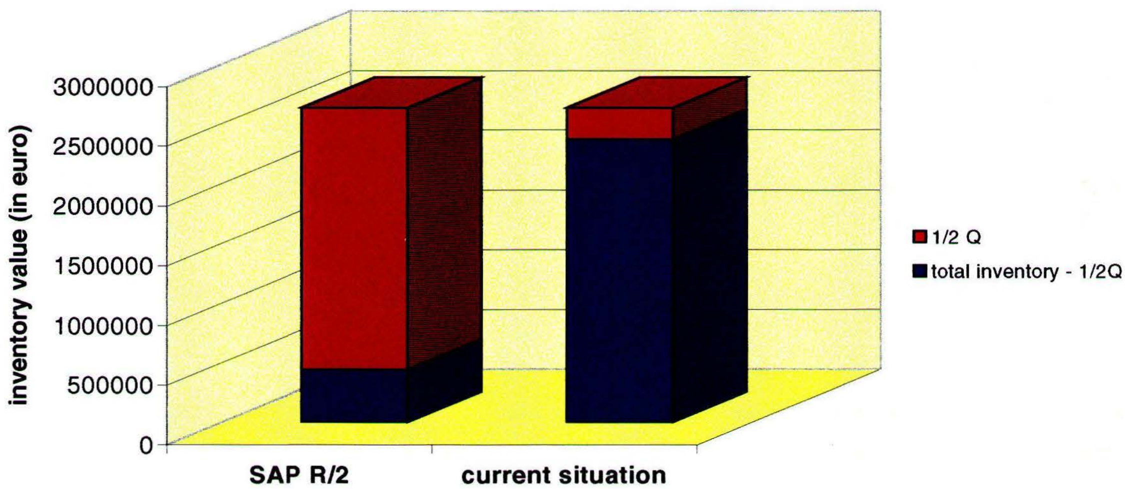

Figure 8.1 *Lot size and safety stock according to SAP and in reality.*

To give an indication of the level of the safety stock, the safety stock is compared to the turnover of the components. The turnover of the components is equal to k€ 16,931. This would mean that k€ 2,371 equals 7 weeks inventory. Although this is just an average, this relation to the turnover gives an impression of the level of the safety stock.

Because now the actual safety stock is known, the service level of the components can be calculated, based on the formulas described in chapter 6. The calculation has been done in a reverse way: when calculating the needed safety stock, the 'known value' is the P_2-value. Now the safety stock is known and the corresponding P_2-value is calculated. Based on the model of 'the average configuration', represented in appendix 22, the service level for end products can be calculated. The results are shown in table 8.1.

Table 8.1 Service level of the end products in the current situation

end product	service level
705X	89%
9300	93%
TDS400	71%
TDS600	99%
TDS800	95%

The overall service level, as defined in section 5.6 is equal to 85%. The low value of the TDS400 can be explained because several cheap components have a relatively low service level which has a large influence on the service level at end product level.

As can be seen in table 8.1, the service levels that are achieved for the 705X, 9300, the TDS400 and the TDS800 are lower than the target of 97.5%. But the service level will probably be higher in reality. The calculated service level is called the *system service level*. But because of interventions of the MRP-controllers, the *actual service level* will be higher. Based on the system service levels, the conclusion can be drawn that the MRP-controllers especially pay attention to components for the 705X and the TDS400. Unfortunately, the actual service level for all end products is not measured at WFPS. Therefore, no judgments can be made about the effectiveness of the actions of MRP-controllers and the difference between the system service level and the actual service level cannot be measured.

A marginal note has to be made about the system service levels for the end products. This service level is based on the actual safety stock of the components. In reality these safety stock levels will be lower: when calculating the average lot size, the packing quantity and the minimum order quantity are not taken into account. When these quantities should be taken into account, the average lot size would be higher. This is further discussed in section 8.2. When the average lot size is higher, this will lead to a lower safety stock level of the components, based on the rule: inventory level = ½ Q + ss. This causes a lower service level at component level and a lower service level for the end products. On the other hand, a higher lot size causes a lower safety stock level in case the service level is kept constant. The influences of both actions cannot be quantified because the average lot size cannot be calculated taking into account the minimum order quantity and packing quantity. Therefore the current calculated system service levels will be used as comparison with the redesign.

In the next sections, the quantitative results of the redesign will be represented. First, the results of the lot size will be described and after that the safety stock level. Then, the consequences for the inventory level will be described when certain components are not stocked anymore and a first-order-estimation will be given if it is remunerative not to offer certain components any longer. At last, a comparison between the current situation and the redesign will be made.

8.2 The results of the Silver-Meal heuristic

The lot size is calculated with the Silver-Meal heuristic. The average lot size per component is shown in appendix 23. In this calculation, the minimum order quantity and the packing quantity are taken into account. These two factors have a large influence on the total lot size value, because for many components, the minimum order quantity or packing quantity is relatively high and the amount that has to be reordered is larger than indicated by the Silver-Meal heuristic. An explanation for the relatively high minimum order quantity and packing quantity is that these quantities are determined, in consultation with the supplier, in the project stage of a product and expectations about the demand are often more optimistic than the actual realisations. Beside this, sometimes the supplier has a position of authority and in that case Océ is a relative small customer and not very important for the supplier. Océ just has to accept the quantities the supplier proposes.

The total lot size value is equal to k€ 1,195.6. This is twice as high as the lot size value in the current situation. The current lot size value is equal to k€ 543. Two reasons can be given for this difference:

- The current lot size is based on the expected annual usage for the period May 2003 – April 2004. The lot size, calculated with the Silver-Meal heuristic is based on the months October 2002 – June 2003; this different time-period shall cause differences, but it is unlikely that this is the main cause of the difference;
- When calculating the lot size with the Silver-Meal heuristic, the minimum order quantity and the packing quantity are taken into account. In the calculation of the current lot size, these factors are not taken into account.

The idea exists that this second reason causes the main part of the difference. This can also be concluded when the Silver-Meal heuristic is carried out without taking into account the minimum order quantity and packing quantity. The lot size value in this case is equal to k€ 858,8. The conclusion can be drawn that the lot size value is about k€ 337 higher than needed because of the minimum order quantity and packing quantity.
That the current lot size value is very low and higher in reality can also be demonstrated when the inventory value is calculated in case the minimum order quantity (this means the minimum order quantity or the packing quantity in case this is higher than the minimum order quantity) is reordered for every component. The inventory value in that case is equal to k€ 567.5. This is higher than the current lot size value which indicates that the current lot size will be higher in reality.
The inventory values are summarized in table 8.2:

Table 8.2 *Comparison of the inventory values when different lot sizing methods are used*

method to calculate the lot size	inventory value
current lot size, based on the annual expected usage	k€ 543.
Silver-Meal heuristic, taking into account the minimum order quantity and packing quantity	k€ 1,195.6
Silver-Meal heuristic	k€ 858.8
lot size equal to minimum order quantity or packing quantity	k€ 567.5

The conclusion can be drawn that the current calculated lot size value and the Silver-Meal lot size value cannot be compared one-to-one. Only the total inventory value in the current situation and in the redesign can be compared. Beside that, the lot size also influences the level of the safety stock. A larger lot size means a lower safety stock level under the same conditions. So, the Silver-Meal heuristic causes a lower safety stock level than in case the lot size is calculated with the POQ method or the EOQ method when the other parameters are kept constant.

8.3 The safety stock level in the redesign

As already indicated in chapter 7, the components are divided into two groups: the cheap components and the more expensive components. Expensive components are components which have a price higher than € 50. First, the results for the cheap components will be given in subsection 8.3.1. In subsection 8.3.2, the results for the expensive components will be represented.

8.3.1 The safety stock level for cheap components

In chapter 7 is explained why the formulas to calculate the safety stock are not used when calculating the safety stock for the cheap components: these components need to be available 100%, which is not possible according to the formula. That is why the maximum demand during the lead-time of the supplier and the review period (L + R) determines the level of the safety stock. The maximum demand during L + R was based on the last nine months because more data were not available.
The results of the safety stock level per component are shown in appendix 23.

The value of the safety stock for cheap components in the redesign is k€ 91. When compared to the safety stock value according to SAP R/2, which is equal to k€ 18.5 this means a safety stock value which is five times higher than the current safety stock. But, when the actual safety stock is taken into account, including all the safety time in the process, the safety stock value in the current situation is equal to k€ 153.

Based on these data, the conclusion can be drawn that the safety stock of the cheap components is unnecessarily high for some components. This conclusion is not valid for all components. When the current service levels for the end products are evaluated, the TDS400 has a lower service level because of the fact that some cheap components have a lower service level. Of the 252 components, 87 components will receive a higher safety stock level in the redesign than in the current situation. The saving on the safety stock value for the cheap components equals k€ 61.8.

8.3.2 The safety stock level for expensive components

In section 7.2.3, five categories of components are defined. The categories are based on the price of the components. Category five, the category of components with a maximum price of € 50 has already been discussed in section 8.3.1. The other four categories contain less than fifty components in total. Because of this reason, the expensive components are treated as one group. Beside that, because the service level for the end products is that high, differentiation is not very useful. The service level for the components is set at 99.5%, 99.0%, 98.5% and 98.0%. The service levels at end product level are also calculated. The service levels at end product level and the safety stock value of the expensive components are represented in table 8.3:

Table 8.3 Service level of the end products and the safety stock value at different service levels for components

end product	$P_2 = 0.995$	$P_2 = 0.99$	$P_2 = 0.985$	$P_2 = 0.98$
705X	0.985	0.97	0.956	0.941
9300	0.985	0.97	0.956	0.941
TDS400	0.961	0.923	0.886	0.851
TDS600	0.975	0.951	0.927	0.904
TDS800	0.942	0.886	0.834	0.785
safety stock value	k€ 2,001	k€ 1,781	k€ 1,660	k€ 1,570
overall service level	0.972	0.945	0.919	0.893

As can be seen in table 8.3, it is not possible to achieve the service level of 97.5% for all end products. Especially the service level of the TDS800 is below the 97.5%. This is because this end product contains the highest amount of expensive components in comparison with the other end products. The TDS800 contains 12 expensive components, based on an average configuration whereas the 705X only contains 3 expensive components.
But these service levels are again the system service levels. The achieved service levels will be higher because of corrective actions of the MRP-controller. But because the difference between the system service level and the actual service level is not known, the most appropriate service level at component level seems to be 0.995. When the achieved service level is known, the service level may decrease to $P_2 = 0.99$ or even $P_2 = 0.985$. But at this moment it is not known if the actions of the MRP-controller are that effective that for example the service level of the TDS800, 83% in case the P_2-level is equal to 0.985, can be increased to 0.975. To be certain that the service level of 97.5% will be achieved, the safest situation is to set the service level equal to 0.995. The corresponding safety stock value is € 2,001.

In the current situation, the safety stock value of the expensive components is equal to k€ 2,219. In all scenarios the safety stock value is lower. But this does not mean that the safety stock for all expensive components will be lower in the redesign than in the current situation. 11 components of all expensive components will have a higher safety stock in the redesign than in the current situation.
An explanation for the decrease in safety stock level may be that MRP-controllers are very careful with expensive components and a higher inventory level is accepted to be sure there will be enough components available. When a stock-out of these components occurs, more attention is paid to this stock-out than when a cheap component is not available. This behavior cannot be supported with facts and the difference in importance between cheap and expensive components is more an emotional value. For achieving the service level, each component has the same importance.

8.3.3 Savings in the safety stock value
For all P_2-values, the safety stock value is lower than the actual safety stock value. Dependent on which scenario is chosen, the savings will vary between the k€ 218 (when the P_2-value of 0.995 is chosen) and k€ 649 (when the P_2-value of 0.980 is chosen) for the expensive components. In the remainder of this chapter, a P_2-value of 0.995 is assumed because this is the most appropriate level.
The total safety stock value is then equal to k€ 2,092 as compared to k€ 2,371 in the current situation.

8.4 Components not keeping in stock

In section 8.2 and 8.3, the safety stock and the lot size are calculated and the inventory value in the situation when the redesign is implemented is determined. In this new situation, the total inventory value will be slightly higher than in the current situation. An option to reduce the inventory is not to stock certain components any longer. One end product, the TDS800 has a delivery time of 20 days. These days are working days, so the delivery time is equal to four weeks. A Requirement Summary has in most cases a fixed period of 21 days. The components included into this project and reordered with a Requirement Summary have a fixed period of 21 days. This means that when this end product would be configured in the last week, several components do not have to be kept in stock anymore. Several conditions are necessary when these components would not be stocked. First, the difference between the forecast and the actual demand should not fluctuate too strongly, because then the supplier cannot respond to these fluctuations. However, in the current situation these fluctuations cannot be absorbed by the safety stock of Océ, so strong fluctuations are a problem in the current situation too. Second, the supplier should be reliable and should not use the inventory for absorbing his own production fluctuations. Conditions for the components are that they are only delivered with the TDS800 and they are reordered by Requirement Summary. The savings will be made when expensive components are not kept in stock anymore, so the cheap components are left out of consideration.

Nine expensive components which in the current situation are reordered by Requirement Summary should be considered for not keeping in stock anymore. When these components are reordered directly from the supplier and then configured, this would mean a considerable saving in the inventory costs. When the P_2-value of 0.995 is used, the safety stock value of these components is equal to k€ 509. When these components would not be kept in stock anymore, this would mean that the total safety stock value in that case is equal to k€ 1,582. This is a reduction of 25% of the total safety stock value.
The lot size value of these components equals k€ 162. This means that the total lot size value, when these components are not kept in stock any longer is equal to k€ 1,033, a reduction of 14%.
The total inventory value would decrease from k€ 2,690 to k€ 2,099, a reduction of 22%. This is a considerable saving and the option of not keeping these components in stock any longer should receive serious consideration.

Three components which are also only delivered with the TDS800 have lead-times of 42 days and 98 days. If these components would also be reordered by Requirement Summary, an option would be not to stock these components either. The safety stock value of these components, again with a P_2-value of 0.995 is equal to k€ 66 and the lot size value is equal to k€ 187. When these items would not be kept in stock any longer, this would mean a saving of k€ 160. The total inventory value in that case would be equal to k€ 1,939.
When reordering components by Requirement Summary, a commitment has to be given as already has been described in subsection 3.5.3. When evaluating the savings that can be made by not stocking these components, a trade-off should be made between the commitment that has to be given to the supplier and the savings that are made when not stocking these components anymore.

8.5 Offering of configuration components

In section 5.4 the logistics costs of offering a configuration component were analyzed. Beside drawing the conclusion if it is justified to focus on the inventory costs when determining the lot sizing method, this analysis can also be used to give an estimation if it is remunerative to reduce the amount of configuration *items* that are offered. When a configuration *item* is not offered any longer, this means that several unique *components* are not offered anymore. Unique components are defined as components that are only used to assemble this particular configuration item. So, not offering several components should be translated to not offering certain configuration items any longer.

8.5.1 Turnover of the configuration items

Configuration items that should be considered not to be offered any longer, are items that have a low turnover and high costs. The costs in section 5.4 are given at component level; this means a translation should take place. First, the turnover per configuration item is calculated and an evaluation is made which percentage of all configuration items cause 80% of the total turnover. 80% is chosen based on the 80 – 20 rule: 20% of the configuration items cause 80% of the turnover. When calculating the turnover of the configuration items, a distinction is made per assembly line. The demand per assembly line differs significantly. If no distinction would be made, configuration items which belong to the HV-line, the line with the lowest demand, would be considered not to be offered earlier than items which belong to the MV-line, in case these items are priced equally. Because of this reason, a distinction is made in the configuration items and they are categorized per assembly line.

In appendix 24, the cumulative turnover of the configuration items per assembly line is shown. In this appendix, the percentage of configuration items that cause 80% of the turnover is shown. The results are per assembly line:

- LV-line: 5% of the configuration items cause 80% of the turnover;
- MV-line: 15% of the configuration items cause 80% of the turnover;
- HV-line: 10% of the configuration items cause 80% of the turnover.

The other configuration items are selected and a list is made of the unique components of these configuration items. When a component is used in more configuration items but not used in the items that cause 80% of the turnover, these are also taken into account. Of the 290 configuration components that are taken into account in this assignment, 236 components are listed. This is about 80% of all components. The assumption is made that 50% of these 236 components have higher average costs. The effect on the costs when this assumption is changed is shown in appendix 25. This 50% should be considered for not offering any longer.

In figure 8.2, a scheme is given which components should be considered for not offering anymore.

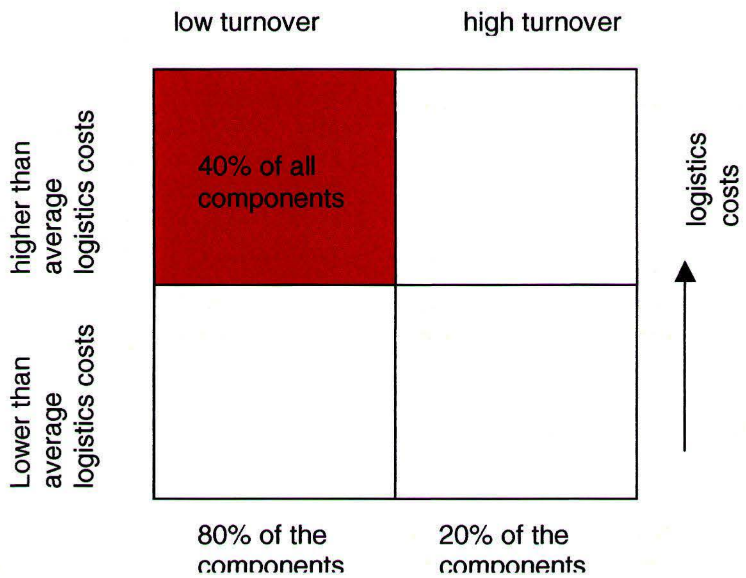

Figure 8.2 *Components categorized according to turnover and logistics costs*

The components in the red part of the figure should first be considered for not offering anymore. These are the components with a high turnover and higher than the average logistics costs. The average costs are about €400. Based on the assumption that 50% of the components with a low turnover have higher costs than the average logistics costs, this leads to the 40% of all components that are included in this analysis that should be considered for not offering anymore.

8.5.2 Estimation of the savings

The costs that are made at component level for *all* components are shown in table 5.3 (see also chapter 5). The assumption is made that these costs are divided equally per component.

Table 5.3 *Costs per cost module in the current situation*

cost module	**costs per month**	**variable costs**	**sunk costs**
materials handling & storage	k€ 42.2	k€ 23.5	k€ 18.7
inventory holding	k€ 154.3	k€ 154.3	
order processing	k€ 16.0		k€ 16.7
transport	k€ 34.2	k€ 34.2	
total	**k€ 247.4**		

The savings can only be made in $^{3}/_{7}$ part of these costs, because this part of the components is taken into account in this assignment. This does not mean that the savings cannot be higher, because configuration components that are not taken into account in this assignment can also be considered for not offering any longer.
The savings can gained in the variable costs in the cost module materials handling & storage, inventory holding and transport. The savings per cost module will be:
Materials handling: k€ 23.5 x 40% x $^{3}/_{7}$ = k€ 4.0;
Inventory holding: k€ 154.3x 40% x $^{3}/_{7}$ = k€ 26.4;
Transport: k€ 34.2 x 40% x $^{3}/_{7}$ = k€ 5.8.
The total maximum savings would be about k€ 36.3 per month. This would be k€ 436 per year. This is about 35% of the total costs that have to be made to offer these 300 components.
Based on this analysis, the conclusion can be drawn that considering not offering several configuration items (this means in fact not offering several configuration components) any longer shall lead to considerable savings.

This analysis is based on financial data from the current situation. In the redesign, the inventory costs per component will change. In appendix 23, the inventory value in the redesign versus the turnover is shown per component. As can be seen, for several cases the inventory value is higher than the turnover. This can be seen in the turn frequency, which is defined as the inventory value / turnover. With turn frequency is meant the number of time the inventory in total is used per year. When this ratio is equal to one or higher, this means that there is more inventory available than is used in one year. This is the case for 134 components which is about 45% of all components that are taken into account. In the analysis, 50% of 210 components were considered for not offering any longer; this is equal to 105 components. When the results of appendix 23 are evaluated, the idea exists that this percentage may be higher. But it is difficult to give an exact saving because in the redesign the costs per cost module will change too. The average lot size will increase in the redesign which will have a positive effect on the materials handling & storage costs and the transport costs but this effect is hardly to quantify. The inventory costs will slightly increase when the options of not stocking certain components is not taken into account.

Generally seen, the costs will not differ that much from the current situation and the conclusion can be drawn that the results of the first-order-analysis are still valid in the redesign. Only the inventory costs may be a point at issue. The expectation is that the savings on the inventory costs will be lower than calculated in this analysis, because it will mainly concern the cheap components which will be considered for not offering. The largest part of the inventory costs are caused by the expensive components so the assumption that the costs are divided equally over the components is not valid. Anyway, because it is not possible to give a better indication of the reduction of the inventory costs these savings are used in the remainder of this chapter.

To define the costs more accurate, categorizing the components according to certain variables, like volume and value may be useful. Based on these categories, the components can be classified and per category, the costs can be estimated. The estimations will be more accurate than in this first-order-analysis.

Anyway, a marginal note has to be made. In the savings, only the logistics costs are taken into account. When several configuration components are not offered anymore, this also means that some customers may choose to order products from another company. A trade-off should be made between the savings that can be made on the logistics costs versus the lack of revenues that may be gained. This is a trade-off between the logistics aspects and the marketing aspects.

8.6 Financial results

When implementing the redesign, the inventory level will change which will have consequences for the inventory value. The financial results are summarized in table 8.4. The current situation is compared with the redesign. The average inventory level value is equal to the half of the lot size value and the safety stock value.

