2014

Optimizing a dairy multinational's inventory control policy

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Master thesis

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Masterthesis – FrieslandCampina Domo

"Optimizing a dairy multinational's inventory control policy"

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Management summary

Research motivation

Due to the significant profit losses caused by perished inventory, Domo Beilen sees possibilities for inventory control improvements. Yet, perished inventory is not the only problem. In contrast, there can be insufficient inventory. Shortage of raw materials can cause production stops. Hence, the required end products cannot be produced in time. As the demand exceeds the supply, this results in huge opportunity cost losses.

> *Domo Beilen is bothered by an inefficient inventory control, resulting in both lacking raw materials (understock) and having redundant raw materials (overstock).*

Research objective

> *Optimize the raw materials' inventory control of Domo Beilen. In particular, redefine the replenishment policy, the safety stock levels, and designate the most critical raw materials.*

Scope

The scope of the research is on the main tasks of the Business Office, i.e. *work preparation* and *production scheduling,* and concerns all ingredients delivered by external suppliers, being around 200 ingredients.

Current situation

Safety stocks are determined using an inadequately model and inappropriate input. The raw material inventory is worth on average 22 million Euros, because additional raw materials are purchased to buffer against undefined uncertainties. There is no clear distinction in importance of the Stock Keeping Units (SKUs). The yearly obsolescence costs amount around 315.000 Euros. Further, discount prices are not actively used in determining order sizes.

Redesigned inventory control policy

The purchasers get an improved safety stock model. With the improved safety stock model, the purchasers do not have to purchase additional raw materials *based on their insight* to prevent for stockouts. With the new safety stock model just 1% of the replenishment orders will result in a (temporarily) stockout. Assuming there are 1100 purchase orders sent per year, there are 11 stockouts, per year. Due to the entrance inspection lead times of the raw material it is known at least two weeks before the planned production. Hence, just as today, the planning can be adjusted to prevent no-production periods. Currently, the detailed planning is adjusted far more than 11 times per year.

Further, a distinction is made regarding the safety stock determination between intermittent demand and non-intermittent demand. The intermittent demand will not get a safety stock *quantity* as result of the safety stock model, but are assigned two weeks of safety time. Optimal order quantities are determined concerning the discount prices and the demand during the SKU's shelf life.

The purchasers will be trained in the usage of the model and the required work instructions will be developed.

Savings

The working capital captured in the raw material inventories can be reduced to approximately 14.4 million Euros. Compared to the current inventory of 22 million Euros, this is a saving of 7.6 million Euros on working capital. Assuming a carry cost rate of 19%, this will save yearly 1.4 million Euros.

The obsolescence costs can be reduced with approximately 75% to 80.000 Euros, instead of 315.000 Euros. The usage of quantity discount will save another 250.000 Euros on yearly basis.

Hence, the total proposed savings amount around 1.700.000 Euros per year.

Recommendations

We advise to implement the calculated safety stock quantities in SAP and to update the safety stock level every three months. Due to changing forecast errors, lead times, and in and out phasing the safety stocks should be reassessed regularly. Further, determine optimal order sizes regarding the quantity discounts. Anticipate timely on expiring inventories using the SLED-anticipation tool. Reassess the safety stocks, inspection lead times and optimal order quantities every quarter, to maintain the inventory control policy up-to-date. Comply with the new inventory control policy, it forms a basis for making decisions and will provide clarity for Domo's entire supply chain.

Further research

Develop a phasing out procedure for raw materials. Currently, the communication about the ending demand for available inventories is limited, causing unnecessary holding costs. Develop a procedure for phasing out raw materials, including responsibilities and time frames, such that every relevant person knows what is coming and that unnecessary costs are minimized.

Domo Beilen could benefit from a tighter collaboration with its suppliers. With for example Efficient Consumer Response a better alignment of needs for both stakeholders can be reached. One of the questions to ask is: how many information would we share with our supplier?

Preface

Two years ago, I wanted to experience the way of working within a small production organization. Therefore, I finalized my bachelor's degree with an assignment at a small enterprise. The drive and dedication the people showed me there, formed a great experience for my career *and* life. Now, two years later, I wanted to show my drive and dedication in a large enterprise. FrieslandCampina gave me the opportunity to improve their business processes. I suggested several research areas to a manager of Domo Beilen and he said: "Yes, the replenishing of raw materials could be improved. Our obsolescence costs are increasing." That meeting formed the basis for this master thesis.

With this thesis I finalize my master Industrial Engineering and Management with a specialization in Production and Logistics Management at University Twente. I would like to acknowledge all people that contributed to fulfilling my master's degree. Even to the people who I will not mention by name; I am thankful for your interest and advices.

I would like to thank all lecturers of University Twente for their work. In particular Matthieu and Leo, who supervised me during my master's assignment. I am grateful to all lecturers for sharing their knowledge, experience and insights with younger people. Knowledge is one of the things you can multiply by sharing it.

I would like to thank Mathijs for his believe in my abilities. He is a capable supervisor, who gave me the idea that my ideas are useful and he supported me in bringing them into practice.

I will say thanks to all employees of FrieslandCampina Domo Beilen, meanwhile my colleagues, for their help. I always felt welcome and I would like to forward that feeling also to my current and future colleagues.

Thanks, to my parents for creating the conditions to study carefree. You are in multiple disciplines a role model for me.

Finally, a special thanks to my wife Johanneke. She brought endless patience, while I was working on my thesis. – Yes, this also says something about the effort I had to bring– I am grateful for her encouragements, especially when I had enough it for a while. I wish that she will support me in all my future activities, as she has done during this assignment.

I am ready to take the next challenge.

Sander Lommers

Zwolle – August 2014

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List of Abbreviations

Abbreviation	Explanation
AMMP	Agglomeraat Magere Melk Poeder (English: agglomerate skimmed milk powder)
B2B	Business to business
B2C	Business to consumers
CV	Coefficient of Variation
Domo	Dutch company name: Drentse onder-melk organisatie
ERP	Enterprise Resource System
Eq.	Equation
HPP	Masterplan (Dutch: Hoofd Productie Plan)
i.e.	'Id est' – that is/ in other words
IEM	Industrial Engineering & Management
IFT	Infant, Follow-up, and Toddler (nutrition)
Mgt.	Management
MRP	Materials Requirement Plan(ning)
MTO	Make-To-Order; Only raw materials and components are kept in stock. Every customer is a specific project.
OWC	Demineralized Whey Concentrate (Dutch: Ontzoute Wei Concentraat)
PO	Purchase Order
PKV	Poeder Klein-Verpakkingen afdeling (English: Packaging department)
R&D	Research & Development
RM	Raw Materials
RMO	Rijdende Melk Ontvangst (English: Milk transport)
SAP	German company name: Systeme, Anwendungen und Produkte in der Datenverarbeitung
SKU	Stock Keeping Unit
SLED	Shelf Life Expiration Date
SPB	Supply Point Beilen
VMI	Vendor Managed Inventory
w.r.t.	With reference to

1 Introduction

This thesis serves as milestone for finalizing my master Industrial Engineering and Management. The first chapter provides an insight in the subject of the research. Section 1.1 introduces the company and the local activities. Section 1.2 explains the motivation of research. Finally, Section 1.3 presents the problem description, which serves as basis for this research.

1.1 Company description

Royal FrieslandCampina NV and Domo Beilen

Since December 30th, 2008, Royal FrieslandCampina is a merger of Friesland Foods and Campina. The organization is one of the five largest dairy companies in the world. FrieslandCampina is composed of various dairy corporations and one of them is Domo. On its turn, Domo consists of six factories, including Domo Beilen (province Drenthe). Domo Beilen is a former milk powder manufacturer.

Nowadays, Domo Beilen produces child nutrition. Within the company, the child nutrition is called IFT, which stands for Infant, Follow-up, and Toddler nutrition. Figure 1.1 depicts the key figures of Royal FrieslandCampina in 2012. Please note: the figures involve all corporations within FrieslandCampina and Domo is one of them. The Domo division is responsible for 1400 FTEs and yielded €788 million during 2012 (FrieslandCampina Domo, 2013).