Table 8.4 Inventory value in current situation and in redesign

	current situation	redesign	not stocking TDS800-components	reordering TDS800 components with RS
lot size value	k€ 543	k€ 1,195	k€ 1,033	k€ 846
safety inventory value	k€ 2,371	k€ 2,092	k€ 1,583	k€ 1,516
average inventory level value	k€ 2,643	k€ 2,689	k€ 2,099	k€ 1,939

As can be seen from table 8.4, the inventory value in the redesign is higher than the inventory value in the current situation. The difference is k€ 46. But more important is that the overall service level will increase from 85% to 97%. The current relative low service level of the TDS400 has a high impact on the current overall service level because the demand is the highest for this end product. In the redesign, the service level will be equal to 96.1%, compared to the 70% in the current situation. These are the system service levels and in reality, higher service levels will be achieved. But in practice this means that the MRP-controller can pay attention to more urgent cases and does not have to spend a lot of time to undertake corrective actions to increase the service level of the TDS400. The conclusion can be drawn that because of the decreased risk on stock-outs, the savings will be considerable instead of making extra costs.

Beside that, not stocking unique components for the TDS800 should be considered too. Components which are now reordered by Requirement Summaries should be considered for not stocking any longer. This could lead to a saving of k€ 591, almost 25% in the inventory value, a considerable percentage. The inventory value would then be equal to k€ 2,099. When other expensive and unique components are reordered by Requirement Summary and not stocked any longer too, this would lead to another saving of k€ 160 and the inventory value would be equal to k€ 1,939.
Another option to reduce the costs is not offering certain components any longer. This option can be carried out together with the option of not stocking certain components anymore because it concerns different components. Based on a first-order-estimation the savings would be around 35% of all costs that have to be made to offer these components. This would be about k€ 436 per year.

The three main conclusions that can be drawn when this redesign is implemented are:

- The average inventory value will increase because of an increased lot size;
- The availability of components will increase because of a better allocation of safety stock to the components which will have a positive influence on the overall service level at end product level, from 85% to 97%;
- Options to reduce the costs are not stocking unique and expensive TDS800-components and reducing the amount of components that are offered.

Chapter 9 Conclusions and recommendations

In this chapter, the main conclusions and recommendations will be given. In the conclusions will be referred to the results of the redesign and how the implementation should take place. In the recommendations, areas that need further investigation will be highlighted.

9.1 Conclusions

The main problems in the current situation
In the current situation, the inventory level is not controlled. The safety stock level is defined, based on the insight of the MRP-controller but cannot be supported with facts. Beside that, the safety stock level is fixed and is never updated.
The lot sizing method is more suitable for a constant demand pattern but in case of reordering configuration components, the demand pattern is time-varying. The order conditions are not updated either.
WFPS offers a lot of configuration components, but there has never been evaluated if this amount is really necessary and if it is remunerative to offer such an amount of components.

Forecast reliability measurement by using the standard deviation
During the analysis stage, a new method to measure the forecast reliability is proposed. This method uses the standard deviation and the variation coefficient to measure the forecast reliability. Measuring the forecast reliability at product-family level is most useful because this forecast is used as input for the configuration planning. In this measurement, the structural forecast error should be taken into account when translating this forecast to the configuration planning. The method that is proposed in this report will lead to a more objective method to judge the forecast reliability and gives a better indication when and which corrective actions are needed when using this forecast to do the configuration planning. This method can also be used when SAP R/3 is implemented and WFPS will provide the forecasts to the OpCo's.

The lot sizing method
The lot sizing method which is proposed in this report is the Silver-Meal heuristic. In comparison with the current methods, the Silver-Meal heuristic is dynamic and 'recalculates' every time the optimal lot size when components need to be reordered. Therefore, the conditions do not have to be updated from time to time, as should occur in the current situation. The Silver-Meal heuristic suits better for the reordering of configuration components than the current methods and is able to follow the varying demand of the configuration components. This method does not lead to smaller lot sizes than the current methods. This means that the transport costs and materials handling costs will not increase in the redesign. The best way to implement this lot sizing method is to use this method in SAP R/3.

The safety stock
A structured way of calculating the safety stock is developed. In this method, several uncertainties are taken into account: the forecast error of the undershoot and of the demand during the lead-time of the supplier and the uncertainty in the lead-time of the supplier. The P_2-value is determined empirically, because at this moment the scholarly literature does not provide a way to determine the P_2-value. The P_2-value in the new situation should be equal to 0.995. When this method is used, the overall service level at end product level will increase and it is very likely that, due to the actions of the MRP-controllers, the target of 97.5% will be achieved. SAP R/3 offers the possibility to calculate the safety stock in a dynamic way. The best way to implement this method is to use these formulas in SAP R/3.
This method will lead to a well-organized safety stock. Including safety time into several processes is not necessary anymore.

Financial results
In the current situation, the inventory value is equal to k€ 2,643. In the redesign, the inventory value, when the P_2-value is equal to 0.995 is equal to k€ 2,690. This is an increase of k€ 46 without an increase in the other costs like transport costs and material handling costs. But more important is that a higher overall service level at end product level is achieved and the inventory level is controlled in a structured way. The overall service level increases from 85% to 97%. Beside that, the risk of a stock-out decreases so the savings will be considerable.

9.2 Recommendations

Several recommendations will be given about the redesign and aspects that need further investigation.

Implementing the redesign in SAP R/3
- The possibility of calculating the lot size in SAP R/3 by using the Silver-Meal heuristic needs further investigation. The best way to implement the redesign and creating a basis for this heuristic, is using this method in SAP R/3;
- The same advice applies for the safety stock; further research is necessary how these formulas should be implemented in SAP R/3.
- When calculating the order point, the undershoot should be taken into account. In chapter 6, a formula for calculating the expected undershoot is given. When SAP R/3 calculates the order point, this undershoot should be taken into account. Further research is necessary if it is possible to include the undershoot in this calculation.

Not stocking certain components
As already indicated in chapter 8, not stocking unique and expensive TDS800 components any longer should lead to considerable savings. Further research is necessary if this is a possibility. This research has to be carried out in collaboration with the Department Purchasing because they draw up contracts in consultation with the suppliers.
Beside that, expensive and unique components for the TDS800 that are not reordered by Requirement Summary at this moment should be considered to be reordered by Requirement Summary. A possibility is that these components are not stocked too. This should be investigated too in consultation with the department Purchasing.
When implementing this, the cooperation with the supplier is needed but at this moment, the expectation is that not stocking certain components will not have a strong impact on the processes of the supplier. When these components would not be stocked any longer, the maximum saving would be equal to k€ 751, a saving of almost 30% in the inventory value of the redesign.

Not offering certain components
In chapter 8, a first-order-analysis is carried out if it would be remunerative not to offer certain components any longer. A more precise analysis is not possible because the required data are not available. Anyway, the first-order-analysis indicates that the maximum saving would be around 35% of all costs that have to be made to offer about 300 components. The recommendation is to investigate this opportunity more thoroughly.
To be able to carry out a more detailed analysis, the transport costs and materials handling costs should be known at a more detailed level. At this moment, these costs are only known at aggregate level. Beside that, the marketing aspects should be taken into account. Some items will be offered because of marketing aspects but it is very unlikely that this will apply for all components. A trade-off should be made between the logistics costs that should be made versus the marketing aspects. Marketing aspects could be the lack of revenues because customers will not order a certain product at Océ anymore but they will order a product from the competitor.
To be able to estimate the costs more accurate, classifying the components into categories may help. First, variables for the categories should be defined. Variables can be the value of components or the dimensions of components. Based on the categories, better estimations of the logistics costs can be made which will lead to a more accurate estimation of the savings that could be made.

Measuring the service level of the end products
At this moment, the service level of the end products is not measured and therefore it is not possible to measure what influence the MRP-controller can have on the system service level. It is recommended that this service level is measured by comparing the actual *standard delivery date* (the day of the entry of an order + the standard delivery time) with the actual *realized delivery date.* When this measurement shows that the actual service level is higher than the system service level and the difference is large enough to decrease the system service level without the actual service level dropping below the 97.5%, the P_2-value can drop to 0.99 or even lower, which means a decrease in safety stock value.

Updating of data in the regular stage of the life cycle of a component
In this report, a few times has been indicated that in the project stage of a product several aspects are determined, like the lot sizing method, the ABC-classification of a component and the minimum order quantity and the packing quantity. Because the project stage differs significantly from the regular stage of a product, as can be seen in the current situation. It is recommended to update the data of a component in the regular stage of a product.

Also in the redesign, data have to be updated. When calculating the safety stock, the c-value is equal to 0.75. But this value has to be recalculated regularly, because when the standard deviation of the forecast error will change, this value will change too. Calculating with a wrong c-value will lead to incorrect safety stock levels.

9.3 Reflection on the assignment

The final assignment was formulated as follows:

Analyze the current inventory control for configuration components with the focus on two aspects: - the order policy; - the safety stock. Determine the optimal order policy and the level of the safety stock per component with the purpose to minimize the inventory costs while taking into account the desired service level of 97.5% at end product level.

Related to this assignment, several research questions were formulated.

At the end of this report, a reflection is carried out to see if the assignment is fulfilled and the research questions are answered.

Another lot sizing method is proposed: the Silver-Meal heuristic. A method to calculate the safety stock is described while taking into account the forecast error of the undershoot and of the demand during the lead-time of the supplier and the variance of the lead-time. An attempt has been made to achieve a service level for the end products as close as possible to the target of 97.5% which was defined by the management. For two of the five end product, the system service level is lower than the target of 97,5%, but because of the corrective actions that can be taken by the MRP-controllers, the expectation is that the target will be achieved for all end products.

The research questions are answered too in this report. These answers can be found in chapter 5 up to 8.

When reflecting on the assignment and the research questions, the conclusion can be drawn that the assignment is fulfilled and the research questions are answered.

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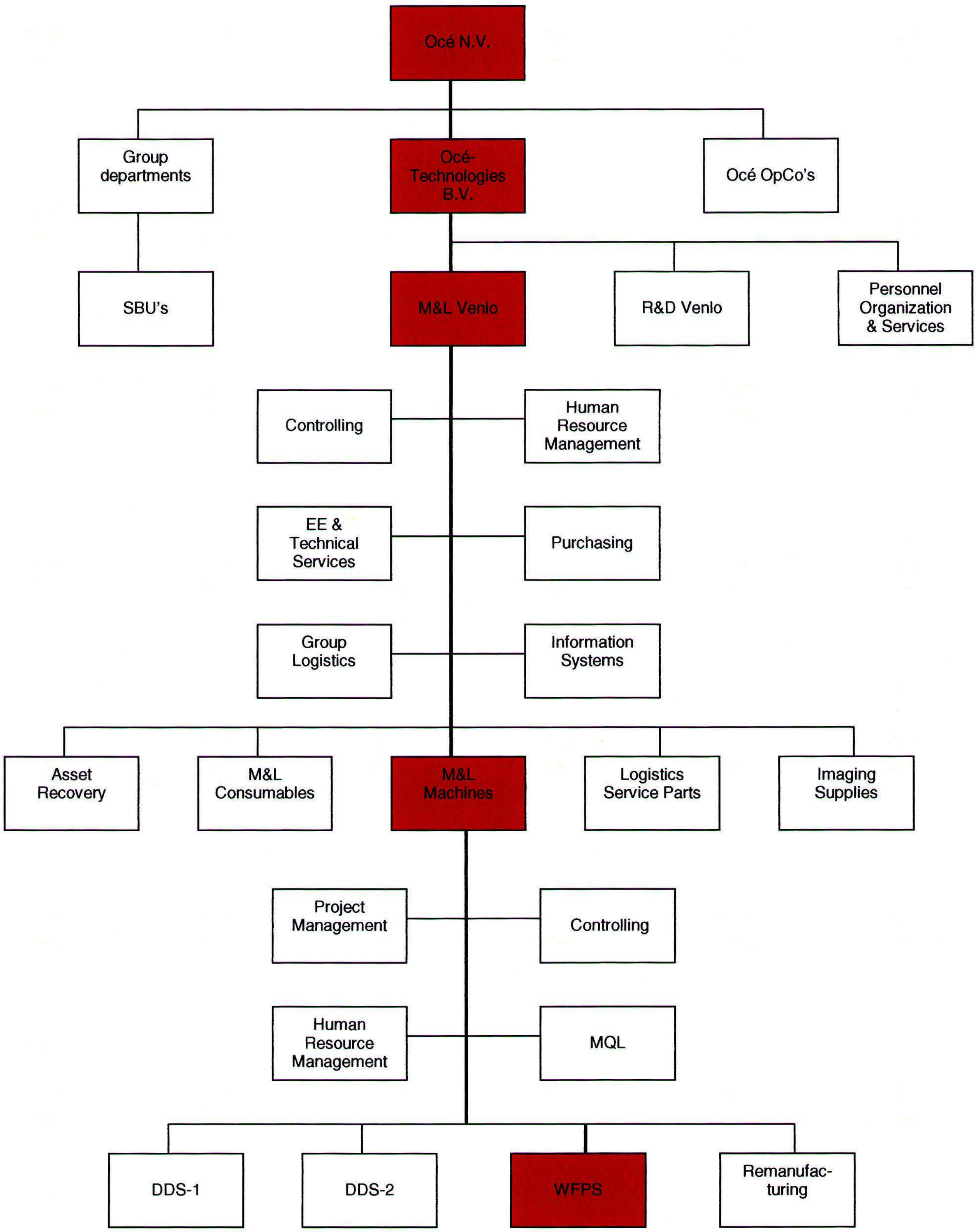
Appendices

Appendix 1 List of abbreviations

ALB	Automatische lijnbevoorrading (automatic line replenishment)
APW	Asian Pacific Warehouse
CODP	Customer Order Decoupling Point
det	Deterministic
DDS-1	Digital Document Systems 1
DDS-2	Digital Document Systems 2
DMD	Direct Machine Delivery
EOQ	Economic Order Quantity
fe	Forecast error
FML	Frans Maas Logistiek
k€	€ 1000
HV-line	High Volume line
JIT	Just-in-Time
L	Lead-time of the supplier
LV-line	Low Volume line
M&L	Manufacturing and Logistics
MQ	Manufacturing engineering and Quality assurance
MRP	Materials Requirements Planning
MV-line	Mid Volume line
OpCo	Operating Company (sales office)
P60	Warehouse where the inventory is stocked until it is needed in the assembly or configuration line
PBI	Proces, Besturing, Informatie
Placements	Deliveries from the OpCo's to end users
PLX	Single order with forecast
POQ	Periodic Order Quantity
Q	Lot size/order quantity
Q_{MIN}	Minimum order quantity
Q_{PACK}	Packing quantity
Q_{SM}	Lot size calculated with the Silver-Meal heuristic
R	Review period
R&D	Research and Development
SBU	Strategic Business Unit
ss	Safety stock
var	Variance
VC	Variation coefficient
WFPS	Wide Format Printing Systems
2Z	Cross dock where the final products are collected and sent to the OpCo's
σ	Standard deviation

Appendix 2 Organization diagram Océ N.V.

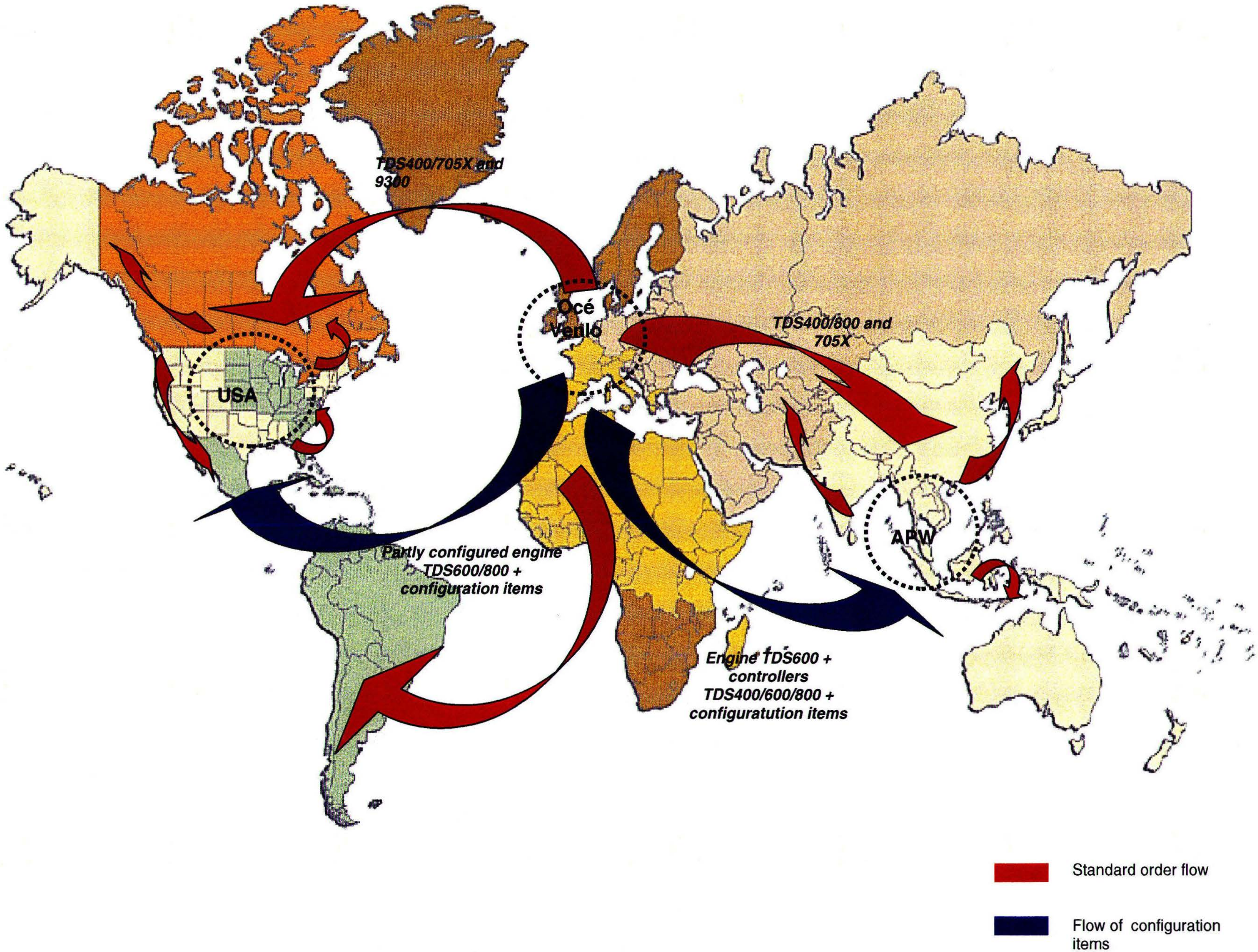


Appendix 3 WFPS Products

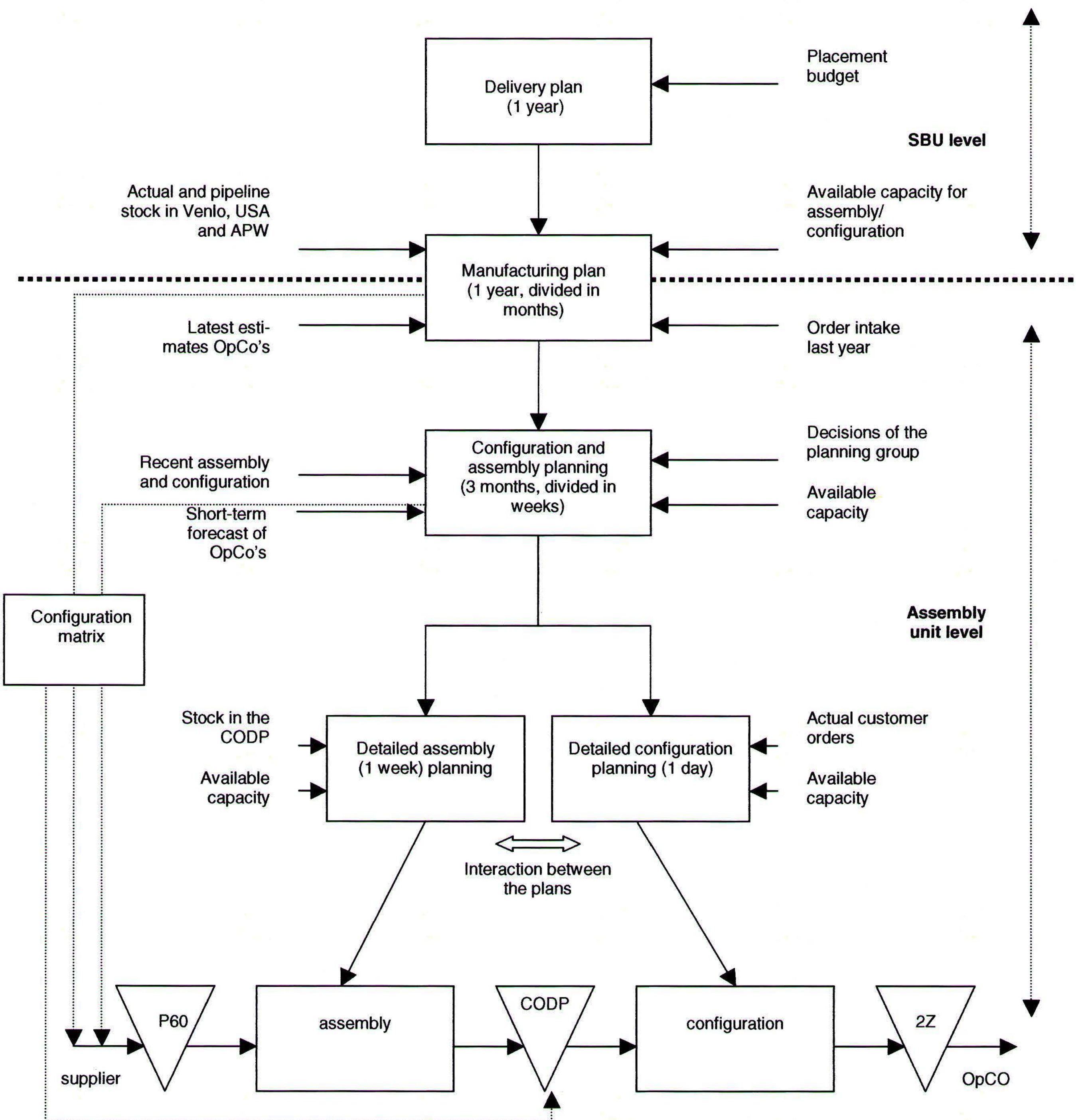
business group	product category	product name	description	speed
technical documentation systems	black/ white systems	Océ TDS800	wide format digital print/copier system for high volumes	13 metres/minute
		Océ TDS600	wide format digital print/copier system for mid volumes	5 metres/minute
		Océ TDS400	wide format digital print/copier system for low volumes	2 metres/minute
		Océ 9300	wide format printer for low volumes	2 metres/minute
		Océ 7050	analogous wide format copier system	3 metres/minute
	color systems	Océ TCS400	low volume, wide format printer for color and black/white printing	21 square metres/hour (color); 41 square metres/hour (black/white)
		Océ 5250	low volume color inkjet printer	not applied here
	software	Océ print Exec Pro	print management software for printer control and sending print tasks to several printers and/or one or several recipients	not applied here
		Doc Exec Pro	software for importing, controlling and distributing of released technical documents	not applied here
		Océ Repro Desk	software for repro-graphs for electronic receiving and processing of wide format print tasks	not applied here
		Océ Plan Center	software for publishing drawings of buildings on a protected website. Partners can order prints of these drawings.	not applied here
		Océ Print Exec LT	software for making and sending print tasks	not applied here
	scanners	Océ CS4025/4035	25"/36" wide color scanner	not applied here
		Océ CS4040/ 4050	40"/50" wide color scanner	not applied here
		Océ CS4020/ 4030	25"/36" wide black/white scanner	not applied here
		Océ color Copy	software for making wide format color copies and scans	not applied here

business group	product category	product name	description	speed
display graphics systems	printers	Seiko IP4500	wide format color inkjet printer for promotion applications (inside and outside)	until 37 square metres/hour
		Océ 5090	wide format color inkjet printer for promotion applications (inside)	until 12.4 square metres/hour
		Océ lightjet 500XL	excess wide productive wide format photo laser printer	until 45 square metres/hour
		Océ lightjet 430	productive wide format photo laser printer	until 40 square metres/hour
		Arizona T220	flatbed inkjet printer for printing non flexible materials with a thickness till 5 cm	until 16 square metres/hour
		Arizona 500	inkjet printer for excess wide format promotion applications (outside)	until 46.5 square metres/hour
		Arizona 180	inkjet printer for wide format promotion applications (outside)	until 16.7 square metres/hour
		Arizona 90	inkjet printer for wide format promotion applications (outside)	until 8.36 square metres/hour
		Arizona 30-s	inkjet printer for wide format promotion applications (outside)	more than 2.7 square metres/hour
software	onyx poster-shop	RIP-software	for wide format promotion print tasks	not applied here

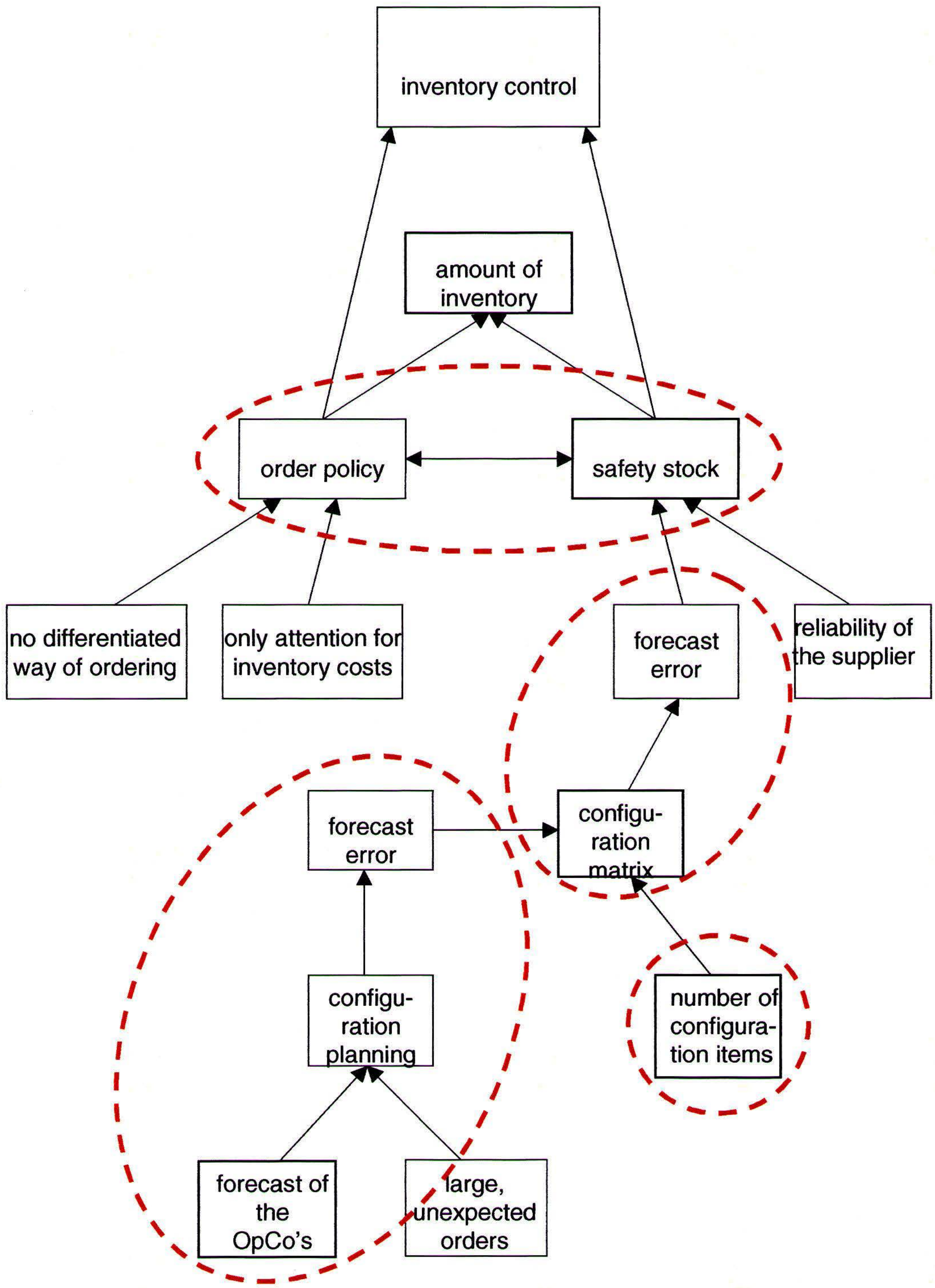
Appendix 4 Order flow WFPS products



Appendix 5 Planning structure



Appendix 6 Relations between the different research areas



Appendix 7 Forecast error on product-family level

Table 7A Forecast error 9300

month	forecast	order intake	forecast error
June	46	26	-20
July	42	39	-3
August	43	21	-22
September	38	31	-7
October	44	32	-12
November	80	38	-42
December	27	33	6
January	36	39	3
February	36	42	6
March	37	32	-5
April	55	33	-22
total	484	366	-118
structural forecast error	-10.72		
standard deviation	14.72		
variation coefficient	0.44		

Table 7B Forecast error 705X

month	forecast	order intake	forecast error
June	299	236	-63
July	295	294	-1
August	268	270	2
September	336	238	-98
October	282	216	-66
November	279	348	69
December	229	173	-56
January	267	171	-96
February	284	191	-93
March	279	236	-43
April	261	200	-61
total	3079	2573	-506
structural forecast error	-46.00		
standard deviation	50.88		
variation coefficient	0.22		

Table 7C *Forecast error TDS400*

month	forecast	order intake	forecast error
June	290	292	2
July	312	361	49
August	312	315	3
September	293	179	-114
October	294	268	-26
November	369	376	7
December	253	276	-7
January	289	187	-102
February	277	230	-47
March	246	193	-53
April	255	329	74
total	3193	2976	-214
structural forecast error	-19.45		
standard deviation	57.37		
variation coefficient	0.21		

Table 7D *Forecast error TDS600*

month	forecast	order intake	forecast error
June	145	126	-19
July	126	98	-28
August	121	124	3
September	152	100	-52
October	158	136	-22
November	146	143	-3
December	99	133	34
January	110	67	-43
February	129	68	-61
March	114	113	-1
April	128	101	-27
total	1428	1209	-219
structural forecast error	-19.91		
standard deviation	27.29		
variation coefficient	0.25		

Table 7E *Forecast error TDS800*

month	forecast	order intake	forecast error
June	36	26	-10
July	31	24	-12
August	32	33	1
September	38	23	-15
October	44	22	-22
November	48	45	-3
December	25	18	-7
January	29	14	-15
February	34	17	-17
March	20	8	-12
April	15	25	10
total	352	255	-97
structural forecast error	-8.81		
standard deviation	9.05		
variation coefficient	0.39		

Appendix 8 Forecast error per order flow

Table 8A Forecast error DMD-countries

product-family	forecast[5]	order intake	structural forecast error	standard deviation	variation coefficient
9300	381	311	-6.36	14.51	0.51
705X	1250	1092	-14.36	32.61	0.33
TDS400	1826	1613	-19.36	60.07	0.41
TDS600	771	593	-16.18	26.70	0.50
TDS800	58	47	-1.00	3.79	0.89

Table 8B Forecast error Océ USA

product-family[6]	forecast[7]	order intake	structural forecast error	standard deviation	variation coefficient
705X	1459	1389	-11.53	55.31	0.68
TDS400	2046	2036	-0.59	46.79	0.39
TDS600	875	864	-0.79	21.20	0.42
TDS800	299	223	-4.75	7.64	0.58

Table 8C Forecast error APW

product-family	forecast[8]	order intake	structural forecast error	standard deviation	variation coefficient
9300	191	111	-17.25	17.02	1.84
705X	599	392	-6.67	10.79	0.33
TDS400	536	412	-10.33	13.92	0.41
TDS600	207	166	-3.42	6.49	0.47
TDS800	30	26	-0.33	2.81	1.30

[5] The total forecast and order intake is calculated over the time-period June 2002 – May 2003;
[6] The 9300 is not delivered anymore to Océ USA;
[7] The total forecast and order intake is calculated over the time-period January 2002 – May 2003. The total forecast and order intake for the TDS600 is calculated over the time-period April 2002 – May 2003. Earlier data were not available. The order intake data of the TDS600 were replaced by the shipment data, because the order intake data were not available;
[8] The total forecast and order intake is calculated over the time-period June 2002 – May 2003.

Appendix 9 Forecast error of the configuration planning

Table 9A Forecast error 705X

week	forecast	actual demand	forecast error
49	75	80	5
50	75	98	23
51	70	108	38
52	25	11	-14
2	75	81	6
3	75	68	-7
4	75	75	0
5	75	62	-13
6	70	52	-18
7	70	53	-17
8	70	61	-9
9	70	59	-11
10	40	32	-8
11	65	79	14
12	65	90	25
13	65	91	26
14	75	79	4
15	70	61	-9
16	75	77	2
17	60	26	-34
18	60	44	-16
19	75	91	16
20	70	74	4
21	75	59	-16
22	40	38	-2
23	70	63	-7
24	55	60	5
25	70	63	-7
26	70	50	-20
27	50	30	-20
28	50	24	-26
29	50	55	5
30	50	36	-14
31	35	55	20
total	2160	2085	-75
structural forecast error	-2.21		
standard deviation	16.44		
variation coefficient	0.27		

Table 9B *Forecast error 9300*

week	forecast	actual demand	forecast error
49	10	16	6
50	10	4	-6
51	10	11	1
52	5	6	1
2	10	21	11
3	10	16	6
4	10	18	8
5	10	15	5
6	10	17	7
7	15	16	1
8	10	20	10
9	10	21	11
10	5	9	4
11	15	19	4
12	15	15	0
13	15	13	-2
14	15	17	2
15	15	18	3
16	15	12	-3
17	10	12	2
18	10	10	0
19	15	9	-6
20	15	3	-12
21	15	5	-10
22	5	2	-3
23	10	18	8
24	10	10	0
25	10	1	-9
26	10	5	-5
27	10	9	-1
28	10	8	-2
29	10	11	1
30	10	7	-3
31	10	7	-3
total	375	401	26
structural forecast error	0.76		
standard deviation	5.82		
variation coefficient	0.49		

Table 9C *Forecast error TDS400*

week	forecast	actual demand	forecast error
49	75	72	-3
50	75	77	2
51	70	74	4
52	30	14	-16
2	75	57	-18
3	75	83	8
4	75	65	-10
5	75	69	-6
6	45	42	-3
7	55	42	-13
8	70	75	5
9	70	62	-8
10	35	39	4
11	70	76	6
12	70	56	-14
13	70	69	-1
14	70	71	1
15	75	84	9
16	70	89	19
17	65	72	7
18	65	62	-3
19	70	61	-9
20	75	71	-4
21	70	76	6
22	35	44	9
23	70	60	-10
24	60	66	6
25	70	97	27
26	70	91	21
27	65	67	2
28	65	47	-18
29	65	23	-42
30	65	45	-20
31	35	61	26
total	2195	2159	-36
structural forecast error	-1.06		
standard deviation	14.01		
variation coefficient	0.22		

Table 9D *Forecast error TDS600*

week	forecast	actual demand	forecast error
49	35	43	8
50	35	36	1
51	30	42	12
52	10	8	-2
2	35	36	1
3	35	34	-1
4	35	33	-2
5	35	34	-1
6	35	32	-3
7	35	34	-1
8	35	26	-9
9	35	25	-10
10	20	8	-12
11	28	13	-15
12	28	15	-13
13	28	15	-13
14	25	18	-7
15	25	19	-6
16	25	15	-10
17	25	29	4
18	20	28	8
19	25	31	6
20	25	21	-4
21	25	32	7
22	15	18	3
23	25	21	-4
24	20	20	0
25	25	34	9
26	25	37	12
27	30	28	-2
28	30	32	2
29	30	38	8
30	25	38	13
31	15	41	26
total	929	934	5
structural forecast error	0.15		
standard deviation	8.96		
variation coefficient	0.33		

Table 9E *Forecast error TDS800*

week	forecast	actual demand	forecast error
49	7	7	0
50	7	8	1
51	7	8	1
52	7	1	-6
2	5	3	-2
3	5	2	-3
4	5	2	-3
5	5	1	-4
6	5	1	-4
7	5	4	-1
8	5	3	-2
9	5	3	-2
10	3	2	-1
11	5	4	-1
12	5	6	1
13	5	5	0
14	5	5	0
15	5	4	-1
16	5	1	-4
17	4	0	-4
18	4	4	0
19	3	4	1
20	3	3	0
21	3	3	0
22	2	0	-2
23	4	8	4
24	3	3	0
25	4	3	-1
26	4	4	0
27	4	2	-2
28	4	6	2
29	4	3	-1
30	4	7	3
31	3	7	4
total	154	127	-27
structural forecast error	-0.79		
standard deviation	2.28		
variation coefficient	0.61		

Appendix 10 The forecast error of the configuration matrix

component	structural forecast error with forecasted configuration	structural forecast error with actual configuration	structural forecast error caused by the configuration planning	average usage per month	standard deviation	variation coefficient
2954831	-446.77	-401.32	-45.45	4589.00	1875.84	0.41
2955100	-6.36	-29.12	22.76	474.13	166.44	0.35
2955124	-4.94	4.56	-9.50	201.38	43.51	0.22
2977814	-3.08	-0.67	-2.41	42.88	8.72	0.20
2978089	-4.28	2.36	-6.63	66.38	36.18	0.55
2978181	-65.97	-53.10	-12.88	919.13	266.81	0.29
2999732	-8.15	-7.57	-0.58	5.63	14.82	2.63
2999826	-26.26	-13.82	-12.44	437.75	88.57	0.20
3913035	-10.71	-11.19	0.48	4.50	14.34	3.19
3925000	5.60	2.35	3.25	110.88	21.59	0.19
3925007	-18.21	-21.09	2.88	77.50	59.68	0.77
3925009	1.50	1.41	0.09	3.50	3.72	1.06
3936350	0.60	0.56	0.05	13.75	10.52	0.76
3936352	2.44	2.55	-0.11	3.88	10.11	2.61
3936353	5.09	5.03	0.06	8.00	13.08	1.64
3936695	-1.36	-1.28	-0.08	2.38	4.36	1.84
3936795	0.00	0.00	0.00	0.00	0.00	[9]
3985011	-0.90	2.16	-3.06	16.00	4.87	0.30
3985020	-34.58	-17.61	-16.98	7.25	44.59	6.15
3985030	0.06	1.03	-0.97	6.00	4.44	0.74
3985040	0.46	0.67	-0.21	1.63	1.84	1.13
5630033	-4.94	4.56	-9.50	201.38	43.51	0.22
5630034	-4.94	4.56	-9.50	201.38	43.51	0.22
5630042	7.29	3.13	4.16	27.75	13.59	0.49
5630043	4.25	1.20	3.05	20.13	11.07	0.55
5630044	0.11	1.90	-1.78	17.00	8.21	0.48
5630053	18.24	15.30	2.94	100.75	27.71	0.28
5630055	5.19	-2.88	8.08	228.50	69.07	0.30
5630056	7.82	-1.00	8.82	250.63	65.56	0.26
5630057	-8.65	1.26	-9.91	92.38	32.25	0.35
5630058	-7.83	-1.03	-6.80	61.13	24.95	0.41
5630911	0.11	1.90	-1.78	17.00	8.21	0.48
5630912	0.11	1.90	-1.78	17.00	8.21	0.48
7013354	3.44	5.15	-1.70	57.63	22.26	0.39
7013594	-2.81	-0.54	-2.27	10.50	8.28	0.79
7013595	3.81	5.61	-1.79	12.50	9.55	0.76
7013683	1.14	1.98	-0.85	26.50	9.47	0.36
7013697	-0.12	-0.07	-0.05	1.88	1.43	0.76
7013698	-0.20	-0.25	0.04	1.13	2.04	1.81

[9] The variation coefficient cannot be calculated in this case because the actual usage is zero. This is also valid for the other components when no variation coefficient is given.

component	structural forecast error with forecasted configuration	structural forecast error with actual configuration	structural forecast error caused by the configuration planning	average usage per month	standard deviation	variation coefficient
7013702	0.04	0.13	-0.09	1.38	1.32	0.96
7013703	0.36	0.40	-0.04	1.38	1.69	1.23
7013704	-0.56	-0.56	0.00	0.88	1.59	1.82
7013705	-0.12	-0.12	0.00	0.00	0.13	
7013866	0.23	0.24	-0.01	2.38	4.73	1.99
7013886	0.23	0.24	-0.01	2.38	4.73	1.99
7014051	0.03	0.08	-0.05	0.25	0.50	2.01
7014052	-4.10	-2.13	-1.97	6.63	9.29	1.40
7014107	-0.04	-0.04	0.00	0.00	0.06	
7014108	-0.02	-0.02	0.00	0.00	0.02	
7014109	-0.02	-0.02	0.00	0.00	0.02	
7014213	-0.84	-0.29	-0.56	3.13	4.87	1.56
7029156	-5.12	-9.08	3.96	378.88	105.93	0.28
7033530	3.36	4.47	-1.11	7.88	6.79	0.86
7033531	-0.53	-0.20	-0.33	1.50	2.76	1.84
7033534	3.36	4.47	-1.11	7.88	6.79	0.86
7033535	-4.54	-2.63	-1.92	6.63	8.70	1.31
7033537	-4.54	-2.63	-1.92	6.63	8.70	1.31
7045004	-4.28	-7.05	2.78	5.38	18.54	3.45
7048550	-4.94	4.56	-9.50	201.38	43.51	0.22
7048599	-4.94	4.56	-9.50	201.38	43.51	0.22
7048600	4.25	1.20	3.05	20.13	11.07	0.55
7048600	-4.94	4.56	-9.50	201.38	43.51	0.22
7048661	16.64	-2.08	18.71	449.17	130.67	0.29
7055817	10.72	15.37	-4.64	52.00	37.72	0.73
7055827	-0.27	-0.25	-0.02	0.00	0.29	
7055828	-0.92	-0.71	-0.21	1.00	1.83	1.83
7055829	-0.36	-0.32	-0.04	0.13	0.67	5.33
7078640	-0.07	-0.03	-0.04	1.13	2.91	2.59
7078649	-4.77	-4.60	-0.17	0.00	5.19	
7083690	-0.13	4.37	-4.50	41.38	28.56	0.69
7083691	-13.69	-3.56	-10.13	89.13	26.70	0.30
7083692	-9.87	-2.86	-7.01	62.25	26.06	0.42
7083695	2.12	5.99	-3.87	40.13	8.94	0.22
7083717	0.11	1.90	-1.78	17.00	8.21	0.48
7083723	7.82	-1.00	8.82	250.63	65.56	0.26
7083724	7.82	-1.00	8.82	250.63	65.56	0.26
7083762	22.00	19.38	2.63	26.88	44.04	1.64
7092873	6.75	8.50	-1.76	12.25	15.03	1.23
7093139	-1.54	-2.63	1.09	61.63	19.74	0.32
7094089	3.50	1.39	2.11	55.75	10.64	0.19
7094355	-16.48	0.23	-16.71	153.50	52.63	0.34
7094368	0.11	1.90	-1.78	17.00	8.21	0.48
7094380	-14.83	0.96	-15.78	239.50	55.50	0.23
7094381	-82.87	-42.13	-40.74	869.13	298.12	0.34
7094382	15.02	4.97	10.05	253.78	68.76	0.27
7094402	-8.94	3.38	-12.33	111.38	54.19	0.49