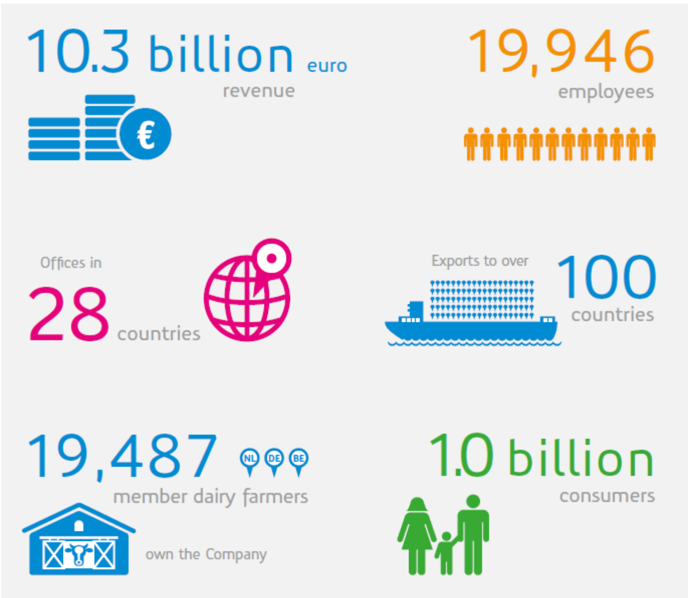


Figure 1.1 – Key figures of Royal FrieslandCampina NV (Annual Report, 2012)

Domo Beilen

Beilen is the location of fulfilling my graduation assignment for my master program Industrial Engineering and Management (IEM). Appendix A incorporates a constricted organizational chart depicting the exact location within Royal FrieslandCampina, where this research is initiated.

During recent years, the demand for Domo Beilen's child nutrition has grown tremendously. As a result, the demand is larger than the production capacity. In line with the current demand growth, major investments are made in Domo Beilen. In the past three years, FrieslandCampina invested 600 million Euros in expanding the production capacity and especially in nutrition for children and in single ingredients, i.e. whole Domo (Royal FrieslandCampina NV, 2013). The tranche intended for Domo Beilen amounts 143 million Euros (Royal FrieslandCampina NV, 2012).

In 2013, Domo Beilen produced around 65.000 tons of infant and toddler nutrition. The nutrition is divided over around 600 end products, which were distributed across more than 100 nations worldwide. Yearly, around 200 different ingredients have to be ordered and processed for the purpose of providing parents the best baby food in the world.

Production of infant and toddler nutrition

Domo Beilen operates as a make-to-order (MTO) company. Ingredients and packaging materials are kept in stock for production and the production starts after an order is received. Two thirds of the total production is destined for the B2C-market, i.e. sold in supermarkets in many countries. The remainder, one third, goes to other businesses (the B2B-market). Other companies buy finished goods or semi-finished goods (e.g. base), which serve as raw materials for their own products. Together with the customer the product specifications will be defined from ingredients, nutrition values, packaging, lead times to batch quantities. Without an order, nothing will be produced, except for a sample-batch.

Figure 1.2 - One of Domo's IFT-nutrition products

A brief description of the production process at Domo Beilen is as follows. Fresh cow milk, straight from the farmers is delivered at the Beilen site by tank trucks. Then, there is whey, also delivered by tank trucks. Whey is a liquid product released by the production of cheese. Finally, numerous additives, like vitamins and glucose, are required for the production of child nutrition. Then several production steps follow (which will not be outlined here), after which the product will be packed and shipped. Figure 1.3 depicts a high level overview of the production process. The numbered elements (1 to 4) form the subgroups, which are blended into the so-called ‘mixed product’. A part of the bases and ‘Agglomeraat Magere Melk Poeder’ (AMMP) is destined directly to the B2B-market. Yet, the main part of the bases and AMMP is used for end-products. After the mixed product is packed, the finished goods will be delivered to the customer.

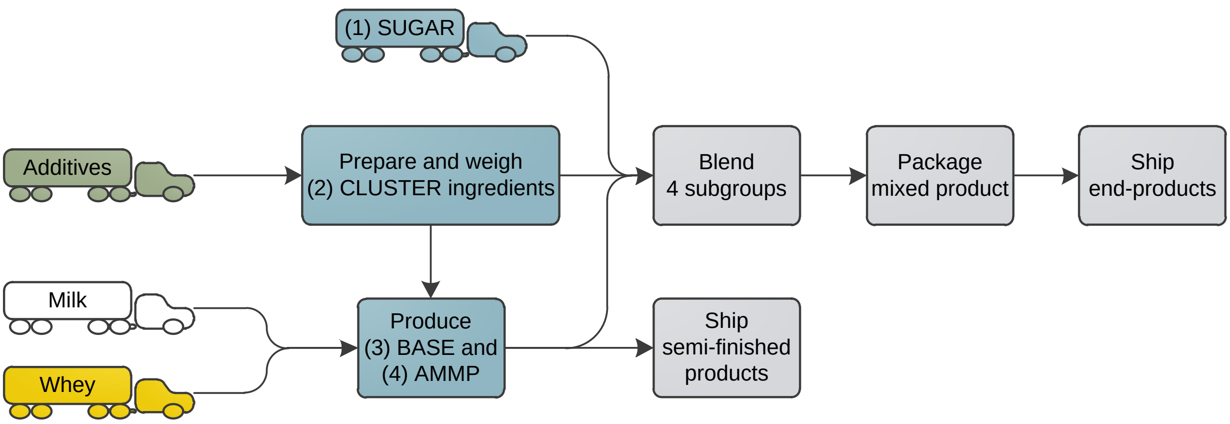


Figure 1.3 – High level overview of Domo Beilen's production process of child nutrition

1.2 Research motivation

Domo Beilen wants to organize their inventories in an efficient way. Nowadays, the (re)order points and quantities are proposed by Domo Beilen's Enterprise Resource System (ERP). Two employees share the responsibility for approving the proposed purchase requests related to the ingredients. Therewith, they are mainly responsible for the availability of the ingredients when the production process commences.

Currently, the focus is on producing high-quality products as much as possible, because the demand exceeds the production capacity. However, the current striving for maximum production of high-quality products removes the focus from optimizing Domo Beilen's supply chain.

As a nutrition supplier, Domo Beilen processes mainly perishable ingredients. Some of the ingredients have a short shelf life related to the throughput time. Due to changes or misinterpretations, parts of the inventory may not be processed further into end-products. If so, there are two options left: (1) the inventory will be devalued as cattle feed, or (2) if the inventory is useless, it has to be destroyed by a third party. Nevertheless, it costs money. Hence, Domo Beilen wants to minimize scrapped inventories while non-interrupting the production process.

1.3 Problem description

Due to the significant profit losses caused by perished inventory, Domo Beilen sees possibilities for improvement. Yet, perished inventory is not the only problem. In contrast, there can be insufficient inventory. Shortage of raw materials can cause production stops. Hence, the required end products cannot be produced in time. As the demand exceeds the supply, this results in huge opportunity cost losses. Additionally, shortages can induce that the available raw materials pass their shelf-life-expiration-date (SLED), with all its consequences.

> *Domo Beilen is bothered by an inefficient inventory control, resulting in both lacking raw materials (understock) and having redundant raw materials (overstock).*

2 Research design

This chapter presents the research approach in order to develop a solid basis for the research. Section 2.1 outlines the research approach. Then, Section 2.2 presents the research objective and scope, based on the problem description provided in Chapter 1. Section 2.3 outlines the research questions that serve as backbone of the research. At the end, Section 2.4 describes the research methodology.