component	structural forecast error with forecasted configuration	structural forecast error with actual configuration	structural forecast error caused by the configuration planning	average usage per month	standard deviation	variation coefficient
7094406	-0.81	-0.50	-0.31	2.25	2.93	1.30
7094407	-0.66	0.34	-1.00	9.88	5.48	0.55
7094408	-2.96	-2.52	-0.44	1.75	3.57	2.04
7094409	-0.69	-0.52	-0.17	6.63	4.50	0.68
7094410	-2.04	-0.84	-1.20	11.13	6.85	0.62
7094411	0.20	0.20	0.00	0.88	1.00	1.15
7094412	-0.92	-2.44	1.52	12.75	6.42	0.50
7094417	-10.17	-4.35	-5.81	50.13	22.92	0.46
7094419	11.78	8.28	3.50	23.51	19.22	0.82
7094420	-0.30	-0.64	0.34	1.88	1.86	0.99
7094422	0.48	0.41	0.08	0.75	1.69	2.25
7094425	0.05	0.02	0.04	0.38	0.53	1.41
7094426	-0.08	-0.28	0.21	0.75	1.47	1.96
7094427	-2.10	-3.00	0.89	2.63	3.03	1.15
7094428	-0.22	-0.22	0.00	0.25	0.62	2.48
7094429	0.48	0.41	0.08	0.75	1.69	2.25
7094430	1.13	0.78	0.35	2.50	1.99	0.80
7094431	-0.72	-0.59	-0.13	0.00	1.58	
7094432	0.86	0.50	0.36	2.88	2.91	1.01
7094509	-0.07	-0.07	0.00	0.00	0.08	
7094510	-0.07	-0.07	0.00	0.00	0.08	
7094511	-0.30	-0.64	0.34	1.88	1.86	0.99
7094512	12.05	8.07	3.98	29.75	19.14	0.64
7094514	-2.10	-3.00	0.89	2.63	3.03	1.15
7094518	0.48	0.41	0.08	0.75	1.69	2.25
7094520	-0.22	-0.22	0.00	0.25	0.62	2.48
7094526	-4.28	2.36	-6.63	66.38	36.18	0.55
7094527	-1.29	-1.15	-0.14	0.25	1.65	6.58
7094532	-1.29	-1.15	-0.14	0.25	1.65	6.58
7094537	0.18	0.05	0.13	0.50	1.58	3.15
7094543	0.48	0.41	0.08	0.75	1.69	2.25
7094544	-0.08	-0.28	0.21	0.75	1.47	1.96
7094545	-2.10	-3.00	0.89	2.63	3.03	1.15
7094546	0.86	0.50	0.36	2.88	2.91	1.01
7094548	11.93	7.34	4.59	34.75	18.07	0.52
7095065	0.23	0.24	-0.01	2.38	4.73	1.99
7095325	1.13	1.08	0.05	3.50	3.64	1.04
7097681	-3.09	-0.34	-2.75	12.38	8.82	0.71
7114121	-0.39	0.12	-0.51	4.75	3.10	0.65
7114122	0.13	1.30	-1.17	13.13	7.62	0.58
7114123	-2.04	-0.84	-1.20	11.13	6.85	0.62
7114124	-6.67	-1.86	-4.81	40.00	26.49	0.66
7114125	-0.58	0.27	-0.85	8.38	5.30	0.63
7114126	-0.21	-0.18	-0.03	0.13	0.46	3.69
7114127	-0.35	-0.15	-0.20	1.63	2.41	1.48
7114128	0.14	0.18	-0.04	0.50	0.92	1.83
7114129	-0.08	0.06	-0.14	1.50	0.78	0.52

component	structural forecast error with forecasted configuration	structural forecast error with actual configuration	structural forecast error caused by the configuration planning	average usage per month	standard deviation	variation coefficient
7114130	-9.45	-3.76	-5.69	50.13	23.13	0.46
7114131	-0.82	-0.55	-0.27	1.88	2.53	1.35
7114132	0.11	0.15	-0.03	0.38	0.96	2.56
7114419	-0.31	-0.14	-0.17	1.38	1.41	1.03
7128954	-14.86	-31.02	16.15	431.75	166.18	0.38
7128969	-50.10	-85.36	35.26	921.13	387.49	0.42
7128970	-14.83	0.96	-15.78	239.50	55.50	0.23
7128999	-40.34	-48.78	8.44	337.96	153.86	0.46
7136534	-2.52	-2.78	0.26	13.00	12.67	0.97
7136535	-3.65	-4.10	0.44	22.00	18.31	0.83
7136536	-0.54	-0.63	0.09	2.38	1.67	0.70
7136537	0.42	0.18	0.24	8.13	4.41	0.54
7136538	0.19	0.20	-0.01	0.50	1.07	2.14
7136541	-0.28	-0.26	-0.01	0.88	1.46	1.66
7136542	2.48	2.37	0.10	10.50	6.18	0.59
7136544	-0.29	-0.29	0.00	0.13	0.48	3.88
7136545	-0.29	-0.29	0.00	0.13	0.48	3.87
7136940	0.13	1.30	-1.17	13.13	7.62	0.58
7136942	-10.52	-4.91	-5.61	45.50	30.74	0.68
7136948	-9.45	-3.76	-5.69	50.13	23.13	0.46
7136952	8.04	13.07	-5.02	53.13	36.61	0.69
7136958	5.18	6.12	-0.94	16.25	18.96	1.17
7165930	12.03	6.19	5.85	40.13	17.48	0.44
7165931	0.21	0.07	0.14	1.13	1.47	1.31
7165932	-0.72	-0.59	-0.13	0.00	1.58	
7165933	-0.05	-0.05	0.01	0.00	0.05	
7165934	-0.05	-0.05	0.01	0.00	0.05	
7166360	0.23	0.24	-0.01	2.38	4.73	1.99
7166620	-8.08	-15.97	7.89	228.50	77.34	0.34
7218940	4.62	6.43	-1.81	61.63	22.63	0.37
7218948	-2.34	1.26	-3.61	17.38	9.07	0.52
7219010	10.92	4.92	6.00	41.25	16.70	0.40
7219064	11.42	5.36	6.06	41.38	17.09	0.41
7225742	-8.92	-8.68	-0.24	0.88	10.76	12.30
76500030	4.03	4.59	-0.57	11.88	11.67	0.98
1060000980	-9.93	-18.69	8.77	234.75	72.97	0.31
1060002098	-6.60	-10.06	3.46	309.25	94.78	0.31
2945263	-63.97	-56.49	-7.48	79.43	136.65	1.72
2945264	-235.43	-225.28	-10.15	389.14	383.26	0.98
2945265	-13.82	-13.09	-0.73	5.57	20.28	3.64
2954831	-35.94	-25.37	-10.57	243.43	150.61	0.62
2977977	-4.84	-2.49	-2.35	40.00	25.34	0.63
2978088	-21.15	-2.91	-18.24	187.57	43.87	0.23
3936351	-11.20	-11.23	0.03	0.00	12.64	
5630054	133.48	131.60	1.89	170.86	150.83	0.88
7013693	-0.53	-0.27	-0.26	3.71	2.16	0.58
7013694	-0.04	0.37	-0.41	6.43	3.08	0.48

component	structural forecast error with forecasted configuration	structural forecast error with actual configuration	structural forecast error caused by the configuration planning	average usage per month	standard deviation	variation coefficient
7013699	0.14	0.15	-0.01	0.71	1.20	1.67
7013700	-0.19	-0.13	-0.06	0.57	0.68	1.19
7013706	0.01	0.05	-0.04	0.71	0.70	0.97
7013899	0.22	0.58	-0.36	2.71	5.59	2.06
7014028	0.70	1.11	-0.41	2.00	2.68	1.34
7048549	-19.18	-7.70	-11.48	221.43	37.54	0.17
7048551	-38.36	-15.40	-22.95	442.86	75.07	0.17
7048692	-38.36	-15.40	-22.95	442.86	75.07	0.17
7055826	7.09	8.41	-1.33	21.14	18.66	0.88
7070374	-78.24	-32.66	-45.58	1030.29	278.58	0.27
7092959	4.42	7.88	-3.46	14.29	10.21	0.71
7093824	0.44	3.39	-2.95	8.43	8.20	0.97
7094088	0.14	0.33	-0.19	12.57	4.10	0.33
7094353	-1.43	3.23	-4.66	53.43	36.29	0.68
7094379	192.78	207.02	-14.25	549.71	218.78	0.40
7094385	-22.54	-4.66	-17.88	268.86	47.08	0.18
7094400	-5.49	-3.91	-1.58	13.29	8.83	0.66
7094404	-3.86	3.39	-7.25	79.29	31.41	0.40
7094413	-7.63	-3.67	-3.96	93.71	34.89	0.37
7094414	-0.11	0.44	-0.55	12.71	5.42	0.43
7094416	0.27	0.10	0.17	4.00	0.88	0.22
7094418	-0.20	-0.22	0.02	2.43	1.93	0.80
7094515	0.71	0.46	0.26	3.00	3.08	1.03
7094516	-0.20	-0.36	0.17	0.71	1.43	2.00
7094517	-0.24	-0.11	-0.12	0.00	0.48	
7094519	0.11	0.10	0.01	0.43	0.52	1.22
7094523	-7.85	-6.36	-1.50	10.29	21.76	2.12
7094525	-12.41	3.51	-15.92	168.57	28.71	0.17
7094562	-8.25	5.27	-13.52	239.71	47.75	0.20
7094896	0.22	0.58	-0.36	2.71	5.59	2.06
7094976	430.64	423.37	7.27	561.71	475.62	0.85
7095127	424.36	419.61	4.75	569.71	469.73	0.82
7095401	-35.84	-21.77	-14.07	333.71	96.86	0.29
7165930	-0.20	-0.36	0.17	0.71	1.43	2.00
7166721	-0.69	0.46	-1.15	2.71	4.26	1.57
7170656	0.85	0.99	-0.15	1.29	2.05	1.59
7170742	-8.19	-4.42	-3.77	3.29	10.08	3.07
7170910	-7.35	6.01	-13.36	31.57	32.08	1.02
7170911	-105.83	-43.14	-62.69	5.71	125.78	22.01
7171048	-0.40	0.24	-0.64	1.43	1.96	1.37
7171049	-0.13	0.29	-0.42	1.00	2.19	2.19
7171051	0.00	0.36	-0.36	1.00	1.08	1.08
7171052	-0.04	-0.03	-0.01	0.00	0.04	
7171053	-0.11	0.00	-0.11	0.14	0.56	3.94
7171056	-0.25	0.02	-0.27	0.57	1.58	2.77
7171058	-0.02	-0.01	-0.01	0.00	0.02	
7171059	-0.02	-0.01	-0.01	0.00	0.02	

component	structural forecast error with forecasted configuration	structural forecast error with actual configuration	structural forecast error caused by the configuration planning	average usage per month	standard deviation	variation coefficient
7171065	-0.10	0.35	-0.46	1.14	2.05	1.80
7171066	0.70	1.03	-0.34	1.71	2.52	1.47
7171074	-6.76	-4.06	-2.70	1.86	7.83	4.22
7171490	-4.00	3.29	-7.29	17.86	11.45	0.64
7174710	-15.84	-15.70	-0.14	8.00	23.40	2.93
7174955	-0.10	0.06	-0.16	2.14	1.47	0.69
7174956	-4.74	0.29	-5.04	21.14	9.88	0.47
7174957	-0.52	1.00	-1.53	25.86	6.92	0.27
7174969	-15.24	-7.18	-8.06	128.86	82.77	0.64
7175083	-0.31	-0.16	-0.15	0.43	0.66	1.53
7175664	-22.22	-6.94	-15.28	345.86	94.40	0.27
7176024	-60.46	-55.03	-5.42	365.71	210.41	0.58
7176341	-35.84	-21.77	-14.07	333.71	96.86	0.29
7176342	-3.01	4.42	-7.43	19.29	11.79	0.61
7176343	-8.86	-1.57	-7.29	13.00	19.79	1.52
7177838	6.34	6.60	-0.26	12.14	14.94	1.23
7208553	-22.22	-6.94	-15.28	345.86	94.40	0.27
7209330	-0.56	-0.55	-0.01	0.00	0.60	
7209682	-0.28	-0.27	0.00	0.00	0.30	
7225303	3.30	5.22	-1.92	8.86	7.90	0.89
7225304	-8.19	-4.42	-3.77	3.29	10.08	3.07
7225305	3.30	5.22	-1.92	8.86	7.90	0.89
7225306	-8.19	-4.42	-3.77	3.29	10.08	3.07
7225307	1.72	2.43	-0.71	3.86	4.01	1.04
7225433	0.15	1.07	-0.92	2.71	3.64	1.34
7225564	1.72	2.43	-0.71	3.86	4.01	1.04
1060000364	-3.40	-2.75	-0.65	12.00	11.53	0.96
2945254	-6.63	-5.00	-1.63	43.00	14.00	0.33
2945259	-10.63	-8.99	-1.65	61.33	20.15	0.33
2945266	-60.27	-55.17	-5.10	32.67	86.26	2.64
7013707	0.05	0.07	-0.01	2.17	0.71	0.33
7013773	-1.66	-0.94	-0.72	28.00	2.37	0.08
7055819	12.19	6.51	5.68	310.17	22.14	0.07
7055820	-0.26	0.00	-0.26	9.00	1.32	0.15
7055821	-0.37	-0.11	-0.26	10.00	0.87	0.09
7055823	-0.12	-0.01	-0.10	4.17	0.51	0.12
7055824	-0.50	-0.45	-0.05	0.00	0.51	
7055825	-2.19	-1.99	-0.20	1.17	2.36	2.02
7094090	-0.85	-0.77	-0.09	65.83	3.42	0.05
7094356	-53.03	-24.01	-29.02	4051.67	114.55	0.03
7094365	-1.14	1.16	-2.30	109.50	8.97	0.08
7094366	-1.14	1.16	-2.30	109.50	8.97	0.08
7094405	-0.39	-0.32	-0.07	1.00	0.51	0.51
7095076	-30.43	-31.74	1.32	687.83	55.13	0.08
9780102	-6.05	-5.47	-0.58	75.83	12.89	0.17
9780103	-6.05	-5.47	-0.58	75.83	12.89	0.17
7055818	-1.66	-0.47	-1.19	0.00	0.32	

component	structural forecast error with forecasted configuration	structural forecast error with actual configuration	structural forecast error caused by the configuration planning	average usage per month	standard deviation	variation coefficient
7055822	-0.29	-0.20	-0.09	0.00	0.58	
7094403	-0.60	-0.25	-0.35	0.40	0.61	1.53
7094415	0.11	0.09	0.02	1.00	2.07	2.07
7094524	-5.21	-2.65	-2.57	4.60	4.50	0.98
7225479	-7.72	5.40	-13.12	4.60	4.50	0.98
7225522	-1.07	1.38	-2.45	3.80	3.92	1.03
7225523	-0.95	1.10	-2.05	19.00	3.92	0.21
7225524	-0.18	0.75	-0.93	8.00	3.92	0.49
7078641	0.71	1.48	-0.76	7.50	6.08	0.81
7094097	-17.59	-15.30	-2.29	84.50	32.88	0.39
7094378	-52.98	-38.73	-14.25	449.50	72.85	0.16
7094386	-30.92	-21.43	-9.49	258.00	56.86	0.22
7094399	0.37	0.89	-0.52	7.25	1.86	0.26
7094401	-3.52	-1.74	-1.78	22.75	9.92	0.44
7094521	2.29	1.64	0.65	3.75	2.73	0.73
7094522	-0.03	-0.04	0.01	0.00	0.04	
7097241	-4.77	-0.41	-4.36	5.50	5.93	1.08

Appendix 11 The selection of components and the calculation of the reliability

11.A The selection of the components

Because of the demarcation, made in section 4.2, not all components are relevant anymore. Several selections have been made to determine for which components the reliability of the configuration matrix is calculated. This selection is now explained:.

- Acquisition components: based on the demarcation made in section 4.2 the acquisition components are left out of consideration. Because acquisition components cannot be selected on the component number, they were filtered out by selecting them on MRP-controller who reordered these components;
- Components reordered by other units: WFPS uses components that are used by other units too. Dependent on which unit is the largest user, this unit makes sure that the components are reordered. Components that are reordered by other units and only used in the configuration at WFPS are left out of consideration;
- Software and licenses: software components like CD's and licenses are left out of consideration. These are treated in a special way. Beside that, licenses have a component number but are fictive components and are not kept in stock;
- Components controlled by Vendor Managed Inventory: these components are not visible in the system and the inventory control is the responsibility of the supplier;
- 'Project' components: components that are new because a new product is developed are not taken into account. Only when the component is used in other 'regular' products, the component is included in the selection;
- New components or components that will be replaced: components that are new are not taken into account. These are components that replace other components in a regular product. Also components that will be replaced and not reordered anymore are left out of consideration.

11.B The calculation of the reliability of the configuration matrix

After the selection of the components, the usage of the components has to be determined. The usage of configuration items in a particular month is converted into the usage of components. For example, in one configuration item, three identical components are used and the actual usage of this configuration item has been 10, the usage of the component has been 30. This has been done for the months October 2002 till June 2003. Earlier data were not available. Based on the lead-time of the component, this lead-time is rounded off upwards to get a lead-time in months. For example, 14 days will be one month. This rounding off has to be done because there are only monthly data available.
The lead-time is used to determine the order-month. Based on the used percentage in the order month and the forecasted amount of engines that will be configured, a forecast is made for the needed amount of components. So, when the lead-time is one month and a forecast has to be made for June, the percentage in May is needed and the forecast in May for the configured engines The calculated forecast has to be compared with the actual usage of the component. The forecast error can be calculated by subtracting the forecast from the actual usage. When the component is used in more configuration items, the total forecast and usage per month has to be determined to be able to calculate the forecast error.

From this point, the procedure is equal to the method used to calculate the forecast reliability. The structural forecast error is calculated. The structural forecast error is not calculated over the same time-periods for every component. This depends on the lead-time. When the lead-time is four months, less data are available than when the lead-time is one month. The standard deviation is calculated and the variation coefficient is calculated. When the standard deviation is calculated, the forecast error is not corrected for the bias. This is the only difference with the method to calculate the forecast reliability of the OpCo's. The standard deviation is also used to calculate the safety stock but first needs adjustments. This will be explained in subsection 5.3.4.

Appendix 12 Actual inventory level versus calculated order quantity

component	average inventory level	price	safety stock	current average lot size	order method	expected lot size	expected average lot size
2945254	206.71	5.16	0	206.71	E	100	50
2945259	74.71	19.34	0	74.71	E	120	60
2945263	857143	0.55	0	857143	E	500	250
2945264	5124	0.09	2500	2624	E	3500	1750
2945265	107.28	7.68	0	107.28	E	120	60
2945266	998.14	0.55	250	748.14	E	1000	500
2954831	43711.57	0.09	0	43711.6	E	39200	19600
2955100	5114.5	0.12	250	4864.5	E	10000	5000
2955124	471.42	3.55	0	471.42	Y	212.64	106.32
2977814	300.71	8.5	100	200.71	E	100	50
2977977	179.57	9.52	0	179.57	E	240	120
2978088	1991.42	0.25	100	1891.42	E	2000	1000
2978089	1568.42	0.39	0	1568.42	E	2000	1000
2978181	6124.85	0.13	0	6124.85	E	6000	3000
2999732	69.71	14.6	20	49.71	E	30	15
2999826	1906.42	0.49	100	1806.42	E	2000	1000
3913035	47.14	22.21	0	47.14	A	3.58	1.79
3925000	95.43	1585	60	35.43	A	26.78	13.39
3925007	145.86	1591	50	95.86	A	22.04	11.02
3925009	9.8	1691	4	5.8	A	0.94	0.47
3936350	48.29	384.6	10	38.29	A	4.56	2.28
3936351	187.57	384.4	10	177.57	A	6.82	3.41
3936352	13	407.9	0	13	A	1.44	0.72
3936353	90.28	17.43	40	50.28	X	10.6	5.3
3936354	71.28	25.88	20	51.28	A	4.2	2.1
3936695	12.67	2630	6	6.67	A	0.96	0.48
3936795	6.29	3882	2	4.29	A	0.24	0.12
3985011	38.71	5941	8	30.71	A	4.04	2.02
3985020	11.29	2827	5	6.29	A	1.92	0.96
3985030	10.29	3309	3	7.29	A	1.58	0.79
3985040	4.86	7291	2	2.86	A	0.48	0.24
5630033	211	4.63	20	191	A	45.6	22.8
5630034	210.57	4.97	20	190.57	A	45.46	22.73
5630042	26.14	314.7	0	26.14	A	2.64	1.32
5630043	36.43	405.3	0	36.43	A	2.64	1.32
5630044	18.43	166	0	18.43	A	3.64	1.82
5630053	91.71	243	25	66.71	A	24.42	12.21
5630054	182	251.3	45	137	A	36.76	18.38
5630055	441	5.6	80	361	E	360	180
5630056	424.29	5.94	80	344.29	E	360	180
5630057	57.43	356.9	0	57.43	A	24.54	12.27
5630058	47	447.6	0	47	A	15.64	7.82
5630911	184.42	7.66	0	184.42	E	300	150
5630912	193.85	7.98	0	193.85	E	300	150

component	average inventory level	price	safety stock	current average lot size	order method	expected lot size	expected average lot size
7013354	279.28	3.65	0	279.28	E	300	150
7013594	285.14	0.51	25	260.14	E	1000	500
7013595	1240.42	0.51	75	1165.42	E	1500	750
7013683	69.71	19.05	0	69.71	E	50	25
7013693	36.57	13.91	0	36.57	E	50	25
7013694	24	13.91	0	24	E	50	25
7013697	49.14	13.91	0	49.14	E	50	25
7013698	25.71	16.55	0	25.71	E	50	25
7013699	4.85	16.55	0	4.85	E	50	25
7013700	32.14	16.55	0	32.14	E	50	25
7013702	17.42	16.55	0	17.42	E	50	25
7013703	27	16.55	0	27	E	50	25
7013704	21.14	13.91	0	21.14	E	50	25
7013705	43	16.55	0	43	E	50	25
7013706	33.42	16.55	0	33.42	E	50	25
7013707	17.28	16.55	0	17.28	E	50	25
7013773	32.28	15.32	0	32.28	E	50	25
7013819	422.57	0.63	0	422.57	E	6	3
7013866	1006.71	1.91	100	906.71	E	700	350
7013886	344.57	1.52	50	294.57	E	500	250
7013899	458.57	1.32	50	408.57	E	500	250
7014028	103.14	15.68	2	101.14	E	150	75
7014051	152	2.26	0	152	E	150	75
7014052	73.85	2.26	8	65.85	E	150	75
7014107	149	9.54	0	149	E	300	150
7014108	150	9.45	0	150	E	300	150
7014109	100	9.9	0	100	E	150	75
7014213	129	9.00	0	129	E	160	80
7029156	1017.71	6.93	100	917.71	A	161.86	80.93
7033530	278	0.57	10	268	E	500	250
7033531	462.42	0.57	10	452.42	E	500	250
7033534	278	0.57	10	268	E	500	250
7033535	94.14	0.57	10	84.14	E	500	250
7033537	94.14	0.57	10	84.14	E	500	250
7045004	18258.5	0.04	0	18258.5	E	31200	15600
7048549	360.14	2.55	0	360.14	Y	181.84	90.92
7048550	375	2.55	0	375	Y	181.84	90.92
7048551	1252.71	0.30	0	1252.71	E	1500	750
7048599	273.14	6.67	0	273.14	E	204	102
7048600	222.85	6.67	0	222.85	E	204	102
7048661	466.86	4.75	100	366.86	A	122.6	61.3
7048692	749.42	1.86	0	749.42	Y	363.68	181.84
7055817	119	2.31	25	94	E	150	75
7055818	32	2.18	10	22	E	25	12.5
7055819	28	2.22	10	18	E	25	12.5
7055820	21.42	2.14	10	11.42	E	25	12.5
7055821	18.42	2.18	10	8.42	E	25	12.5
7055822	37	2.14	10	27	E	35	17.5