2.1 Research approach

The problem description provided in Section 1.3 has a wide range of possible solution approaches. To provide a selection of some possible approaches:

I. Optimizing the demand forecasts.
II. Optimizing the supplier base, with other/more suppliers being able to deliver the required amount of raw materials, satisfying the quality specifications of Domo.
III. Optimizing the quality inspection process. The quality of almost every ingredient and (semi-) finished product is being assessed.
IV. Improvement in supply chain integration, e.g. through Continuous Replenishments (CR) or Vendor Managed Inventories (VMI).
V. Optimizing the replenishment policy.

The size of a multinational as FrieslandCampina brings a separation of responsibilities along. The approaches above can be assigned to four different clusters within Domo Beilen. The cluster Supply Chain is responsible for points I, II and IV, whereas Quality Assurance and Quality Control are responsible for point III. Approach V can be assigned to the Business Office (in Dutch: Bedrijfs-bureau).

The Business Office is mainly responsible for the work preparation and production scheduling. One of its activities is the replenishment of raw materials. That is why the responsibility for efficient and effective replenishments is felt at the Business Office too. Hence, the Business Office wants to know what the key indicators are for realizing optimal replenishment decisions. As the Business Office requested this research, the research will deal with approach V.

2.2 Research objective and scope

As Domo Beilen wants to organize their raw materials replenishments in an optimal manner, we define the problem statement as:

> *Optimize the raw materials' inventory control of Domo Beilen. In particular, redefine the replenishment policy, the safety stock levels, and designate the most critical raw materials.*

The scope of the research is within the main tasks[1] of the Business Office and concerns all ingredients delivered by external suppliers, being around 200 ingredients.

[1] The Business Office main tasks are *work preparation* and *production scheduling*

2.3 Research questions

In order to achieve the research objective, a number of research questions will be established. The research questions serve as backbone of the research and contribute to the development of useful recommendations and the required replenishment model. The headers denote the research subjects.

Current situation – Chapter 3

1. What does the current situation look like?
    a. What does the **production process** look like? In particular, where are new ingredients added to the production process?
    b. What does the **replenishment policy** look like, w.r.t. order points and order quantities?
    c. On what basis are the current **safety stocks** determined?
    d. What are the **consequences** of the current approach of replenishing?
        i. How many ingredients pass their *shelf life expiration date* (SLED)?
        ii. How often/much delay is caused by non-available ingredients?
        iii. What costs are made due to understocking and overstocking?

Literature review – Chapter 4

2. According to the literature…
    a. What **SKU classification models** are recommended?
    b. What **replenishment policies** are recommended?

Redesign of replenishment policy – Chapter 5

3. How to organize Domo Beilen's replenishment policy?
    a. Develop a procedure to **classify** Domo Beilen's ingredients.
    b. Develop a model to **determine** the **safety stocks**.

Savings – Chapter 6

4. What are the **benefits** of the new inventory control policy?
    a. What is the difference compared to the former inventory control policy?

Implementation plan – Chapter 7

5. How should the inventory control policy be **implemented** at Domo Beilen?

2.4 Research methodology

This section outlines the approach of the research questions defined in Section 2.3. First, an analysis will be made of the current situation. Second, a research will be executed about the desired situation. Third and finally, a solution will be developed. The research questions proposed in Section 2.3 are already listed in this sequence. Table 2.1 provides an overview of the research methodologies used per research question.

1. *What does the current situation look like?*
   The importance of this question is to attain understanding of the current situation. As the production is dependent of the availability of the required raw materials, it is helpful to understand the production process. Further, understanding of the current replenishment process is needed, as the replenishment policy needs to be improved. Then, the most critical raw materials have to be recognized to develop a suitable solution for these items. The analysis of the current situation serves as starting point for the desired improvement.

2. *What SKU classification models and replenishment policies are recommended?*
   FrieslandCampina Domo is not the only firm that deals with large and perishable stocks. Therefore, the literature will be studied to find methods applicable to Domo Beilen. Further, the literature will be searched for the best practices of the classification of SKUs. Domo Beilen purchases hundreds of raw materials with various characteristics. This mix of characteristics results in a certain importance for Domo Beilen, i.e. the criticality. For a given importance, a certain level of attention is required (Silver, Pyke, & Peterson, 1998). By classifying the raw materials the inventory control becomes easier. Thereafter, different replenishment policies and the determination of safety stocks will be reviewed. Herewith, the most appropriate replenishment policy can be applied and proper safety stocks can be determined.

3. *How to organize the inventory control policy?*
   Based on the literature review, we are now able to redesign Domo Beilen's inventory control policy. With the information gathered from the literature review, we are able to classify the SKUs in an effective manner and to select a proper replenishment model.

4. *What are the benefits of the new inventory control policy?*
   To determine the importance of a new replenishment policy, the new and the former situation will be compared. Herewith, the benefits and possible drawbacks will become clear.

5. *How should the inventory control policy be implemented at FrieslandCampina Domo Beilen?*
   After all, Domo Beilen wants to know how the new inventory control policy is applicable. Therefore, a project plan will be provided for the implementation of the new replenishment policy.

Research question	Chapter	Subject	Research methodology
RQ 1	Ch. 3	Current situation	Interviews Observations Data-analysis Documentation review
RQ 2	Ch. 4	Literature review	Literature search
RQ 3	Ch. 5	Redesign of the replenishment policy	Data-analysis Case study
RQ 4	Ch. 6	Savings	Case study
RQ 5	Ch. 7	Implementation plan	Case study

Table 2.1 – Research methodologies used

3 Current situation

This chapter answers *Research question 1: What does the current situation look like?* The answer will fulfill three objectives. The first objective is to unveil the circumstances with which Domo Beilen, and in particular the Business Office deals. Therewith, the activities will be better understood. The second objective is to unveil opportunities to improve Domo Beilen's activities. The third objective is to create a reference point for the recommendations that this report will deliver.

Chapter 3 is structured as follows. Section 3.1 describes the customer order fulfillment process. Section 3.2 explains the production process of consumer products. Section 3.3 describes the replenishment process. Section 3.4 describes the current inventory control performance. Section 3.5 outlines some SKU characteristics. Finally, this chapter ends with a conclusion in Section 3.6.

3.1 Customer order fulfillment

This section illustrates the customer order fulfillment process of Domo Beilen in order to unveil the dependencies and relationships between the various departments. Domo Beilen is a so-called make-to-order firm. This means that Domo Beilen starts a production run after a customer order is received (Hoekstra & Romme, 1992). To shorten the lead times for the customers, a firm can purchase raw materials before a customer order is received. In such a situation, the firm has to purchase on forecast.

Developing forecasts contributes to a faster customer order fulfillment. The customer order fulfillment of Domo Beilen is as follows. The order fulfillment is triggered by a customer's need. To fulfill the need, the customer makes contractual agreements with the Logistics department, which is responsible for sales. One component of the agreement is that the customer provides forecasts. Then, the demand planner collects the demand forecasts and combines them into one production forecast. The forecast covers 18 months. Subsequently, the demand planner loads the forecasts every month into the production module (R3) of the enterprise resource (ERP) system, developed by SAP. Hence, at this moment the forecast is available for the master and detail planners (and many others within Domo Beilen).

The masterplanners translate the forecasts into two master production plans (HPP), covering 13 weeks, and check the feasibility of the plans with respect to the production capacity. One HPP is intended for the Towers' production, i.e. for the production of bases. The other HPP is intended for the packaging lines, i.e. for packing the mixed product. Then, the masterplanners enter the HPPs into SAP. Subsequently, an MRP-run will be executed. MRP stands for Material Requirements Planning. The system calculates what quantity of each ingredient is needed to produce the required products and when purchase orders have to be submitted. Hence, according to the bill-of-material dependencies all requirements will be updated from raw materials to semi-finished goods. Figure 3.1 depicts the sequence of the information flow as described above.

Figure 3.2 outlines the customer order fulfillment process in more detail. The most relevant demand uncertainties occur in the HPP-phase. In the remainder of this chapter the causes for these uncertainties will be outlined.

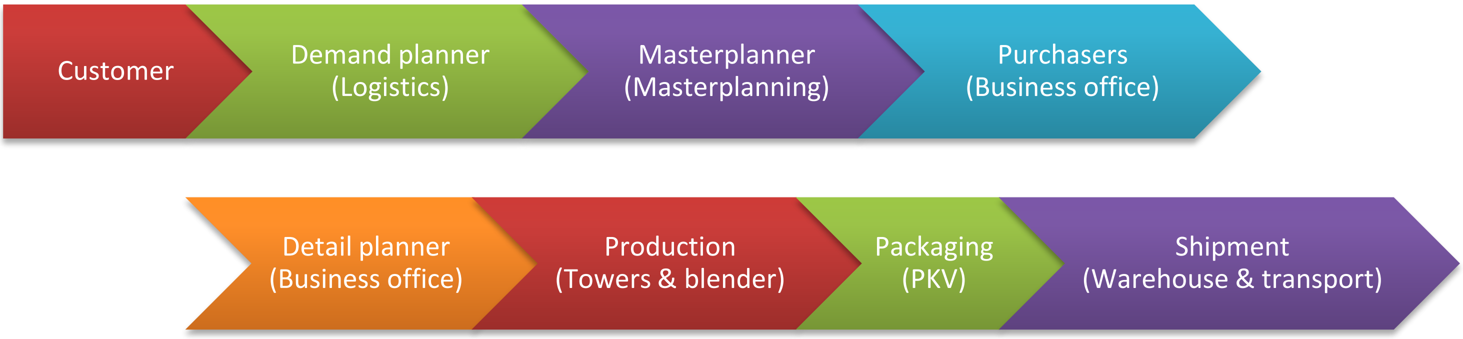


Figure 3.1 – Customer order fulfillment dependencies within Supply Point Beilen

This section described all departments directly involved in the customer order fulfillment. In the next section, the production process will be explained.

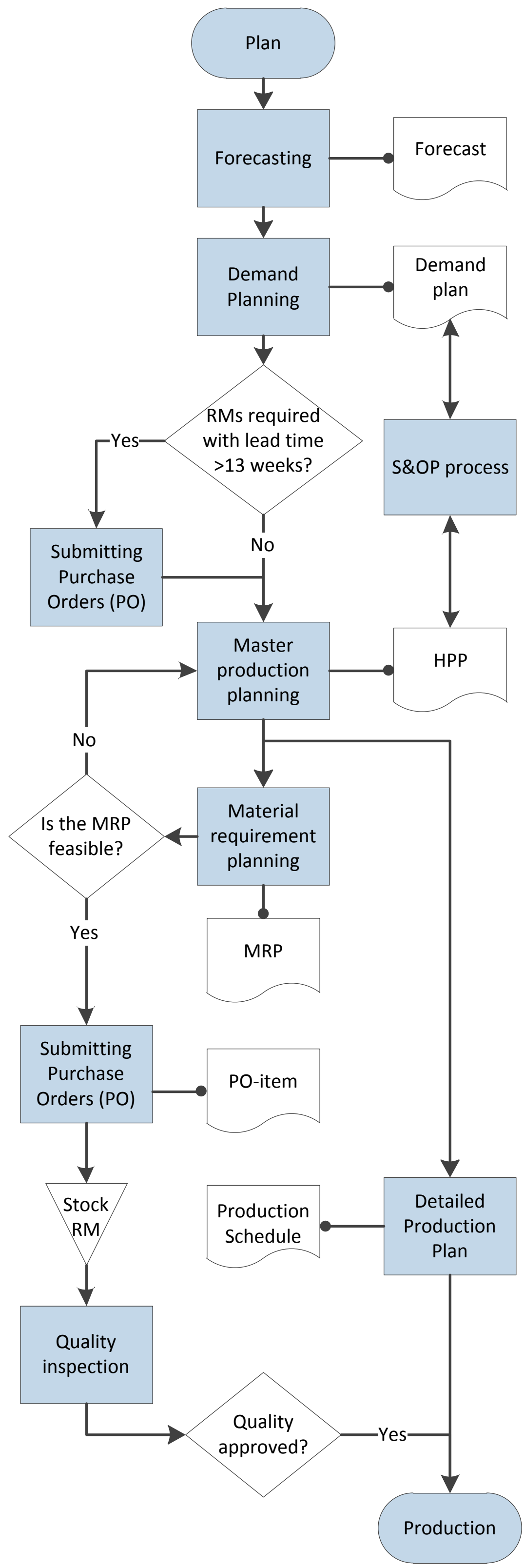
Flowchart	Explanation	Responsible
	The customer creates an **<u>18 months</u>** rolling Forecast and forwards the Forecast to the Demand Planner.	Customer + Demand Planner
	The customer forecasts are bundled into a demand plan. The forecasts are **<u>reviewed monthly</u>** and incorporated into a long-term planning.	Demand Planner
	During Sales and Operations Planning (S&OP), the demand is leveled with the production capacity.	Masterplanner + Mgt. Team
	For raw materials with a lead time exceeding 13 weeks, the Purchase Orders will be submitted based on the (long-term) demand planning.	Purchaser
	Based on the demand plan the Masterplan (HPP) is made for the coming **<u>13 weeks</u>** including the material requirements. The HPP enables two distinct activities: (1) the Material requirement planning and (2) the Detailed production plan.	Masterplanner
	(1) If the material requirement planning (MRP) is not feasible (due to unavailable raw materials), the HPP needs to be changed.	Masterplanner + Purchaser
	For the remaining required raw materials (i.e., raw materials with lead time ≤13 weeks), the Purchase Orders are submitted considering the SKU's lead time.	Purchaser
	(2) Meanwhile, the detail planners construct production schedules (at Domo Beilen : detailed production plans). For the PKV, a schedule for the coming 4 weeks is constructed (X+4). For the Towers, a schedule for the coming two weeks is constructed (X+2).	Detail planner PKV + Detail planner Towers
	When the raw materials (RM) are received and stocked the goods are inspected on their quality w.r.t. the predetermined quality specifications.	Warehouse & Transport; inspection: Quality Control
	Finally, when the RM quality is approved, the production may start.	Processing

Figure 3.2 – Customer order fulfillment (detailed)

3.2 Production process

For a manufacturing firm, the procurement of raw materials is a facilitating activity. In order to provide proper support for the actual production, it is helpful to gain insight in the production process. Section 1.1 already provided a high-level overview of the production process of IFT. This section will describe the process in more detail. However, it is not intended to outline the entire technological process; it is intended to gain insight in the different locations and especially points in time where ingredients unite. At the end of this section, these occasions are set against the packaging date. That is because the packaging date is directly derived from the delivery date, which is agreed with the customer.

During the production, multiple semi-finished products and ingredients congregate. Figure 3.3 depicts the processing of the required ingredient groups during the production process. It is a swimlane diagram. Each 'swimlane' represents a location or responsible department. The different colors mean that the ingredients are processed in the same production phase, except for the additives (yellow pentagons).

It is desired to start the production as soon as the required ingredients are approved. The various ingredients undergo their own preparations before they are united into the (semi-) finished products. In Figure 3.3 you can see, that RMO (milk) and whey are processed into skimmed milk and OWC, respectively. OWC is demineralized whey concentrate (in Dutch: Ontzoute Wei Concentraat). These two semi-finished products are united with the fat-blend. The fat-blend consists of fat, which is fortified with nutritious additives. These three semi-finished products together are condensed into base concentrate (see the blue pentagons). In addition, some of the skimmed milk is condensed to AMMP, which is a direct ingredient for the end product.