component	average inventory level	price	safety stock	current average lot size	order method	expected lot size	expected average lot size
7055823	7.57	2.18	0	7.57	E	5	2.5
7055824	24	1.72	10	14	E	25	12.5
7055825	33	1.72	8	25	E	25	12.5
7055826	56	2.14	0	56	E	100	50
7055827	29	2.18	0	29	E	25	12.5
7055828	21	1.84	0	21	E	35	17.5
7055829	17	1.68	0	17	E	25	12.5
7070374	2956	0.09	500	2456	E	2400	1200
7078640	482.57	58.58	5	477.57	E	72	36
7078641	41.86	107.7	5	36.86	E	40	20
7078649	2652	0.19	0	2652	E	1500	750
7083690	136.57	34.38	20	116.57	X	29.64	14.82
7083691	222.85	33.65	25	197.85	X	50.08	25.04
7083692	179.28	33.65	20	159.28	X	31.52	15.76
7083695	98.85	33.24	15	83.85	X	22.56	11.28
7083717	516.85	0.26	0	516.85	E	720	360
7083723	1523.14	1.35	150	1373.14	Z	858.24	429.12
7083724	1353.57	1.35	175	1178.57	E	960	480
7083762	369.43	1593	0	369.43	A	3.44	1.72
7092873	366.86	0.29	25	341.86	E	100	50
7092959	203	5.81	15	188	E	216	108
7093139	913.28	0.22	0	913.28	E	170	85
7093824	218.42	0.15	0	218.42	E	1000	500
7094088	638.42	4.84	0	638.42	E	500	250
7094089	299.14	4.63	0	299.14	E	500	250
7094090	492.57	4.63	0	492.57	E	500	250
7094097	437.57	4.63	0	437.57	E	500	250
7094353	148.57	10.61	0	148.57	A	16.08	8.04
7094355	212.57	11.69	0	212.57	X	81.04	40.52
7094356	908.57	1.46	50	858.57	Y	623.2	311.6
7094365	100.42	4.2	0	100.42	E	240	120
7094366	108.42	4.2	0	108.42	E	240	120
7094368	42.57	4.83	0	42.57	Y	14.56	7.28
7094378	719.28	2.9	150	569.28	X	228.04	114.02
7094379	778.14	2.9	150	628.14	X	228.4	114.2
7094380	201.57	22.79	0	201.57	A	52.82	26.41
7094381	990.14	1.89	50	940.14	X	465.96	232.98
7094382	476	11.69	150	326	X	133.68	66.84
7094385	178.71	51.43	0	178.71	A	52.82	26.41
7094386	272	50.64	0	272	A	52.82	26.41
7094399	131.42	1.49	10	121.42	E	500	250
7094400	319.42	1.49	25	294.42	E	500	250
7094401	233.14	1.43	25	208.14	E	500	250
7094402	782.57	0.92	50	732.57	E	1500	750
7094403	36	4.9	10	26	E	100	50
7094404	435.57	1.06	0	435.57	E	1000	500
7094405	41.42	4.9	10	31.42	E	100	50
7094406	45.28	4.9	10	35.28	E	100	50

component	average inventory level	price	safety stock	current average lot size	order method	expected lot size	expected average lot size
7094407	157.14	2.34	24	133.14	E	250	125
7094408	31.42	4.9	10	21.42	E	100	50
7094409	208.57	1.52	25	183.57	E	500	250
7094410	430.42	1.17	0	430.42	E	1000	500
7094411	117.42	2.21	15	102.42	E	250	125
7094412	745.14	1.13	0	745.14	E	1000	500
7094413	881.14	2.09	50	831.14	E	1000	500
7094414	259.14	1.52	25	234.14	E	500	250
7094415	140.28	2.21	10	130.28	E	250	125
7094416	358	2.56	10	348	E	200	100
7094417	563.42	1.17	0	563.42	E	1000	500
7094418	227.42	2.21	10	217.42	E	250	125
7094419	149.42	4.67	0	149.42	E	4	2
7094420	71	4.85	0	71	E	1	0.5
7094422	96.57	2.56	0	96.57	E	200	100
7094425	138.57	5.69	0	138.57	E	1	0.5
7094426	63	7.12	0	63	E	1	0.5
7094427	69.57	7.39	0	69.57	E	1	0.5
7094428	78.85	7.39	0	78.85	E	1	0.5
7094429	72.57	7.39	0	72.57	E	1	0.5
7094430	25.16	7.39	0	25.16	E	1	0.5
7094431	224.85	4.85	0	224.85	E	1	0.5
7094432	78.57	7.39	0	78.57	E	1	0.5
7094509	16	7.39	0	16	E	1	0.5
7094510	107	3.14	0	107	E	150	75
7094511	117	4.14	0	117	E	1	0.5
7094512	373.14	1.32	0	373.14	E	3	1.5
7094514	440.57	1.32	0	440.57	E	1	0.5
7094515	130.57	1.79	0	130.57	E	1	0.5
7094516	132	2.38	0	132	E	1	0.5
7094517	535.85	1.32	0	535.85	E	1	0.5
7094518	17.57	4.14	0	17.57	E	1	0.5
7094519	9.42	4.14	0	9.42	E	1	0.5
7094520	6.85	4.14	0	6.85	E	1	0.5
7094521	42.28	4.14	0	42.28	E	1	0.5
7094522	53	4.14	0	53	E	1	0.5
7094523	71.42	2.59	0	71.42	E	100	50
7094524	2479.57	0.55	0	2479.57	E	2500	1250
7094525	661	3.18	100	561	E	500	250
7094526	388.28	3.18	0	388.28	E	500	250
7094527	133	4.75	10	123	E	50	25
7094532	68	4.75	10	58	E	50	25
7094537	51.14	4.75	0	51.14	E	1	0.5
7094543	412.57	4.63	0	412.57	E	100	50
7094544	388	3.71	0	388	E	100	50
7094545	184.57	3.88	0	184.57	E	250	125
7094546	364.57	3.71	0	364.57	E	300	150
7094548	355.71	3.71	0	355.71	E	5	2.5

component	average inventory level	price	safety stock	current average lot size	order method	expected lot size	expected average lot size
7094562	2538.85	0.61	250	2288.85	E	1800	900
7094896	1137.42	0.27	250	887.42	E	2000	1000
7094976	2164.71	0.25	200	1964.71	E	3400	1700
7095065	596	6.99	200	396	Y	241.44	120.72
7095076	227.85	9.2	10	217.85	E	150	75
7095127	2084	0.15	200	1884	E	2880	1440
7095325	156.57	3.68	0	156.57	E	250	125
7095401	491	131.2	100	391	A	101.02	50.51
7097241	118.71	13.89	0	118.71	E	100	50
7097681	39.85	23.84	10	29.85	X	2.74	1.37
7114121	52.85	2.43	15	37.85	E	50	25
7114122	39.28	2.35	0	39.28	E	50	25
7114123	66.14	2.43	0	66.14	E	100	50
7114124	128.42	2.43	25	103.42	E	150	75
7114125	24.71	2.39	6	18.71	E	25	12.5
7114126	34.42	1.84	10	24.42	E	25	12.5
7114127	18.71	2.35	10	8.71	E	25	12.5
7114128	22	1.84	10	12	E	25	12.5
7114129	25.28	2.48	10	15.28	E	25	12.5
7114130	169.85	2.26	0	169.85	E	250	125
7114131	16.14	1.95	0	16.14	E	25	12.5
7114132	3.14	2.35	0	3.14	E	5	2.5
7114419	18.14	2.48	0	18.14	E	25	12.5
7128954	1922.57	0.26	200	1722.57	E	2100	1050
7128969	1214.85	2.42	150	1064.85	E	1600	800
7128970	234.71	17.72	0	234.71	A	52.98	26.49
7128999	2516.14	0.15	200	2316.14	E	3000	1500
7136534	47.42	3.82	0	47.42	E	50	25
7136535	70.28	3.82	0	70.28	E	50	25
7136536	58.29	3.89	0	58.29	E	50	25
7136537	68.14	3.98	15	53.14	E	50	25
7136538	45.42	3.34	0	45.42	E	25	12.5
7136541	18.85	3.86	0	18.85	E	25	12.5
7136542	43.14	3.9	0	43.14	E	40	20
7136544	5.85	3.94	0	5.85	E	1	0.5
7136545	25.14	3.9	0	25.14	E	25	12.5
7136940	187.25	7.13	0	187.25	E	200	100
7136942	236.28	6.01	25	211.28	E	200	100
7136948	156.85	6.5	0	156.85	E	200	100
7136952	185.14	7.7	25	160.14	E	200	100
7136958	138.42	6.01	0	138.42	E	200	100
7165930	556	0.44	0	556	E	6	3
7165931	658.57	0.44	0	658.57	E	1	0.5
7165932	590.85	0.44	0	590.85	E	1	0.5
7165933	648	0.44	0	648	E	1	0.5
7165934	642	0.44	0	642	E	1	0.5
7166360	453	3.71	100	353	E	500	250
7166620	132.83	462	0	132.83	E	63	31.5

component	average inventory level	price	safety stock	current average lot size	order method	expected lot size	expected average lot size
7166721	107.71	13.56	0	107.71	E	150	75
7170656	1.85	201.8	0	1.85	E	1	0.5
7170742	229	17.23	10	219	E	216	108
7170910	83.71	441.9	16	67.71	A	7.3	3.65
7170911	59.85	31.3	5	54.85	E	40	20
7171048	101.28	13.97	0	101.28	E	450	225
7171049	124	13.97	0	124	E	450	225
7171051	131.28	13.97	0	131.28	E	450	225
7171052	147	13.97	0	147	E	450	225
7171053	145.14	13.97	0	145.14	E	450	225
7171056	134	13.97	0	134	E	450	225
7171058	148	13.97	0	148	E	450	225
7171059	148	13.97	0	148	E	450	225
7171065	89.85	14.95	0	89.85	E	200	100
7171066	666	14.95	0	666	E	200	100
7171074	295.42	13.78	0	295.42	E	600	300
7171490	40.14	253.9	10	30.14	E	28	14
7174710	27.71	1257	0	27.71	A	1.84	0.92
7174955	43.28	27.68	12	31.28	A	0.62	0.31
7174956	74.28	17	25	49.28	A	6.42	3.21
7174957	72.85	17	25	47.85	E	10	5
7174969	174.29	154	40	134.29	A	43.98	21.99
7175083	44.85	27.68	5	39.85	A	0.22	0.11
7175664	992.71	0.4	100	892.71	E	1500	750
7176024	231.28	3.45	50	181.28	A	93.28	46.64
7176341	459.29	643	100	359.29	A	90.04	45.02
7176342	37.14	155.3	12	25.14	E	20	10
7176343	247.29	77.62	60	187.29	E	80	40
7177838	69	13.89	0	69	E	100	50
7208553	936.28	0.09	100	836.28	E	500	250
7209330	536	7.83	0	536	E	250	125
7209682	500	1.31	0	500	E	500	250
7218940	323.57	1.76	0	323.57	E	150	75
7218948	161.85	1.76	0	161.85	E	150	75
7219010	99.25	1.76	0	99.25	E	6	3
7219064	107.75	4.61	0	107.75	E	6	3
7225303	308	2.04	10	298	E	500	250
7225304	104.14	2.04	10	94.14	E	500	250
7225305	303	2.04	10	293	E	500	250
7225306	124.14	2.04	10	114.14	E	500	250
7225307	459.57	2.04	0	459.57	E	500	250
7225433	106.57	11.84	0	106.57	E	200	100
7225479	85.57	35.75	5	80.57	E	40	20
7225522	24.29	4331	2	22.29	A	1.6	0.8
7225523	36	1119	2	34	E	2	1
7225524	25.14	387.1	0	25.14	E	1	0.5
7225564	432.75	0.56	0	432.75	E	250	125
7225742	51.5	19.8	0	51.5	E	60	30

component	average inventory level	price	safety stock	current average lot size	order method	expected lot size	expected average lot size
9780102	206.5	0.01	0	206.5	E	500	250
9780103	493.25	0.01	0	493.25	E	500	250
76500030	22.25	0.45	10	12.25	E	72	36
1060000364	28.75	101.2	0	28.75	E	20	10
1060000980	306	1.76	0	306	E	150	75
1060002098	612	1.76	0	612	E	150	75

Appendix 13 Inventory value per month

The average inventory value is equal to k€ 2,643. The inventory level is not constant but varies per month, dependent on the usage and the order quantity of components. As can be seen in figure 13A, the lowest inventory value, respectively k€ 1,939 is in June and the highest value, k€ 2,983 is in April.

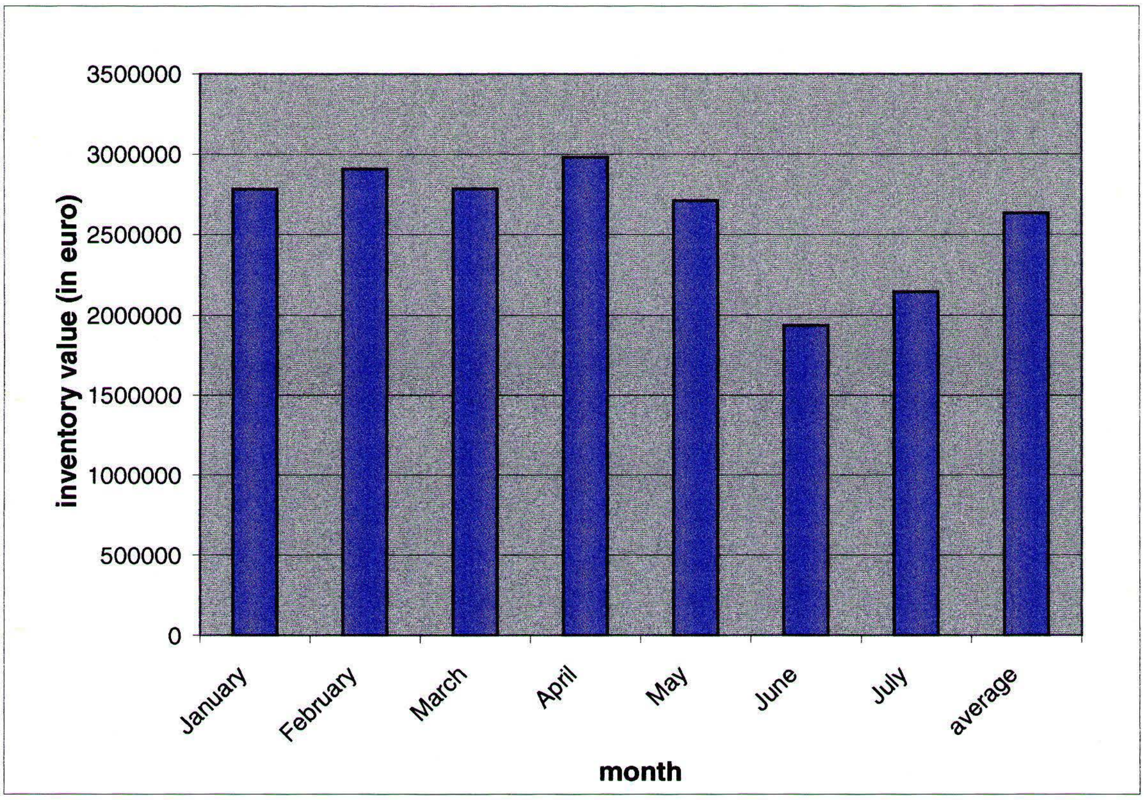


Figure 13A *Inventory value per month*

Appendix 14 Sensitivity analysis logistics costs

In section 5.4, an analysis of the costs for offering a configuration component is carried out. In this analysis several assumptions are made to give an indication of the costs per cost module. In this sensitivity analysis, changes are made in these assumptions and the influence on the final result is measured.

14.A Assumptions in the analysis

Several assumptions have been made during the analysis. A short enumeration of these assumptions will be given here:

- Costs that are made for assembly and configuration components are the same. Only when costs for configuration components are reported separately, this assumption is not valid;
- The percentage that covers the interest costs, space and risk for products becoming obsolete is defined by management at 20% per year. The assumption is made that this percentage is correct;
- The transport costs for WFPS is $^1/_3$ of the total transport costs for M&L.

In the sensitivity analysis, the assumptions are changed one at a time. When changing more than one assumption at the same time, the influence on the final result cannot be measured per assumption anymore.
The results are represented in histograms. In every figure, also the influence on the total costs will be represented. The red circle in every histogram indicates the current assumption value.

14.B The ratio between configuration and assembly components

In this part of the sensitivity analysis, the ratio between the configuration and assembly components is varied. In section 5.4, the assumption is made that the costs are the same. Now, the costs are calculated when the configuration components have 50, 150, 200, 250 and 300 percent of the costs of assembly components. This assumption is used when calculating the costs for the cost module materials handling & storage and the cost module transport. When the ratio is changed, the costs also change. This is shown in figure 14A.

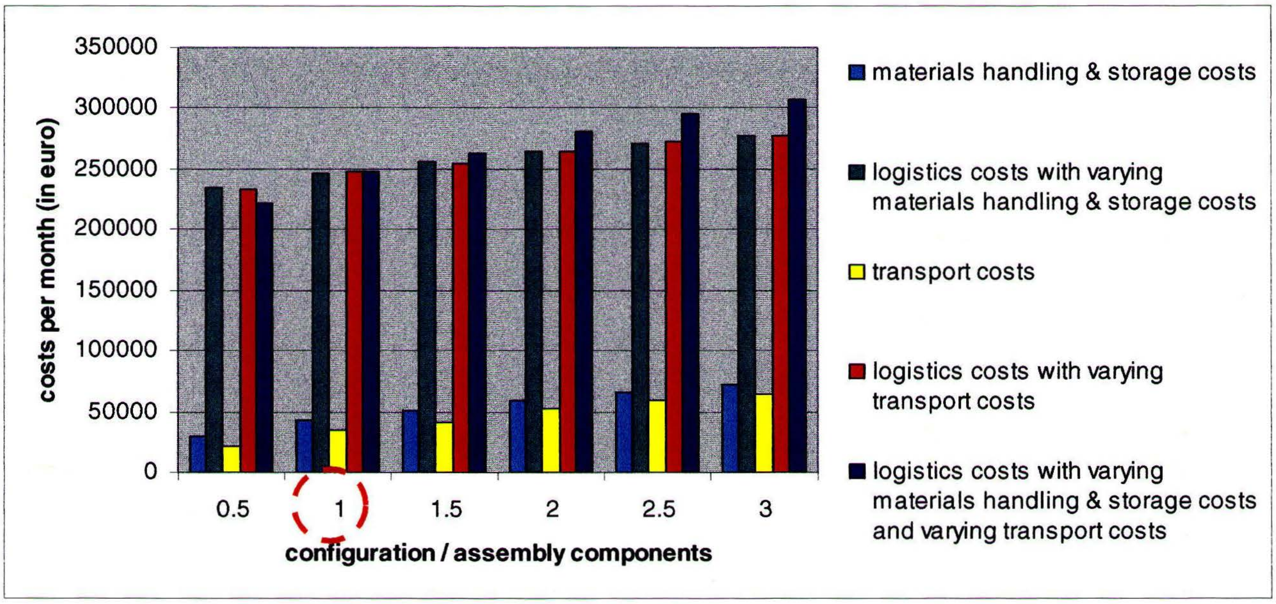


Figure 14A *Ratio between the costs for a configuration component and an assembly component*

14.C The interest costs

The percentage that is used by Océ to determine the inventory costs is 20%. Anyway, as already indicated section 5.4 it is questionable if this percentage is correct and is the same for all components. The calculations and results in this report are all based on this percentage, but in this sensitivity analysis, this percentage is varied to give an indication of the influence on the inventory costs when another percentage is used. The percentage is varied from 15% till 30%. This range is chosen arbitrary; it will not indicate that the 'right' percentage is in this range. It is only meant to measure the influence on the inventory costs. The results are shown in figure 14B.