The yellow pentagons represent groups of additives. One part of the additives is covered already, i.e. the additives intended for the fat-blend. The additives are weighed and dispensed at the dispensary for so-called clusters. Clusters consist of small quantities of various ingredients. At the dispensary, the clusters are prepared for (1) the base, which is produced by the Towers and (2) the mixed product, which is blended by the Ruberg installation. The base is produced 2 to 4 weeks before the packaging date of the end-product. Otherwise, the Ruberg-clusters are prepared 3 to 4 days before processing by the Ruberg, i.e. 7 days before packaging. Hence, the ingredients intended for a Tower-cluster have to be available earlier than ingredients intended for a Ruberg-cluster.

The base concentrate and Tower-clusters are further processed into base. If the end product is intended for infants (0-6 months old children), the combination is enriched with lecithin and MCT oil. Once the quality of the base is approved, the base is blended with sugar, AMMP, and the Ruberg-cluster into mixed product. Finally, the mixed product will be packed and shipped.

For this research, especially the supply of additives is important. The supply of RMO, fat, and whey is not within the scope of this research. Ingredients are added to the production at different moments in the production process. Given these moments, it can be calculated which ingredients could be purchased on order (preferred) and which ingredients have to be purchased based on forecasts.

The ingredients required for the Ruberg-clusters have to be available around 7 days before packing, i.e. 3 to 4 days used for the cluster preparation and 3 days after the blending at the Ruberg. Though, for the blending, base is required. Every type of base is produced at most once per two weeks. The exact production schedule is determined one to two weeks before production. However, due to delay caused by unplanned production stops, the schedules can be adjusted anyway. Before the base production, the dispensary takes 3 to 4 days to prepare the base-clusters. And after the base production, the inspection for base takes another two weeks. Hence, we may assume that the 'lead time' for base amounts at least 31 days.

Finally, the base-concentrate, required for the production of base, has to be evaporated within 30 hours. On average it is evaporated within 24 hours. Except the fat-blends for specialties, no additive-clusters have to be prepared by the dispensary. The additives for *regular* base are available on location. Hence, it takes around 2 days to make base-concentrate for *regular* base and at most 6 days for *specialties*.

Recall that a customer order will be definitive 9 weeks before its packing date, i.e. 63 days. Hence, the period remaining for replenishment 'on order' can be determined. Ingredients with a replenishment lead time longer than the remainder (last column) have to be purchased based on forecast. The ingredients with a replenishment lead time within the remaining period can be purchased on fixed orders. Table 3.1 summarizes the described preparation periods. The values in the last two columns are cumulative 63 days. Note: the inspection result is assumed to be positive, i.e. the ingredients and base are approved.

Please note that there is a significant difference in the time of usage of the *tower*-material versus the *mix*-material. Solely tower-materials with lead time shorter than 19 or 23 days (around 3 weeks) can be purchased on order. The remainder of the orders is based on forecasts. For the mix-materials the lead time for purchasing on order should be less than 56 days (8 weeks).

Ingredients are intended for	Duration of processing phase (days)	Days required before the end-products' packing date	Days left for replenishment
Fat-blend (for specialties)	6	44	19
Fat-blend (for regular base)	2	40	23
Base (Tower-cluster)	31	38	25
Mixed Product (Ruberg-cluster)	7	7	56
Packed end product	-	0	63

Table 3.1 – Preparation periods of ingredients

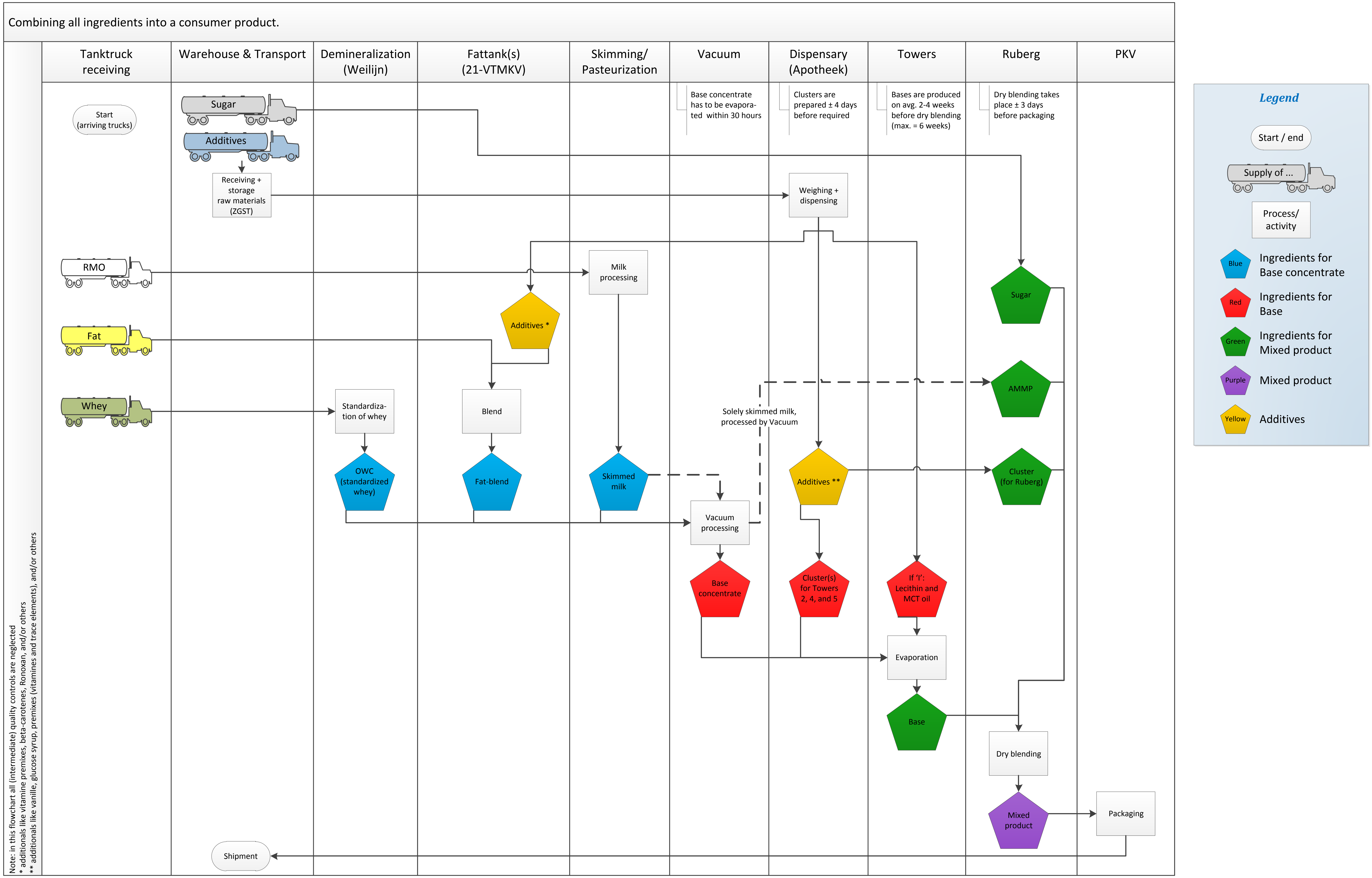


Figure 3.3 – Combinations of ingredients during the production process of the consumer products

3.3 Replenishment process

The goal of this section is to outline the (current) replenishment process for a better understanding and to unveil opportunities for improvement. Domo Beilen takes into account two types of inventory, namely cycle stock and safety stock.

- **Cycle stock**; the result of ordering larger amounts than the demand, for example because of economies of scale.
- **Safety stock**; the (average) inventory kept on hand to buffer against uncertainties in supply and demand.

This section is divided into three subsections. Subsection 3.3.1 describes the replenishment process. Subsection 3.3.2 outlines the uncertainties influencing the purchase orders. Finally, subsection 3.3.3 illustrates how the current safety stocks are determined.

3.3.1 Replenishment policy

In this subsection, the process of ordering raw materials will be described. The ordering takes place as follows. Every Wednesday is 'ordering day'. This is prompted by the preceding planning activities, which are executed every Monday (for the packaging) and Tuesday (for the base production, at the Towers). Hence, on Wednesday all production plans and demand forecasts are updated and the purchasers will order the required raw materials.

Domo Beilen uses two types of replenishment policies. Namely, a periodic review policy with fixed order quantities, called (R,s,Q), and a periodic review policy with variable order quantities, called (R,s,S). The ***R*** represents the *review period*, which is 7 days for Domo Beilen. The small ***s*** denotes the *reorder point*, which equals the *expected demand during the replenishment lead time, including the inspection lead time*. In case of variable lot sizing, the capital ***S*** represents the *Order-up-to-level*. Considering fixed lot sizing, the capital **Q** represents the fixed order quantity.

R	Review period
s (small)	Reorder point
S (capital)	Order-up-to-level
Q	Fixed order quantity

Table 3.2 - Abbreviations inventory policy

During 2013, 193 SKUs were ordered. Most ordered SKUs (96%) have a variable lot sizing policy. The remaining 7 SKUs have a fixed lot size policy (see Table 3.3).

Replenishment policy	Lot sizing	Amount of SKUs	Percentage
(R,s,S)	Variable	186	96%
(R,s,Q)	Fixed	7	4%

Table 3.3 - Current inventory control policies

SAP

Domo Beilen uses a real time Enterprise Resource Planning (ERP) system, called SAP. *Real time* means that whenever the purchasers order, the requirements are up-to-date with respect to the planned and scheduled productions orders. SAP combines the demand of every week into one purchase request. SAP proposes a purchase request considering the preset minimum or fixed order quantities and rounding values. Subsequently, the purchasers check and combine the proposals before they send an official purchase order. The purchasers are enabled to adjust SAP's proposals in timing and quantity. SAP does not consider the review period, instead the purchasers do.

SAP calculates the reorder points and order-up-to-levels, i.e. the purchase requests, based on the expected demand during the *replenishment lead time* and the current *available inventory* and the quantity limitations described above.

$$Purchase\ requisition = forecasted\ demand_{lead\ time\ \&\ inspection\ period} + safety\ stock - available\ stock \quad \text{(Eq. 1)}$$

Further, SAP considers the preset safety stock as reservation. Once the demand during the replenishment lead time and the safety stock exceeds the available stock quantity, a purchase request will be inserted. Table 3.4 shows an example. The planned date (first column) is the date that the available quantity (last column) will change. Please note: the *Purchase Order* mentioned is expected to be delivered at June 30th. If the lead time for this SKU concerns 28 days, the purchase order should be submitted at most at June 2nd. In this example, 21 days of entrance inspection will follow, before the production order may start.

Planned dates	MRP header	Rec./reqd qty	Avail. quantity
05-06-14	-	-	164
05-06-14	Safety Stock	-50	114
30-06-14	**Purchase Order**	**36**	150
21-07-14	Order Reservation	-67	83
22-07-14	Order Reservation	-80	3
21-10-14	**Purchase Requisition**	**36**	39
11-11-14	Order Reservation	-37	2

Table 3.4 – Example of purchase requisition (21-10-2014) proposed by SAP

Although the safety stock is seen as a reservation, it does not influence the size of a purchase order. Hence, SAP´s available stock corresponds with the in inventory management well-known inventory position (Equation 2).

$$Inventory\ position^{*} = stock\ on\ hand + outstanding\ orders - backorders^{\dagger} - reservation \quad \text{(Eq. 2)}$$

$$Order\text{-}up\text{-}to\text{-}level = inventory\ position + planned\ usage_{delivery\ and\ inspection\ lead\ time} \quad \text{(Eq. 3)}$$

SAP distinguishes three types of stock: *approved, blocked,* and *in-inspection* stocks*.* For example, the blocked stocks concerns handling damage, cattle feed, and lost stocks. An important feature is that SAP considers the *in-inspection* stock as available stock. Also, SAP assumes that all in-inspection stock will be approved, i.e. released for production. However, in practice not all inspections lead to an approval.

According to the Purchase Requisition-list the purchasers check whether the raw materials are really required or not. For example, it is possible that a quality inspection takes longer than expected. Then, the choice has to be made (1) await the inspection result or (2) not await and submit an additional purchase order (PO). These choices are based upon internal communication and the purchasers'

* The inventory position is comparable to SAP's *Available quantity*, because the safety stock is seen as reservation.

† Backorders are orders that have been demanded, but are not yet delivered.

experience. Reasons for submitting an additional PO can be the duration of a re-inspection or the expectation that the batch will be disapproved.

In short, SAP does the main calculation and the purchasers are able to adjust the purchase requests in timing and quantity.

Submitting Purchase Orders

> *"We order three to four weeks in advance. We do this to balance possible quality disapprovals and production plan changes."*

During observation and questioning, the purchasers indicate that they order earlier than SAP proposes.

This is remarkable, because they are creating additional safety stocks. Hence, this additional safety stock equals the demand of three to four weeks. Obviously, this is not desirable. These decisions, made on intuition, subvert an optimal inventory policy.

Nevertheless, it is not surprising that the purchasers create safety stock based on their insights, because many changes are made in the master plan, also within the replenishment lead times. Even changes into the detailed planning sometimes are forced from above. The Supply Chain department imposes these changes, motivated by the high market competition. The changes differ from increasing and decreasing to complete elimination of process orders. Increasing orders might cause the worst consequences, as the purchasers have to order additional raw materials. However, decreasing or eliminating process orders result in excess stock, but does not harm the work of the purchasers.

Currently, the order quantities are derived completely from the expected demand during the replenishment cycle. Historic demand is not considered in determining order quantities. Hence, the purchasers are completely depending on the accuracy of the forecasts.

A good example of a poor performance of the supply chain is the following. For months, a customer rejects its forecasts completely around 10 weeks for production. For 10 out of 15 raw materials this is no problem, but for the remaining 5 it is. These raw materials have a longer lead time than the considered 'rejection' period of 10 weeks. These rejections led to the disposal of the materials, being worth €24.000. However, as the purchasers order three to four weeks earlier than SAP proposes, two other ingredients are unnecessarily purchased as well.

Discount prices

While analyzing the procurement contracts, it appeared that for 84 SKUs discount prices exist. SAP does not consider discount prices in proposing its purchase requests. However, the purchasers did not use the discount prices to determine optimal order quantities either. The purchasers indicate that they did not know where to find the discount prices. In order to provide a sustainable solution, the discount prices will be considered in developing a new inventory model as well.

Obsolescence

Until recently, the purchasers were surprised by obsolete stock. SAP does not alert its users that the *available* stock will decrease suddenly. Besides it is a wasted investment, in some cases this causes troubles requiring planning adjustments.

Phasing out of raw materials

Occasionally, the R&D department announces a recipe change. A recipe change can be caused for example by national legislation, by the customer (new requirement), or by procurement (difficulties in supply). It means that an ingredient will be replaced, added, or repelled. Especially a replacement seems difficult to manage efficiently. An efficient replacement means in theory that a new raw material comes in, when the former raw material is fully consumed. However, in practice this is difficult, for example because the safety stock does not match any demand.

Currently, there is no (standardized) change procedure regarding the phasing in/out of raw materials. No one is assigned responsibility to phase out ingredients efficiently. The difficulty with ingredients is that most of the ingredients are used in multiple recipes. For example, if a customer requests a recipe change, it does not automatically mean that the ingredient is not needed anymore for other recipes.

3.3.2 Uncertainties in replenishing raw materials

Within the replenishment process, the purchasers are subjected to various uncertainties impeding their replenishment decisions. Additional stock, better known as safety stocks, are intended to buffer against these uncertainties. In order to determine proper safety stock levels, it is necessary to unveil the uncertainties concerning the replenishments. In the remainder of this subsection the following uncertainties will be outlined:

I. Uncertainty in Supply
   a. Uncertainty in *timing of vendor's supply*
   b. Uncertainty in *duration and outcome of quality inspections*
      1) **Raw materials**
      2) **Base productions**

II. Uncertainty in Demand
   a. Uncertainty in *production plans/schedules*
      3) **Demand plan**
      4) **Masterplans**
      5) **Detailed plans**

Vendor's supply

The purchasers indicate that almost all vendors deliver in time. "In rare occasions, the supplier asks for delay. As long as we know which day it will arrive it is no problem. Then we will change the delivery date in SAP." The Warehouse and Transport department (W&T) receives all incoming raw materials. When the delivery arrives, the goods received have to be scanned. With the scanning, the PO is fulfilled and SAP is updated. Subsequently, the Quality Control department can take a sample, if this is required for these particular raw materials.