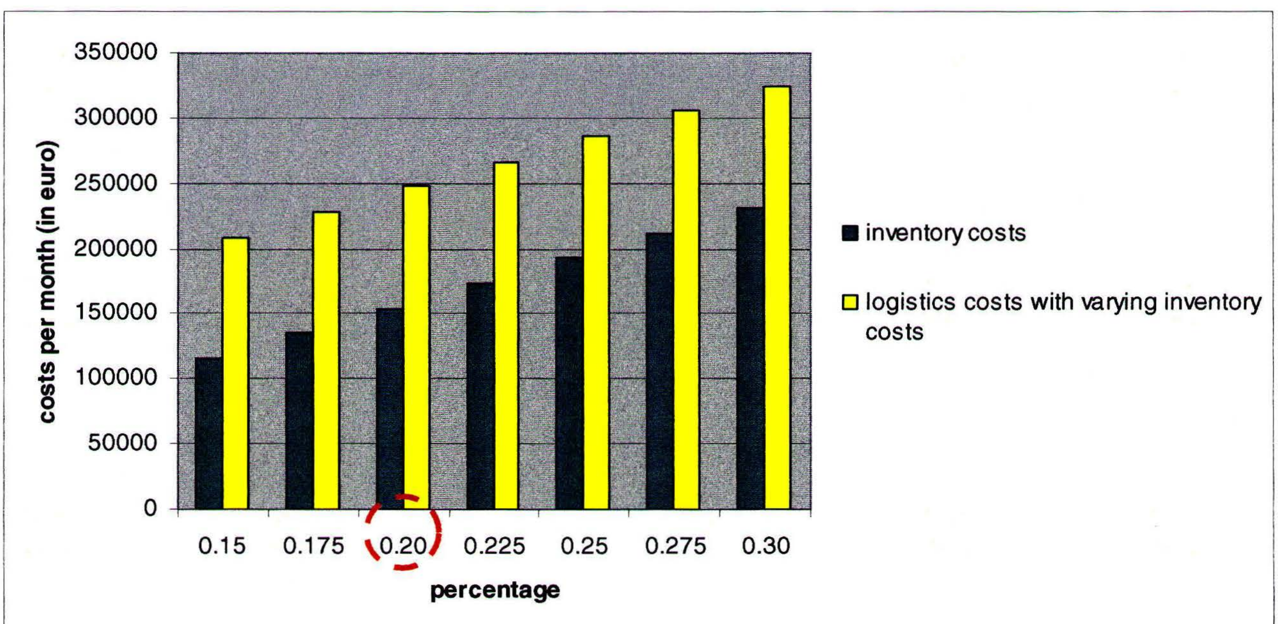


Figure 14B *Percentage to calculate the inventory costs*

14.D The transport costs

In the current analysis, the transport costs for WFPS are $^1/_3$ of the total transport costs for M&L. But these costs can also be divided in another way. At Océ, very little insight exists in the transport costs so no clear ideas exist about the transport costs per assembly unit. The transport costs for WFPS are varied from $^1/_4$, $^1/_3$, $^2/_5$, $^1/_2$ and $^3/_5$ of the total transport costs. These ratios are chosen again arbitrary. The results are shown in figure 14C.

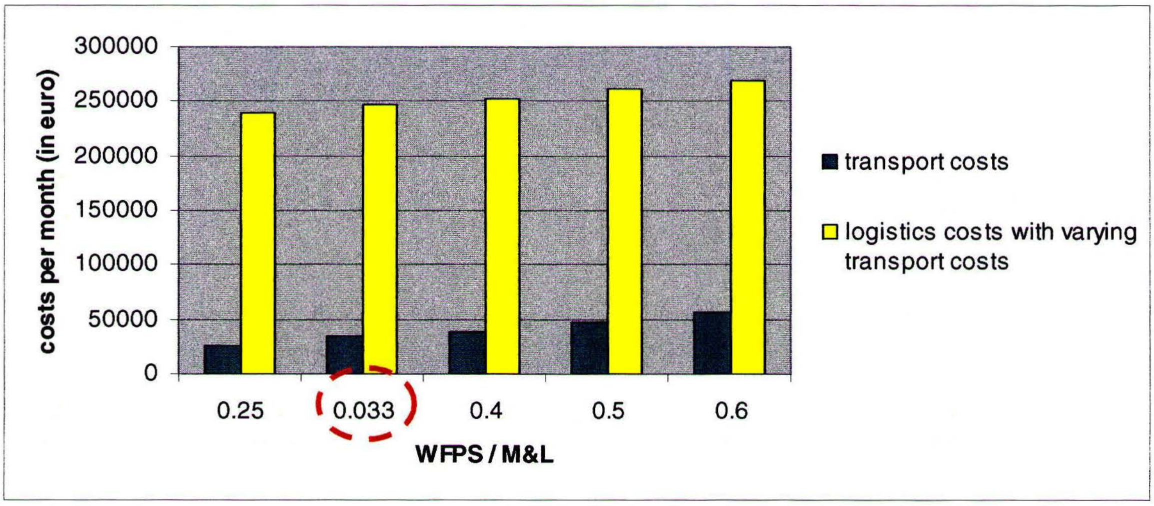


Figure 14C *The share of WFPS in the total transport costs*

14.E Conclusion

As can be seen in the figures 14A – 14C, changing the assumptions influences the costs. When the configuration components are relatively more expensive than the assembly components, the costs also increase. A larger percentage to calculate the inventory costs also causes an increase in costs. When the share of WFPS in the total transport costs increases, the costs also become higher.
So, it is important to be sure of the costs and the validity of the assumptions. At this moment, the validity of the assumptions cannot be checked more thoroughly, because more exact information about the logistics costs is not available. Because of this reason, the costs that are represented in chapter 5.4, will be used in the remainder of this report. Based on this sensitivity analysis, the conclusion can be drawn that the total logistics costs vary between k€ 22 and k€ 325 In this report, the amount of k€ 247.4 is used.

When the logistics costs are equal to k€ 22 it is questionable if it would be remunerative to reduce the amount of configuration components that are offered related to the marketing aspects. When all assumptions would be more to the left part of the histograms (the left part from the red circles), it is likely that the savings do not justify the marketing aspects, like decreasing the turnover because a customer does not buy a certain product anymore from Océ. When the assumptions are correct (the red circles in the histograms) or more to the right part of the histograms the savings will probably be high enough to consider not offering certain components anymore.
Of course, it is also possible that some assumptions are more to the left part and the other assumption more to the right part of the histograms. The costs that have the largest influence are the inventory costs. These costs are most important. So when the interest costs will be higher than 0.20, the costs will be significantly higher too.

So, in general can be concluded that when the assumptions will be more to the right part of the histograms, the savings will be higher, taking into account that some assumptions have a larger influence on the total logistics costs. The exact break-even point cannot be indicated because the trade-off has to be made between the savings in the logistics costs and the marketing aspects. At this moment, no information about the marketing aspects is available so no conclusion about the break-even point can be drawn. Beside that, the exact value of the assumptions is not known.

Appendix 15 Costs split up per activity

In this appendix, the costs per activity in a certain cost module are given. In case a cost module consists only of one activity, this cost module is left out of consideration.

15.A Cost module materials handling & storage costs

This cost module can be split up into several activities. The costs per cost module are represented in table 15A.

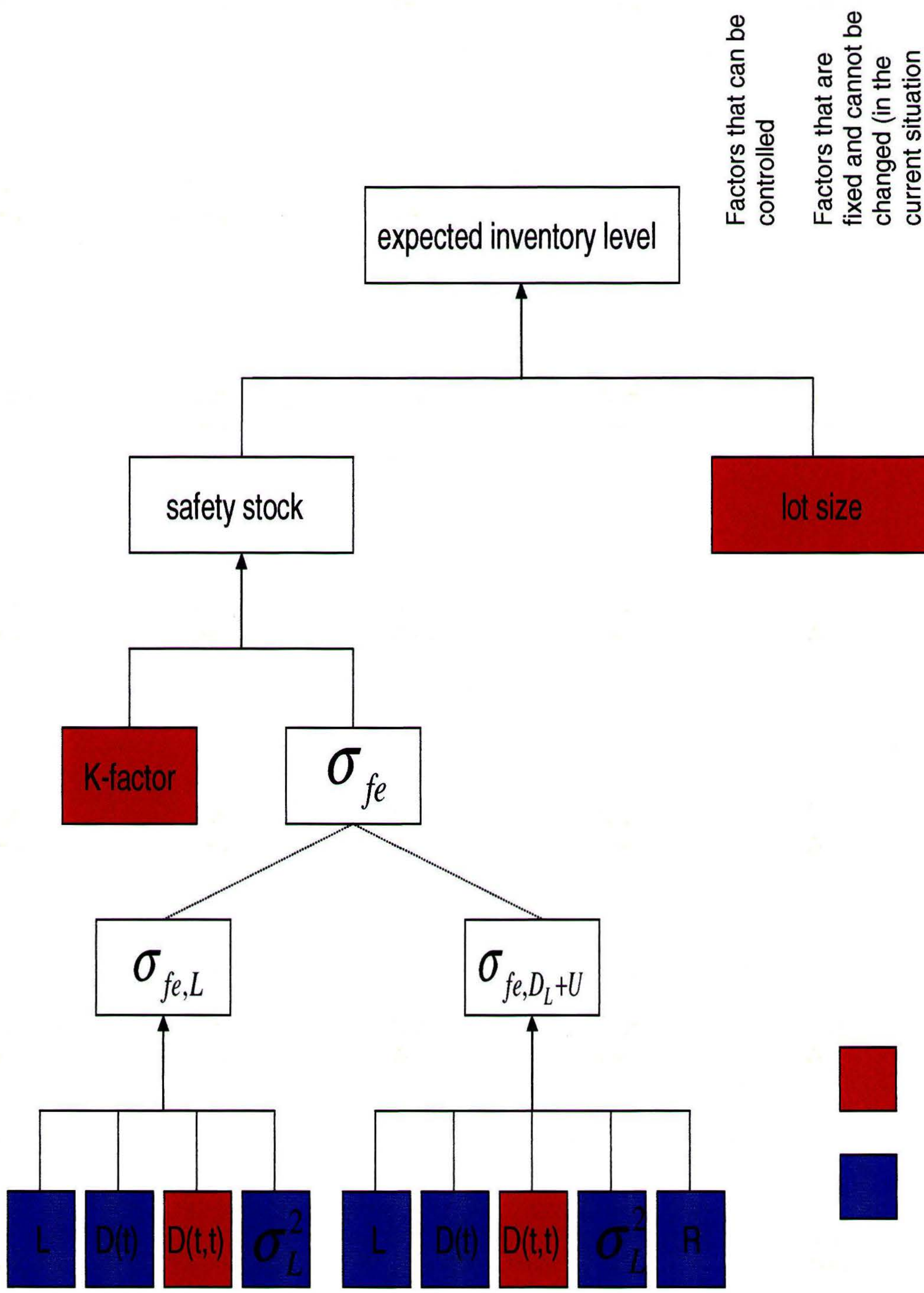
Table 15A Materials handling & storage

cost module	description	total	'normal' configuration components	large configuration components
materials handling (variable costs)	*total materials handling*	*k€ 23.5*		
	goods-in/goods-out costs	k€ 15.8	k€ 4.0	k€ 11.8
	customization activities	k€ 2.9		
	remaining	k€ 4.7		
storage (sunk costs)	*total storage*	*k€ 18.0*		
	SAP deliveries	k€ 3.8		
	linerunning	k€ 4.0		
	group coordinator	k€ 2.1		
	systems	k€ 8.6	k€ 4.4	k€ 4.2
total cost module		**k€ 42.2**		

15.B Cost module transport

The total outbound transport costs, from the supplier to P60, for M&L are equal to k€ 4,732. The assumption is made that $^1/_3$ of these costs are caused by transport for WFPS; this is equal to k€ 1,577. The transport costs from the supplier to P60 for the configuration items are equal to k€ 28.7 per month.
The transport costs, from P60 to WFPS are equal to k€ 5.5 per month. This leads to the total transport costs: k€ 34.2.

Appendix 16 the expected inventory level and influencing factors



Appendix 17 Estimating the standard deviation

The forecast error as a result of the forecast made by the configuration matrix, is calculated and the standard deviation of this forecast error is calculated too. As already indicated in section 5.3, the forecast update interval is not equal to the lead-time. That is why $\hat{\sigma}_{fe,D_1}$, the standard deviation which is measured per forecast update interval, needs to be converted to $\hat{\sigma}_{fe,D_L}$, the standard deviation of the forecast error which is measured per lead-time. In Silver, Pyke and Peterson [7], the following model is given: $\hat{\sigma}_{fe,D_L} = L^c \hat{\sigma}_{fe,D_1}$. This model captures the required relation empirically and is valid for most inventory systems. The coefficient c has to be estimated empirically. Because changes in the value of c influences the standard deviation and finally the stock level, a sensitivity analysis is conducted. The results of this analysis are represented in appendix 18.

Determining the coefficient c
To determine the value of c, a sample of ten components is taken at random. The assumption is made that these components are representative for the other components and that the calculated value of c for these components can also be used for the other components. The forecast of each component is calculated by the configuration matrix. This forecast is compared to the actual demand that resulted over the immediate period of duration L. The forecast error is calculated by using:

Forecast error = $e_t(L) = \sum_{\tau=1}^{L} \hat{x}_{t,t+\tau} - \sum_{\tau=1}^{L} x_{t+\tau}$ with L = 1,2, 3 or 4. Because only nine months of data are available, it is not possible to calculate the forecast error with a larger value of L. For each value of L, the standard deviation is calculated:

$$\hat{\sigma}_{fe,D_L} = s_L = \left\{ \frac{1}{n-1} \sum_t \left[e_t(L) - \bar{e}(L) \right]^2 \right\}^{1/2}$$

$\bar{e}(L) = \sum_t e_t(L)/n$	the structural error for the L under consideration;
n	number of lead-times of length L used.

These calculations result in 10 values of $\hat{\sigma}_L$ per L-value. Per component, the result of $\log(\hat{\sigma}_{fe,D_L} / \hat{\sigma}_{fe,D_1})$ is calculated and plotted against log L. The results are shown in figure 17A. The actual values of $(\hat{\sigma}_{fe,D_L} / \hat{\sigma}_{fe,D_1})$ per component are represented in table 17A.

The model: $\hat{\sigma}_{fe,D_L} = L^c \hat{\sigma}_{fe,D_1}$ can be written as $\log(\hat{\sigma}_{fe,D_L} / \hat{\sigma}_{fe,D_1}) = c \log L$. This shows that the slope of the regression line (the red line in the figure) gives an estimate for c. In this case, c is 0.75.

The 'conversion' formula will be: $\hat{\sigma}_{fe,D_L} = L^{0.75} \hat{\sigma}_{fe,D_1}$

Table 17A *Values of* $(\hat{\sigma}_{fe,D_L} / \hat{\sigma}_{fe,D_1})$ *per component*

component	$(\hat{\sigma}_{fe,D_2} / \hat{\sigma}_{fe,D_1})$	$(\hat{\sigma}_{fe,D_3} / \hat{\sigma}_{fe,D_1})$	$(\hat{\sigma}_{fe,D_4} / \hat{\sigma}_{fe,D_1})$
2978181	1.70	4.06	3.46
7013704	1.26	0.96	1.48
7055828	2.02	1.75	4.55
7094417	1.59	1.67	0.86
7136538	1.41	1.18	0
7078641	2.17	3.00	1.92
7171049	1.38	2.87	3.62
2945263	0.97	2.88	1.86
1060000980	2.12	4.21	4.89
5630033	1.93	3.34	5.38

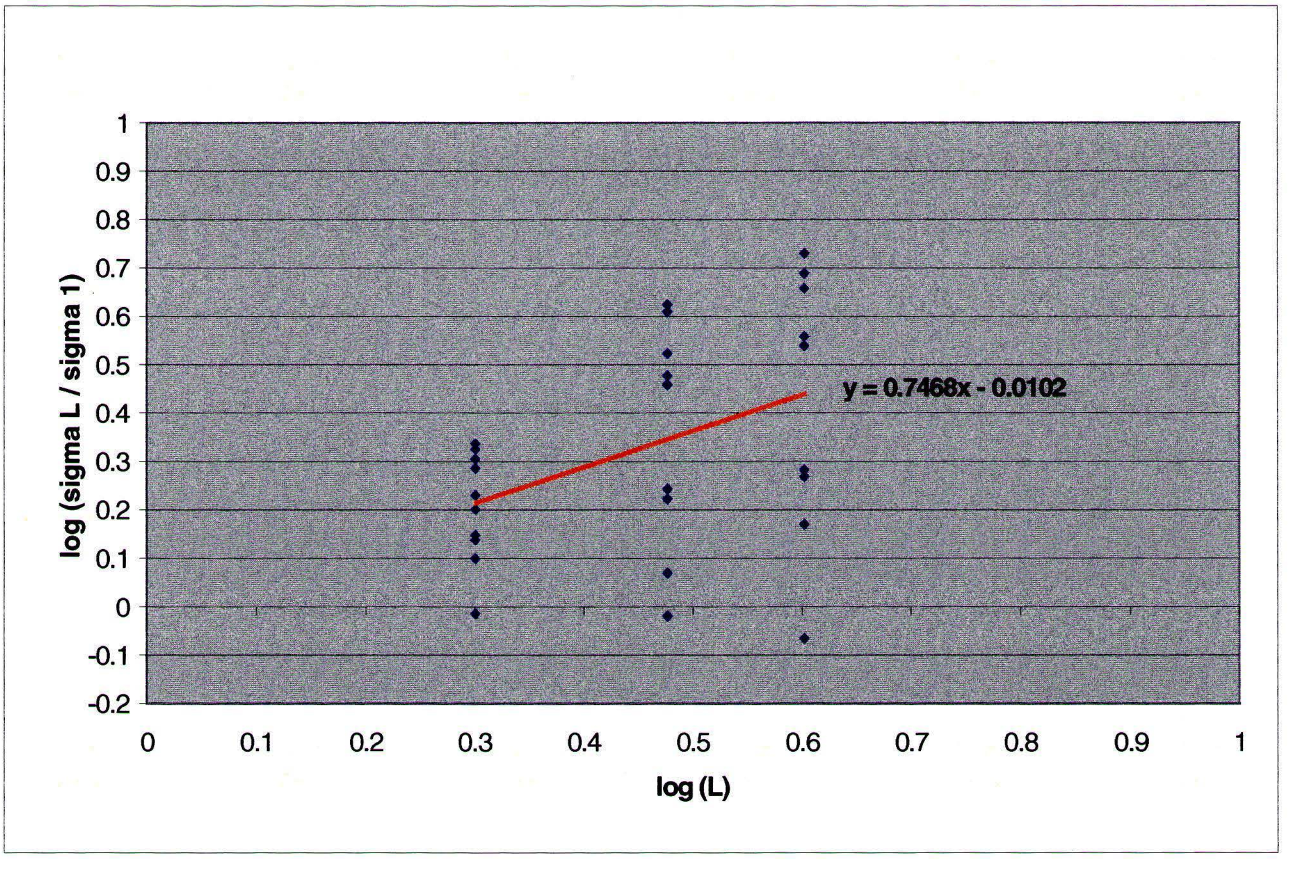


Figure 17A *Relative standard deviations of forecast errors versus lead-time*

Appendix 18 Sensitivity analysis of the value of c

As already explained in appendix 17, c has to be estimated empirically. In this assignment, a sample of ten components is taken at random to determine the value of c. The assumption is made that these components are representative for the other components and the calculated value of c can also be used for the other components.

To show the influence of the value of c on the value of the safety stock, a sensitivity analysis has been conducted. Several values of c have been chosen and then the inventory value has been calculated. Only the c-value has been changed, the other parameters are kept the same. The P_2-value is equal to 99.5%.
The choice has been made to vary the c-value between 0.50 and 1.00. These values are chosen arbitrary; the only purpose is to vary around the used value 0.75.
In figure 18A, the results are shown. The red line indicates the value c = 0.75; this value is used in the actual calculations. As can be concluded from the histogram, the inventory value increases when the c-value is higher. The difference in inventory value between a c-value of 0.50 and 1.00 is about k€ 300.

The c-value is influenced by the standard deviation of the forecast error. Because this error is not constant and changes during the time, it is likely that the value of c will change too. Because of this influence, c has to be updated regularly. As can be seen from the histogram, calculating with a wrong value of c can lead to a wrong safety stock level.

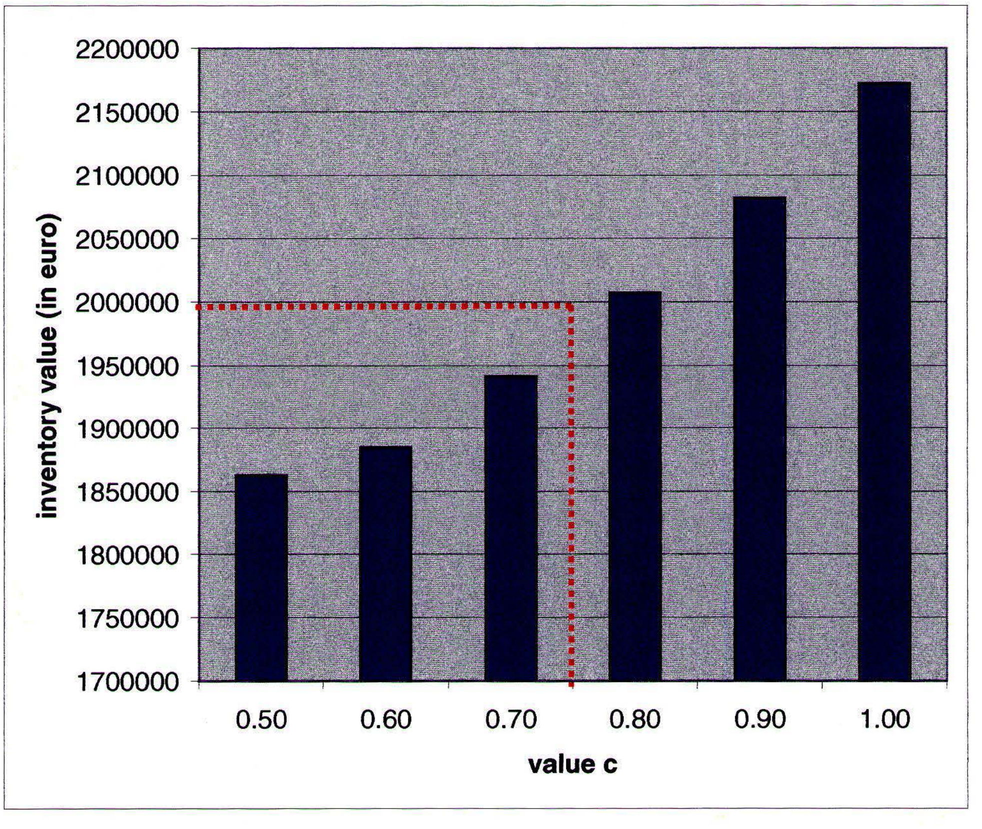


Figure 18A *Histogram of the inventory value with different values of c*

Appendix 19 $G_u(k)$ and the corresponding k-value

Gu(k)	k	Gu(k)	k	Gu(k)	k
0.0000071450	4.00	0.0000608500	3.49	0.0003959000	2.99
0.0000074690	3.99	0.0000633100	3.48	0.0004101000	2.98
0.0000078060	3.98	0.0000658700	3.47	0.0004247000	2.97
0.0000081580	3.97	0.0000685200	3.46	0.0004396000	2.96
0.0000085250	3.96	0.0000712700	3.45	0.0004555000	2.95
0.0000089080	3.95	0.0000741300	3.44	0.0004716000	2.94
0.0000093070	3.94	0.0000770900	3.43	0.0004883000	2.93
0.0000097230	3.93	0.0000801600	3.42	0.0005055000	2.92
0.0000101600	3.92	0.0000833500	3.41	0.0005233000	2.91
0.0000106100	3.91	0.0000866600	3.40	0.0005417000	2.90
0.0000110800	3.90	0.0000900900	3.39	0.0005606000	2.89
0.0000115700	3.89	0.0000936500	3.38	0.0005802000	2.88
0.0000120800	3.88	0.0000973400	3.37	0.0006004000	2.87
0.0000126200	3.87	0.0001012000	3.36	0.0006213000	2.86
0.0000131700	3.86	0.0001051000	3.35	0.0006428000	2.85
0.0000137600	3.85	0.0001093000	3.34	0.0006650000	2.84
0.0000143500	3.84	0.0001135000	3.33	0.0006879000	2.83
0.0000149800	3.83	0.0001179000	3.32	0.0007115000	2.82
0.0000156300	3.82	0.0001222500	3.31	0.0007359000	2.81
0.0000163200	3.81	0.0001273000	3.30	0.0007611000	2.80
0.0000170200	3.80	0.0001322000	3.29	0.0007870000	2.79
0.0000177760	3.79	0.0001373000	3.28	0.0008138000	2.78
0.0000185300	3.78	0.0001426000	3.27	0.0008414000	2.77
0.0000193300	3.77	0.0001480000	3.26	0.0008699000	2.76
0.0000201600	3.76	0.0001537000	3.25	0.0008992000	2.75
0.0000210300	3.75	0.0001596000	3.24	0.0009295000	2.74
0.0000219300	3.74	0.0001657000	3.23	0.0009607000	2.73
0.0000228700	3.73	0.0001720000	3.22	0.0009928000	2.72
0.0000238500	3.72	0.0001785000	3.21	0.0010260000	2.71
0.0000248600	3.71	0.0001852000	3.20	0.0010600000	2.70
0.0000259200	3.70	0.0001922000	3.19	0.0010950000	2.69
0.0000270200	3.69	0.0001995000	3.18	0.0011320000	2.68
0.0000281600	3.68	0.0002070000	3.17	0.0011690000	2.67
0.0000293500	3.67	0.0002147000	3.16	0.0012070000	2.66
0.0000305900	3.66	0.0002227000	3.15	0.0012470000	2.65
0.0000318800	3.65	0.0002311000	3.14	0.0012880000	2.64
0.0000332100	3.64	0.0002396000	3.13	0.0013300000	2.63
0.0000346000	3.63	0.0002485000	3.12	0.0013730000	2.62
0.0000360500	3.62	0.0002577000	3.11	0.0014180000	2.61
0.0000375500	3.61	0.0002672000	3.10	0.0014640000	2.60
0.0000391100	3.60	0.0002771000	3.09	0.0015110000	2.59
0.0000407300	3.59	0.0002873000	3.08	0.0015600000	2.58
0.0000424200	3.58	0.0002978000	3.07	0.0016100000	2.57
0.0000441700	3.57	0.0003087000	3.06	0.0016620000	2.56
0.0000459900	3.56	0.0003199000	3.05	0.0017150000	2.55
0.0000478800	3.55	0.0003316000	3.04	0.0017690000	2.54
0.0000498400	3.54	0.0003436000	3.03	0.0018260000	2.53
0.0000518800	3.53	0.0003560000	3.02	0.0018830000	2.52
0.0000540000	3.52	0.0003689000	3.01	0.0019430000	2.51
0.0000562000	3.51	0.0003822000	3.00	0.0020040000	2.50
0.0000584800	3.50				

Gu(k)	k		Gu(k)	k		Gu(k)	k
0.0020670000	2.49		0.0087210000	1.99		0.0299800000	1.49
0.0021320000	2.48		0.0089570000	1.98		0.0306700000	1.48
0.0021990000	2.47		0.0091980000	1.97		0.0313700000	1.47
0.0022670000	2.46		0.0094450000	1.96		0.0320800000	1.46
0.0023370000	2.45		0.0096980000	1.95		0.0328100000	1.45
0.0024100000	2.44		0.0099570000	1.94		0.0335600000	1.44
0.0024840000	2.43		0.0102200000	1.93		0.0343100000	1.43
0.0025610000	2.42		0.0104900000	1.92		0.0350800000	1.42
0.0026400000	2.41		0.0107700000	1.91		0.0358700000	1.41
0.0027200000	2.40		0.0110500000	1.90		0.0366700000	1.40
0.0028040000	2.39		0.0113400000	1.89		0.0374800000	1.39
0.0028890000	2.38		0.0116400000	1.88		0.0383100000	1.38
0.0029770000	2.37		0.0119500000	1.87		0.0391600000	1.37
0.0030670000	2.36		0.0122600000	1.86		0.0400200000	1.36
0.0031590000	2.35		0.0125700000	1.85		0.0409000000	1.35
0.0032550000	2.34		0.0129000000	1.84		0.0417900000	1.34
0.0033520000	2.33		0.0132300000	1.83		0.0427000000	1.33
0.0034530000	2.32		0.0135700000	1.82		0.0436300000	1.32
0.0035560000	2.31		0.0139200000	1.81		0.0445700000	1.31
0.0036620000	2.30		0.0142800000	1.80		0.0455300000	1.30
0.0037700000	2.29		0.0146400000	1.79		0.0465000000	1.29
0.0038820000	2.28		0.0150100000	1.78		0.0475000000	1.28
0.0039960000	2.27		0.0153900000	1.77		0.0485100000	1.27
0.0041140000	2.26		0.0157800000	1.76		0.0495400000	1.26
0.0042350000	2.25		0.0161700000	1.75		0.0505900000	1.25
0.0043580000	2.24		0.0165800000	1.74		0.0516500000	1.24
0.0044860000	2.23		0.0169900000	1.73		0.0527400000	1.23
0.0046160000	2.22		0.0174200000	1.72		0.0538400000	1.22
0.0047500000	2.21		0.0178500000	1.71		0.0549600000	1.21
0.0048870000	2.20		0.0182900000	1.70		0.0561000000	1.20
0.0050280000	2.19		0.0187400000	1.69		0.0572600000	1.19
0.0051720000	2.18		0.0192000000	1.68		0.0584400000	1.18
0.0053200000	2.17		0.0196700000	1.67		0.0596400000	1.17
0.0054720000	2.16		0.0201500000	1.66		0.0608600000	1.16
0.0056280000	2.15		0.0206400000	1.65		0.0621000000	1.15
0.0057880000	2.14		0.0211400000	1.64		0.0633600000	1.14
0.0059520000	2.13		0.0216500000	1.63		0.0646500000	1.13
0.0061200000	2.12		0.0221700000	1.62		0.0659500000	1.12
0.0062920000	2.11		0.0227000000	1.61		0.0672700000	1.11
0.0064680000	2.10		0.0232400000	1.60		0.0686200000	1.10
0.0066490000	2.09		0.0238000000	1.59		0.0699900000	1.09
0.0068350000	2.08		0.0243600000	1.58		0.0713800000	1.08
0.0070240000	2.07		0.0249400000	1.57		0.0727900000	1.07
0.0072190000	2.06		0.0255200000	1.56		0.0742200000	1.06
0.0074180000	2.05		0.0261200000	1.55		0.0756800000	1.05
0.0076230000	2.04		0.0267400000	1.54		0.0771600000	1.04
0.0078320000	2.03		0.0273600000	1.53		0.0786600000	1.03
0.0080460000	2.02		0.0280000000	1.52		0.0801900000	1.02
0.0082660000	2.01		0.0286500000	1.51		0.0817400000	1.01
0.0084910000	2.00		0.0293100000	1.50		0.0833200000	1.00

Gu(k)	k		Gu(k)	k
0.0849100000	0.99		0.2009000000	0.49
0.0865400000	0.98		0.2040000000	0.48
0.0881900000	0.97		0.2072000000	0.47
0.0898600000	0.96		0.2104000000	0.46
0.0915600000	0.95		0.2137000000	0.45
0.0932800000	0.94		0.2169000000	0.44
0.0950300000	0.93		0.2203000000	0.43
0.0968000000	0.92		0.2236000000	0.42
0.0986000000	0.91		0.2270000000	0.41
0.1004000000	0.90		0.2304000000	0.40
0.1023000000	0.89		0.2339000000	0.39
0.1042000000	0.88		0.2374000000	0.38
0.1061000000	0.87		0.2409000000	0.37
0.1080000000	0.86		0.2445000000	0.36
0.1100000000	0.85		0.2481000000	0.35
0.1120000000	0.84		0.2518000000	0.34
0.1140000000	0.83		0.2555000000	0.33
0.1160000000	0.82		0.2592000000	0.32
0.1181000000	0.81		0.2630000000	0.31
0.1202000000	0.80		0.2668000000	0.30
0.1223000000	0.79		0.2706000000	0.29
0.1245000000	0.78		0.2745000000	0.28
0.1267000000	0.77		0.2784000000	0.27
0.1289000000	0.76		0.2824000000	0.26
0.1312000000	0.75		0.2863000000	0.25
0.1334000000	0.74		0.2904000000	0.24
0.1358000000	0.73		0.2944000000	0.23
0.1381000000	0.72		0.2986000000	0.22
0.1405000000	0.71		0.3027000000	0.21
0.1429000000	0.70		0.3069000000	0.20
0.1453000000	0.69		0.3111000000	0.19
0.1478000000	0.68		0.3154000000	0.18
0.1503000000	0.67		0.3197000000	0.17
0.1528000000	0.66		0.3240000000	0.16
0.1554000000	0.65		0.3284000000	0.15
0.1580000000	0.64		0.3328000000	0.14
0.1606000000	0.63		0.3373000000	0.13
0.1633000000	0.62		0.3418000000	0.12
0.1659000000	0.61		0.3464000000	0.11
0.1687000000	0.60		0.3509000000	0.10
0.1714000000	0.59		0.3556000000	0.09
0.1742000000	0.58		0.3602000000	0.08
0.1771000000	0.57		0.3649000000	0.07
0.1799000000	0.56		0.3697000000	0.06
0.1828000000	0.55		0.3744000000	0.05
0.1857000000	0.54		0.3793000000	0.04
0.1887000000	0.53		0.3841000000	0.03
0.1917000000	0.52		0.3890000000	0.02
0.1947000000	0.51		0.3940000000	0.01
0.1978000000	0.50		0.3989000000	0.00

Appendix 20 Calculation of the lot size with the Silver-Meal heuristic

To give a better insight in how to use the Silver-Meal heuristic, an example will be elaborated in this appendix.

The next data are given for a certain component:

Lead-time:	2 weeks
Price:	€ 500
Reordering costs:	€ 45
Carrying charge r:	20% per year = 0.003846% per week (assumption: a year has 52 weeks)
Minimum order quantity:	1
Packing quantity:	1

The forecast for week 1 – 4 is equal to 10. The actual demand has been equal to 8. The next calculations have to take place to calculate the costs:

Week 1: Total relevant costs are equal to the reordering costs = € 45
Week 2: [45 + (10 * 0.003846 * 500)] / 2 = € 32.12
Week 3: [45 + (10 * 0.003846 * 500) + 2 * (10 * 0.003846 * 500)] / 3 = € 34.23

The results are shown in table 20A:

Table20A Example to calculate the lot size and the reordering moment

week	1	2	3
forecast	10	10	10
demand	8	8	8
costs	€ 45	**€ 32.12**	€ 34.23
reveicing order	20		20
placing order	20		
inventory level	12	4	16

As can be seen in the table, the lowest costs, based on the *forecasted* demand as this is known at the moment of reordering components, are achieved when reordering the forecasted demand for two weeks. When the forecasted demand is compared with the actual demand, it can be seen that the actual demand is lower. This means that there will be inventory left at the end of of week 2. But according to the forecasted demand as known at the moment of reordering, this would not be enough to fulfill the demand of week 3. This means, a new lot size has to be reordered at week 1 which will arrive in week 3. From this point on, the calculation starts again, with one difference; the inventory level is not equal to zero when the order arrives but equal to 4 (the amount that is more forecasted than actually used).

Appendix 21 Cost categories

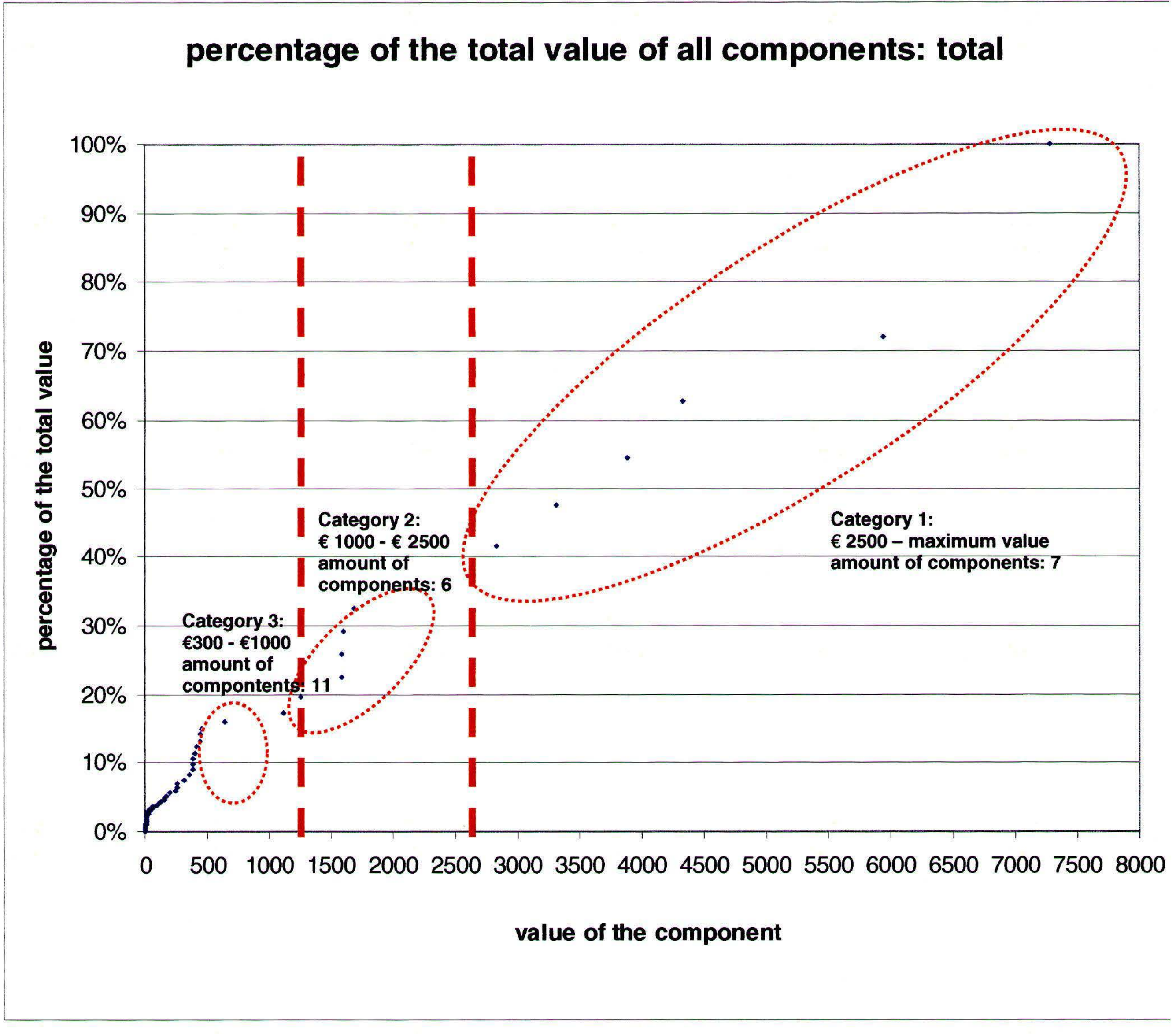


Figure 21A *Value of the components (all components)*

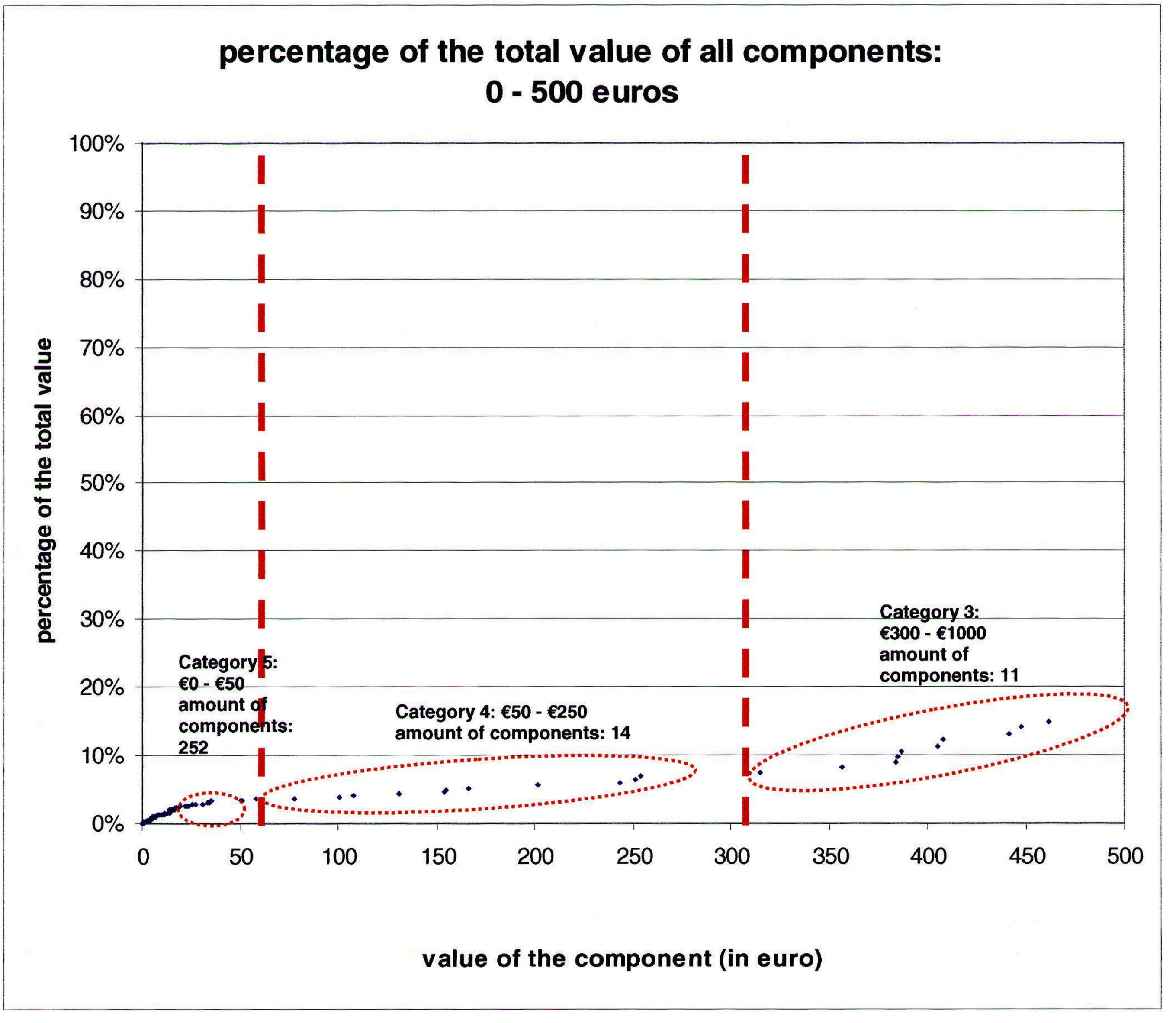
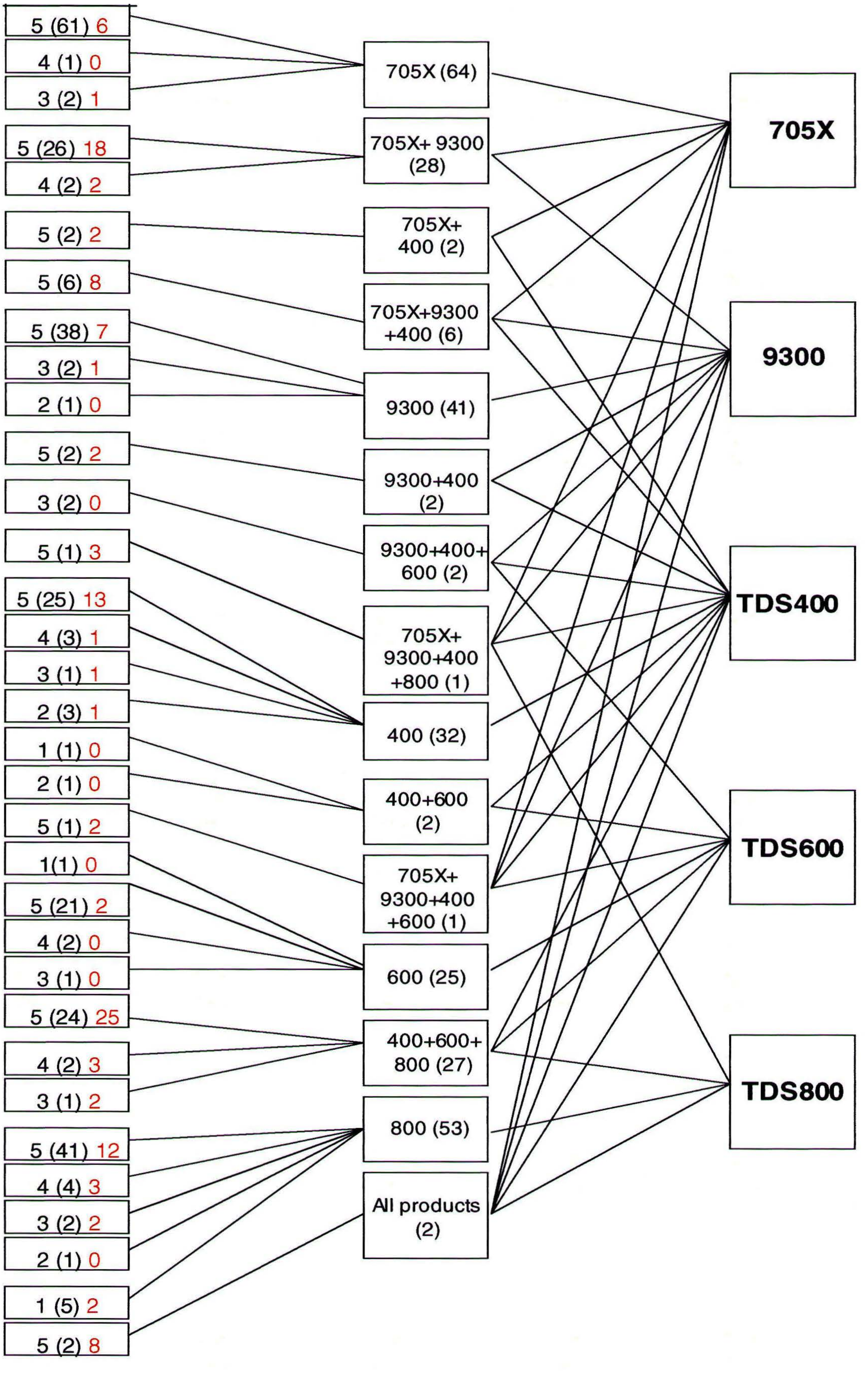