Quality inspection

There are two types of relevant quality inspections: (1) the entrance inspection and (2) the base inspection. For both inspection types holds that the outcome of the inspections is uncertain. For the entrance inspections it applies that the expected *duration* considered is often not realistic. For the base inspections, the timing is reliable. However, the consequences for the required *quantities* of raw materials are not.

Most samples are sent to a laboratory and after a while, the results are sent back. The duration of the entrance inspections considered by SAP, and therefore used for determining purchase orders, does not match reality. I have analyzed the data of all entrance inspections executed in 2013, 1879 inspections in total. Their durations are summarized in Table 3.5. The average excess, i.e. actual minus planned duration in days, and the variability of the inspection lead time are significant. Although the inspections take longer than expected, the quality is acceptable. Table 3.5 makes clear, that the entrance inspection lead times known by SAP need to be adjusted.

Inspection lead times in SAP (days)	Number of inspections	Average excess (days)	Std. dev. of excess (days)
0	266	3,6	7,2
1	38	2,3	2,9
7	8	5,0	7,7
9	392	7,0	11,8
14	821	-1,0	8,4
21	351	14,1	19,8
(empty)	3	10,3	8,6
Totals	**1879**	**4,2**	**13,1**

Table 3.5 – Entrance inspection lead time in practice

The base inspections instead, have a realistic lead time. Around 1% of the total base production is fully impermissible. However, 16% of the base production requires rework, which causes changes in the raw material requirements within the raw material lead times.

It is extremely complex to assess the consequences of rework to the raw materials. Every reprocessing has its own 'adjustment' recipe, existing of different amounts of different raw materials. Nonetheless, I can assess the differences between the forecasted and actually processed raw materials. Within these differences, the consequences of rework are captured. Therefore, there is no necessity to specify the consequences of rework.

Production plans and schedules

Due to numerous influences, such as production failures, base disapprovals or customer order changes, a plan or schedule can change. While replenishing, the purchasers have to consider the material lead times. They want to know timely what is required for the planned production. Therefore, purchasers (and a lot of others) benefit from an accurate forecast. The raw material replenishment lead times vary from 1 to 21 weeks. Around 90% of the SKUs is attainable within 13 weeks. Therefore, I have analyzed ten (weekly published) masterplans, which consider 13 weeks.

To determine the extent of uncertainty I have analyzed the masterplans for the packaging lines of week 2 to 11 by conducting a sample of 170 process orders against a total amount of 732 process orders. The results of my analysis show many adjustments. These adjustments are caused by (1) production failures (internal cause) or (2) customer behavior (external cause). The ratio between these causes is still unclear. However, with my analysis, the consequences can be easily depicted and the supply chain can be asked for explanations. The sample showed the following:

- 13 Process orders are shifted (advanced or delayed), but later returned on their original timeslot.
- 39 Process orders are cancelled (!) (partly production failure/ partly customer behavior)
- 7 Process orders are shifted to a timeslot one week earlier
- 9 Process orders were increased with more than 50%

If a process order is shifted, i.e. advanced or delayed, this concerns often one week in the planning. However, the quantity adjustments fall mostly within the replenishment lead times of the raw materials. In general, there is sufficient stock to buffer against these changes, as the purchasers request the raw materials four weeks in advance. Besides, if purchase orders are submitted, in general they are not delayed or cancelled later on.

The master production plans for the base productions (Towers) show also fluctuations. However, the *Tower* master plan is heavily influenced by the disapproval and reproduction need of base. Once a produced batch is disapproved, it has to be produced again. Therefore, additional raw materials are required, namely if the raw materials are processed, one cannot separate them anymore. As implied, the disapproval of base amounts 1% of the total base production. The reproductions concern 16% of the total base production. Unfortunately, it is nearly impossible to assess the impact of reproduction to the raw material requirements, because all reproductions are order specific.

Concerning the base production planning and production output, it is nearly impossible to assess the impact to the raw material requirements. In contrast, concerning the end product production planning, the planning shifts concern in general one week. Nonetheless, the cancelled end product production orders result in additional holding costs, or even in obsolescence. For the items with the longest lead times, the planning adjustments have the largest impact.

One adjustment of a process order for a final product causes around 15 to 20 changes in the raw material requirements. It is hard to assess to which extent the changes influence the replenishment process. However, it is clear that the changes result in a turbulent production and replenishment process.

3.3.3 Safety stock review

Domo Beilen uses safety stocks already. The safety stock levels are reviewed every quarter during a meeting. The goal of this subsection is to outline the decisions made, during the determination of the safety stock levels.

As preparation of the review meeting, the *stock control officer* calculates an already developed Excel-model. The model recommends four types of characteristic changes, which will be outlined in this subsection:

1) ABC-classification
2) XYZ-classification
3) Allowed amount of weeks coverage
4) Safety stock quantity

ABC-classification

The ABC-classification is a method to assess the importance of SKUs. It is used in many production companies. The methodology is based on the Pareto principle, which states that around 80% of the money is possessed by 20% of the people (Pareto, 1971). However, the annual turnover or annual usage value is the main part in the ABC-classification. The organization's SKUs have to be ranked from highest turnover (=demand*material value) to lowest turnover. Then, the organization is able to classify its SKUs according to certain thresholds. For example, Domo Beilen labels the top 80% as class A, the next 15% as class B, and the remaining 5% as class C.

XYZ-classification

Another classification used by Domo Beilen is the XYZ-classification (see Zäpfel, 1996). The XYZ-classification aims at the demand distribution, e.g. is the demand steady or lumpy over time? For this classification, the *coefficient of variation* (CV) over the demand per week is calculated. Equation 3 shows how Domo Beilen determines the CV of the demand per week.

$$CV_{demand\ per\ week} = \frac{\sigma_{actual\ demand} / \mu_{actual\ demand} + \sigma_{forecasted\ demand} / \mu_{forecasted\ demand}}{2} \quad \text{(Eq. 3)}$$

Domo Beilen uses the thresholds CV≤0.3 for class X, 0.3<CV≤0.7 for class Y, and CV>0.7 for class Z. Hence, class X concerns the steadiest demand and class Z concerns the lumpiest demand.

<u>Remarks</u>

1. The CV is calculated over the *predictable* variance as well. It is not considering the *uncertainty* of the demand alone, i.e. the standard deviation of the forecast error. For predictable variance, there is no safety stock required, because we know it is coming.
2. The variance in the past six months and the variance of *forecasted* demand for the coming six months are weighed equally, while the forecasts capture uncertainty and the actual demand does not.

Week's coverage

The week's coverage variable is an 'approved' period of having a certain SKU in stock. Coverage of 6, 8, or 16 weeks is allocated based on three variables: the material's ABC-class, its XYZ-class, and its replenishment lead time. However, in practice, nothing is done with this characteristic.

Safety stock

The most important output of the review is the new safety stock size. Silver, Pyke & Peterson (1998) stated: "Safety stock is the amount of inventory kept on hand, on the average, to allow for the uncertainty of demand and the uncertainty of supply in the short run." For every SKU a safety stock is determined according to Equation 4.

The k denotes the *safety factor.* Domo Beilen uses three different safety factors are used, which are allocated based on the XYZ-classification (Table 3.6).