Figure 21B *Value of the components (components with a value below € 500)*

Appendix 22 Model of the average configuration



Appendix 23 lot size, safety stock and turn frequency per component

component	Q	safety stock	turn frequency
2945254	500	40	2.64
2945259	120	55	0.42
2945263	2000	61	0.53
2945264	4550	196	0.34
2945265	120	38	0.41
2945266	1000	35	0.12
2954831	39200	2819	0.13
2955100	10000	980	0.56
2955124	800	656	0.40
2977814	200	48	0.06
2977977	240	71	0.24
2978088	2000	495	0.27
2978089	2000	202	1.24
2978181	8000	626	0.34
2999732	90	25	0.39
2999826	3200	583	0.34
3913035	75	8	0.25
3925000	32	74	0.07
3925007	19	19	0.03
3925009	4	182	3.91
3936350	30	61	0.33
3936351	15	266	0.80
3936352	15	22	0.41
3936353	75	32	0.26
3936354	75	17	0.26
3936695	3	261	5.47
3936795	0	9	0.78
3985011	18	24	0.17
3985020	7	19	0.23
3985030	7	34	0.47
3985040	1	45	1.90
5630033	576	353	0.28
5630034	576	353	0.28
5630042	24	13	0.19
5630043	18	7	0.12
5630044	30	118	0.73
5630053	59	4	0.03
5630054	90	25	0.04
5630055	720	928	0.42
5630056	720	980	0.44
5630057	54	48	0.06
5630058	36	73	0.12
5630911	300	52	1.11
5630912	300	51	1.10
7013354	450	113	0.35

component	Q	safety stock	turn frequency
7013594	1000	41	1.38
7013595	1500	31	0.38
7013683	150	52	0.44
7013693	100	8	1.29
7013694	100	13	0.95
7013697	50	5	1.36
7013698	50	7	1.45
7013699	50	3	2.55
7013700	50	3	2.55
7013702	50	4	1.32
7013703	50	5	1.36
7013704	50	4	2.64
7013705	50	0	2.27
7013706	50	2	2.45
7013707	50	2	2.45
7013773	50	12	0.56
7013819	1000	148	2.26
7013886	700	40	0.47
7013899	500	21	0.32
7014028	150	8	3.77
7014051	150	2	7.00
7014052	150	45	1.24
7014107	300	0	12.50
7014108	300	0	12.50
7014109	150	0	6.25
7014213	160	15	1.58
7029156	792	738	0.14
7033530	1000	26	6.66
7033531	500	4	11.55
7033534	500	26	3.49
7033535	500	46	2.16
7033537	500	46	2.16
7045004	500	23	0.12
7048549	600	656	0.42
7048550	600	656	0.42
7048551	3000	656	0.47
7048599	612	225	0.23
7048600	612	225	0.23
7048661	1040	351	0.14
7048692	1125	515	0.24
7055817	450	103	0.45
7055818	150	11	1.19
7055819	50	8	0.61
7055820	50	4	1.21
7055821	25	4	0.75

component	Q	safety stock	turn frequency
7055822	35	1	1.68
7055823	25	4	1.50
7055824	25	1	1.23
7055825	25	13	1.16
7055826	250	44	0.56
7055827	50	0	2.27
7055828	35	4	0.98
7055829	25	1	1.23
7070374	12000	703	0.43
7078640	1356	8	28.57
7078641	40	21	0.17
7078649	300	1	0.01
7083690	120	115	0.24
7083691	240	221	0.27
7083692	120	187	0.31
7083695	120	72	0.23
7083717	720	42	2.09
7083723	1820	351	0.24
7083724	1820	351	0.23
7083762	10	207	1.23
7092873	300	38	0.08
7092959	216	38	0.51
7093139	850	147	0.67
7093824	1000	18	2.83
7094088	500	36	2.18
7094089	500	179	0.62
7094090	500	40	1.72
7094097	500	334	0.59
7094353	160	45	0.16
7094355	300	428	0.29
7094356	2000	786	0.23
7094365	240	68	1.03
7094366	240	68	1.03
7094368	150	108	1.01
7094378	1500	1047	0.32
7094379	1500	1089	0.32
7094380	160	164	0.09
7094381	2250	786	0.16
7094382	500	738	0.30
7094385	192	145	0.09
7094386	192	42	0.05
7094399	500	25	3.48
7094400	500	68	1.66
7094401	500	85	1.19
7094402	1500	464	0.77
7094403	500	3	11.50
7094404	1000	297	0.82
7094405	500	2	11.45
7094406	500	14	8.00
7094407	500	36	2.44

component	Q	safety stock	turn frequency
7094408	500	17	6.07
7094409	500	28	3.97
7094410	500	46	1.57
7094411	1000	4	31.50
7094412	1000	74	2.43
7094413	500	336	0.68
7094414	500	45	2.68
7094415	500	2	15.75
7094416	1000	15	13.92
7094417	500	209	0.66
7094418	200	9	4.04
7094419	500	140	2.48
7094420	500	8	17.20
7094422	200	4	13.00
7094425	200	2	7.29
7094426	200	5	21.00
7094427	200	14	4.22
7094428	200	1	20.20
7094429	53	5	3.94
7094430	100	10	4.00
7094431	200	4	20.80
7094432	200	10	7.33
7094509	500	0	50.00
7094510	500	559	161.80
7094511	500	7	17.13
7094512	500	116	2.58
7094514	500	14	9.78
7094515	500	10	17.33
7094516	500	5	51.00
7094517	500	2	50.40
7094518	500	5	31.88
7094519	500	2	50.40
7094520	500	1	50.20
7094521	500	10	17.33
7094522	425	0	42.50
7094523	425	55	1.74
7094524	2500	34	11.67
7094525	1250	461	0.47
7094526	1250	226	0.80
7094527	1000	2	10.68
7094532	1000	2	10.68
7094537	500	4	50.80
7094543	500	5	31.88
7094544	500	4	50.80
7094545	500	7	9.52
7094546	500	10	10.83
7094548	500	30	1.24
7094562	1800	148	0.23
7094896	2000	18	0.59
7094976	3400	980	0.44

component	Q	safety stock	turn frequency
7095065	720	15	0.12
7095076	300	128	0.15
7095127	5040	502	0.48
7095325	500	13	5.98
7095401	168	10	0.02
7097241	200	36	0.63
7097681	70	17	0.38
7114121	75	8	0.54
7114122	200	28	0.61
7114123	175	22	0.62
7114124	300	76	0.45
7114125	150	21	1.01
7114126	25	1	1.23
7114127	25	6	0.84
7114128	25	1	1.23
7114129	25	3	0.70
7114130	475	78	0.45
7114131	125	4	2.02
7114132	25	5	1.59
7114419	25	3	0.78
7128954	3150	928	0.41
7128969	2200	848	0.16
7128970	320	327	0.18
7128999	5000	980	0.57
7136534	800	21	2.81
7136535	200	55	0.40
7136537	150	8	0.56
7136538	50	0	1.09
7136541	50	3	1.22
7136542	120	10	0.47
7136544	50	2	1.80
7136545	50	1	1.13
7136940	200	21	0.61
7136942	400	74	0.45
7136948	400	74	0.40
7136952	200	75	0.22
7136958	200	30	0.46
7165930	775	148	2.00
7165931	775	5	30.19
7165932	0	2	0.40
7165933	0	0	0.00
7165934	0	0	0.00
7166360	800	21	0.50
7166620	69	92	0.05
7166721	150	12	0.45
7170656	100	8	29.24
7170742	216	36	1.05
7170910	34	218	0.64
7170911	90	63	0.95
7171048	450	10	9.40

component	Q	safety stock	turn frequency
7171049	450	6	10.50
7171051	450	4	20.82
7171052	450	0	20.45
7171053	450	0	18.75
7171056	450	4	20.82
7171058	450	0	18.75
7171059	450	0	18.75
7171065	200	3	4.29
7171066	200	6	4.42
7171074	600	38	1.94
7171490	56	21	0.13
7174710	8	1	0.05
7174955	30	4	0.61
7174956	100	30	0.25
7174957	100	32	0.24
7174969	96	0	0.02
7175083	170	1	7.82
7175664	3000	351	0.51
7176024	924	263	0.16
7176341	128	198	0.06
7176342	80	13	0.10
7177838	100	39	1.35
7208553	4000	234	0.41
7209330	500	0	22.73
7209682	500	0	20.83
7218940	450	85	0.22
7218948	225	32	0.63
7219010	375	50	0.84
7219064	160	50	0.45
7225303	500	26	3.49
7225304	500	46	2.16
7225305	500	26	3.49
7225306	500	46	2.16
7225307	500	18	6.09
7225433	200	12	2.55
7225479	120	168	0.78
7225522	25	14	0.34
7225523	5	163	2.30
7225524	5	57	1.66
7225564	500	13	5.98
7225742	80	3	1.19
9780103	1000	67	2.07
76500030	144	49	0.50
1060000364	160	27	1.33
1060000980	2775	271	0.56
1060002098	3600	351	0.32

Appendix 24 Turnover of the configuration items

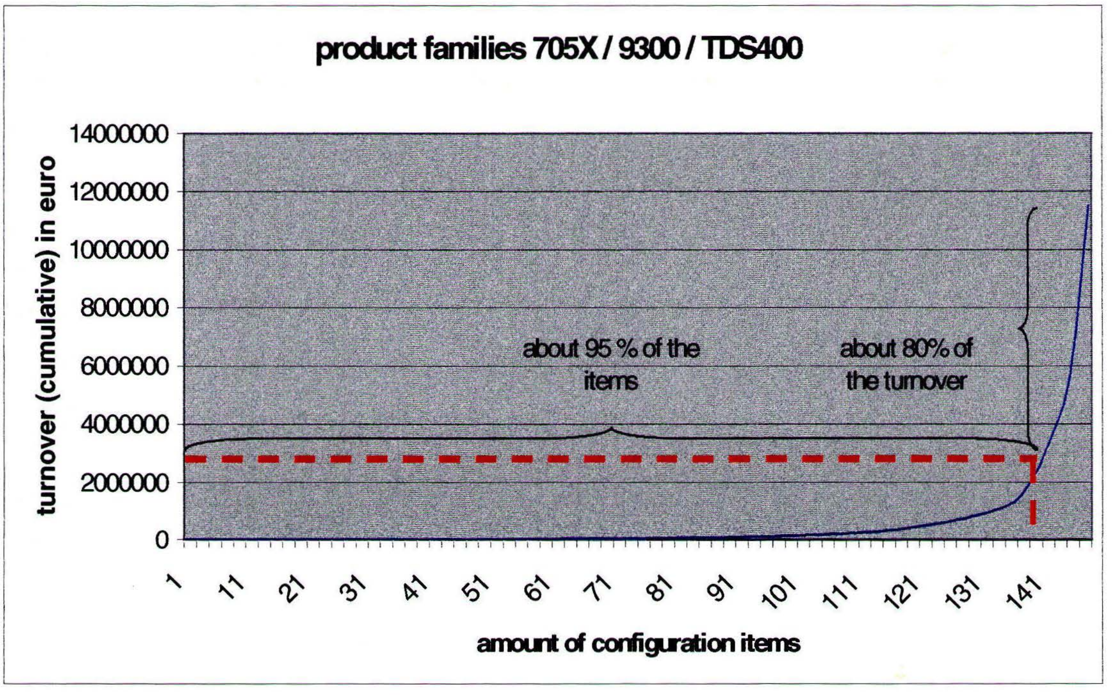


Figure 24A *Turnover of configuration items LV-line*

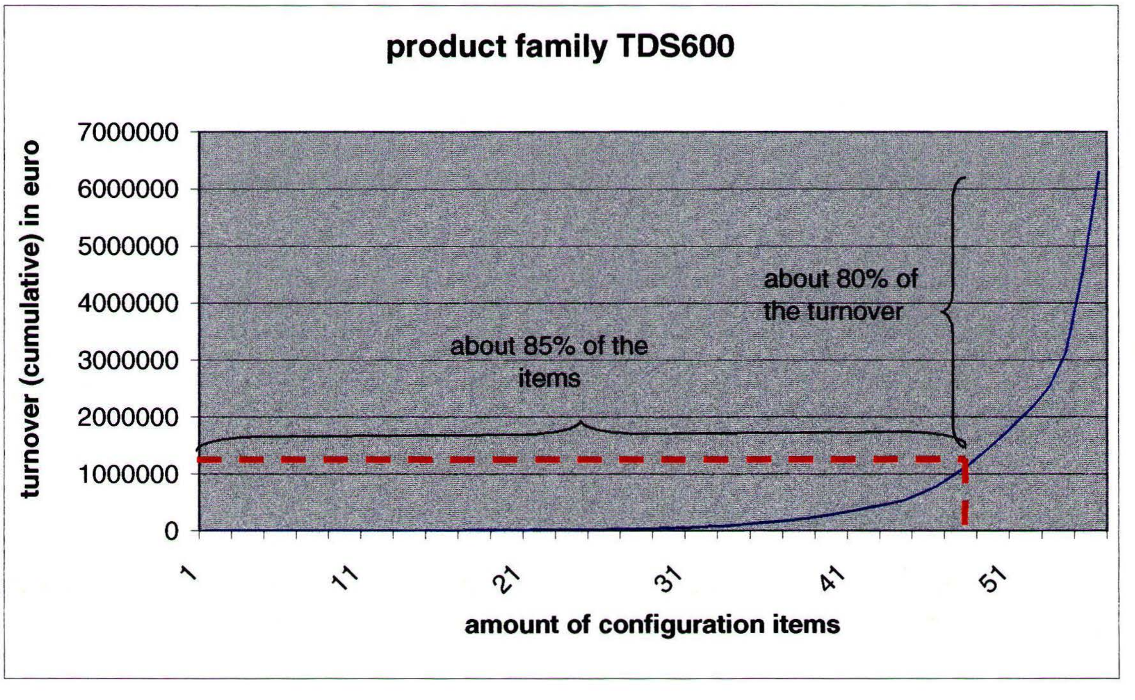


Figure 24B *Turnover of configuration items MV-line*

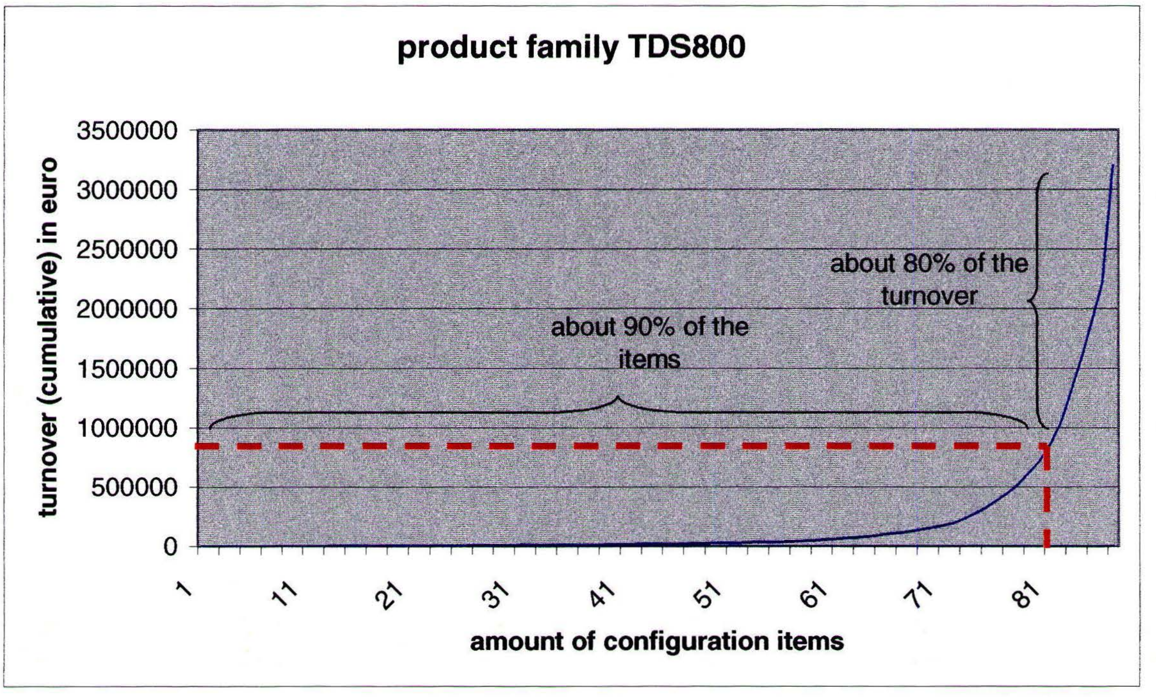


Figure 24C *Turnover of the configuration items HV-line*

Appendix 25 Sensitivity analysis ratio of components with higher average logistics costs

In chapter 8, the possible savings are calculated when several components are not offered any longer. The components that should be considered for not offering any longer are components with a low turnover and higher costs than the average costs. The average costs per component are about € 400 per month. The components that should be considered first for not offering anymore are components with costs that are higher than € 400.
The question now is what percentage of the components has higher costs than € 400. In chapter 8, the assumption is made that 50% of the components with a low turnover have higher costs than the average costs. But when this assumption is violated, the savings that may be achieved when not offering these components will change too. In this analysis, the percentage of components with higher costs is changed and the influence on the savings is measured.

Only the variable costs can be influenced on the short-term. The sunk costs will be the same and not dependent on the amount of components that are offered. That is why this sensitivity analysis only focuses on the variable costs.
In figure 25A, the results are shown. The percentage is changed from 20% till 80% of the components that have higher costs than the average costs. The red circle indicates the value of the assumption in the first-order-analysis.

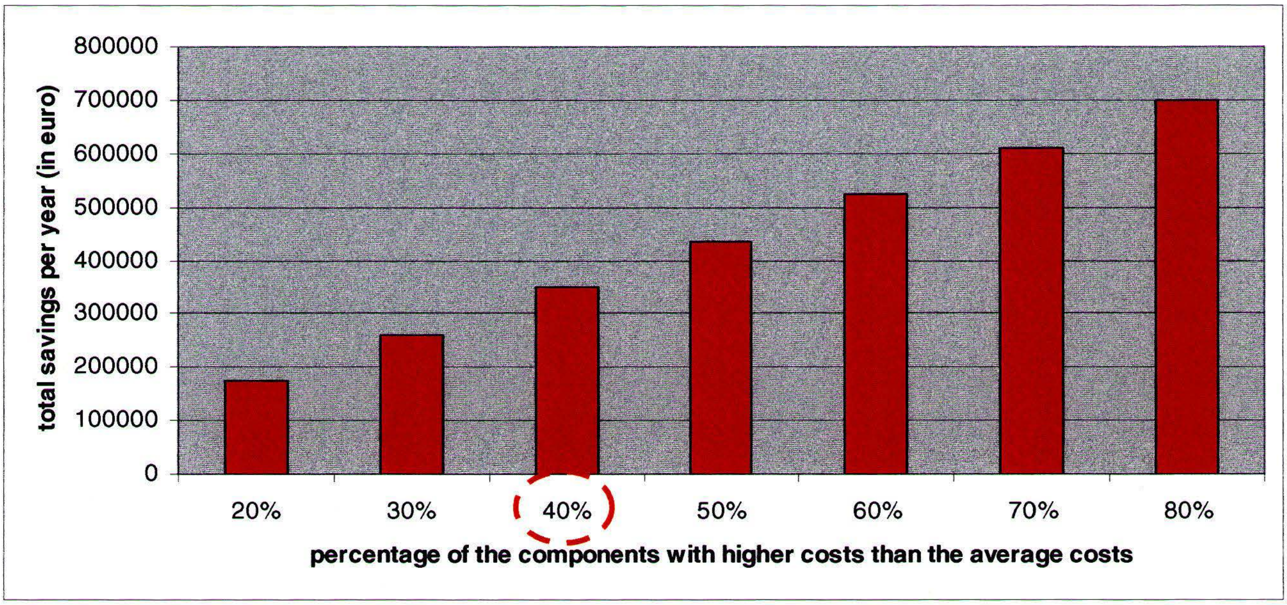


Figure 25A *Savings when the percentage of components with higher costs is changed*

As can be seen in table 25A, the savings depend strongly on the percentage that is used. In chapter 8, a first-order-analysis is given, just to give an indication if it would be remunerative not to offer certain components any longer. As can be seen in figure 25A, the minimum savings would be about k€ 175 a considerable saving already.
But when evaluating the savings, a marginal note has to be made. These savings are the maximum savings, because in the calculation, the assumption is made that *all* components with higher costs are not offered. Marketing aspects are left out of consideration. Not offering all components anymore is very unlikely and the actual savings will be lower than indicated in the figure. Anyway, still the savings can be considerable and not offering certain components to decrease the costs needs further investigation.