Class	Safety factor k	Probability of no stockout
X	1.282	90 %
Y	1.64	95 %
Z	3	99.9 %

Table 3.6 - Safety factor allocation

$$Safety\ Stock = k * \sigma_L \qquad \text{(Eq. 4)}$$

However, because Domo Beilen uses a periodic review policy, the safety stock should also cover the review period. This makes the formula:

$$Safety\ Stock = k * \sigma_{L+R} \qquad \text{(Eq. 5)}$$

Remarks

1. The review model solely considers the demand variance per week. This includes the predictable variance, instead of solely the uncertainty in demand.
2. The review model does not consider (the uncertainty during) the review period.
3. The review model does not consider realistic entrance inspection lead times.

Safety stock meeting

As said, the safety stocks are reviewed every quarter. During the *safety stock meeting* the proposals for the safety stock quantities will be discussed. A masterplanner (from Supply Chain), a purchaser (Business Office), the location procurement manager (Procurement), and the stock control officer (Supply Chain) will attend this meeting. They are expected to determine together optimal safety stock values. I have witnessed one such Safety Stock meeting and there were two interesting peculiarities:

1. No attendee benefits from a tighter safety stock
   The common goal and interest is 'no stockouts'. Higher (safety) stocks make the job easier for the work preparer; higher safety stocks provide the masterplanner more latitude in creating a feasible plan; higher safety stocks mean more replenishments, thus in theory the Procurement Manager is able to agree better contracts. Finally, the Stock control officer did not take a vote.

2. There was no confidence in proposals
   I noticed that the attendees did not have (any) confidence in the proposal calculated by the stock control officer. In practice, every proposal was overruled. Sometimes a safety stock equaled zero, while the model proposed a nonzero safety stock. Except if it concerned a new SKU, this meant that no problems were experienced or that the SKU is purchased by other purchasers (for RMO or whey). Because every proposal was overruled, I explicitly asked: "Do you trust this model?" The attendees told they did not trust it. It turned out, that they did not understand the calculations beyond the model. Though, why do they use it then? They still use it because it provides a complete list of SKUs with a reference point, i.e. the current safety stock levels, its historic demand, its expected demand, and its lead times.

The most important remarks on the model are mentioned already in this chapter (denoted by: remarks). For a more information about the current model, all the models functions are explained in more detail in Appendix C.

3.4 SKU characteristics raw materials

With a business analytics program, named Every Angle, data from SAP is easily analyzable (Every Angle, 2013). With the help of Every Angle (EA) data is filtered from SAP, to provide some interesting statistics about the raw materials and their demand.

Within SAP, 697 article groups are labeled as *raw materials.* Other material types are for example: finished products, packaging, or semi-finished products. Of the 697 article groups, just 195 raw materials are required the past 12 months and two SKUs concern the RMO (milk) and whey, which are purchased by others. Hence, 193 SKUs remain to be analyzed. These findings indicate that the dataset is polluted with redundant information.

ABC classification

The ABC-classes are determined by considering all known *raw material* SKUs, even the SKUs without demand in the future (and/or in the past). In the ABC classification, also bulk articles, like RMO and whey, are incorporated. These SKUs are processed in large quantities and within a day. In other words, these items receive a special treatment with respect to the other SKUs. They bias the ABC-classification if we use it to assess the criticality of the 'on the shelf' SKUs.

Table 3.5 depicts the results of Domo Beilen's ABC classification of March 2014. If we exclude the irrelevant SKUs, i.e. the RMO and whey products and the SKUs without demand, the figures in Table 3.6 remain.

ABC Classificat.	Class	Cumulative turnover	# Article groups	
	A	78.63%	5	0.7%
	B	94.90%	21	3.0%
	C	100.00%	671	96.3%
			697	**100%**

Table 3.5 - ABC-class sizes of all known SKUs

ABC Classificat.	Class	# Article groups	
	A	1	0.5%
	B	21	10.9%
	C	171	88.6%
		193	**100%**

Table 3.6 - ABC-classes of all relevant SKUs with demand

XYZ classification

Furthermore, Domo Beilen uses the XYZ-classification (see Zäpfel, 1996). Table 3.7 depicts the XYZ-class sizes according to the safety stock review of March 2014. The abbreviation CV denotes the coefficient of variance of the demand per week. At Domo Beilen, this is an average of the demand of the past six months and the forecasted demand for the upcoming 6 months.

XYZ Classificat.	Class	CV demand per week	# Article groups	
	X	$0 \leq CV < 0.3$	55	28,5%
	Y	$0.3 \leq CV < 0.7$	91	47,2%
	Z	$CV \geq 0.7$	47	24,4%
			193	**100%**

Table 3.7 - XYZ-class sizes and their CV thresholds

Procurement costs

In order to determine what is cost efficient, i.e. holding more inventory or replenish more often, the procurement costs are researched. FrieslandCampina Domo agreed *all-inclusive* prices for its raw materials. The total procurement costs are made variable per kilogram or multiplicity. Hence, no fixed order costs are incorporated.

Further, I found discount prices for 84 SKUs. These discount prices can lead to cost savings and will therefore be incorporated in the final replenishment model. As explained in Section 3.31, I have provided the purchasers an overview of discount prices and break-even points such that they can make some beneficial decisions already.

Replenishment lead times

The analysis of the lead times leads to other interesting outcomes. The replenishment lead time is the time elapsing between the moment an order is placed and the moment that the raw materials are physically on the shelf ready to satisfy customer demands (Silver, Pyke, & Peterson, 1998). Hence, for Domo Beilen applies:

Replenishment lead time = delivery lead time + inspection lead time (Eq. 6)

Table 3.8 provides insight regarding the replenishment lead times. The black lines represent the boundaries of a planning level (Forecast > Masterplan > Detailed Production Plan PKV). Hence, it means that at least 14 SKUs are ordered on demand forecast, which includes more uncertainty than the master plan.

Another discrepancy exists regarding the replenishment lead time and the material requirement plans. Namely, the Logistics Manager explained that a customer has to submit his (definitive) purchase order 11 weeks for its delivery date. Because the final quality inspection takes 2 weeks, this implies that a customer order is submitted at least 9 weeks before the packaging date. One exception is made: one customer is allowed to submit its purchase orders 6 weeks before packaging. Further applies: “No order changes are allowed, *unless* Master planning gives a positive advice.”

In Table 3.9, we see the 14 SKUs which are not attainable within 13 weeks. The table suggests there is no relation between the replenishment lead time and the ABC or XYZ classification of the SKUs.

Period before available = Planned Deliv. Time + Quality Insp. Time	SKUs	SKUs
Totals	193	193
1 week	1	16,1%
2 weeks	3	31
3 weeks	12	
4 weeks	15	
5 weeks	18	76,7%
6 weeks	16	148
7 weeks	22	
8 weeks	45	
9 weeks	28	
10 weeks	9	
11 weeks	1	
12 weeks	9	
13 weeks	0	
14 weeks	4	7,3%
15 weeks	2	14
16 weeks	1	
17 weeks	0	
18 weeks	1	
19 weeks	4	
20 weeks	1	
21 weeks	1	

Table 3.9 - Replenishment lead times

SKU	Replenishment leadtime	ABC	XYZ	Week coverage	Total shelf	Vendor
1	13,3	B	Y	16	9	Q
2	13,3	C	Y	16	9	Q
3	13,3	C	Y	16	9	Q
4	14	B	Y	16	9	Q
5	14,1	C	X	16	36	R
6	15	B	Y	16	24	Q
7	15,6	#	#	#	24	Q
8	17,3	C	X	16	24	S
9	18,4	B	Y	16	36	R
10	18,4	B	Z	16	36	R
11	18,4	C	Z	16	24	R
12	18,4	C	X	16	24	R
13	19,1	B	Y	16	24	R
14	20,6	C	X	16	24	T

Table 3.8 - Characteristics of SKUs with the longest replenishment lead times

Shelf lives

Most SKUs have shelf lives of 12 months or more. Just five SKUs have shelf lives of six months or less (see Figure 3.4). A shorter shelf life enlarges the possibility of obsolescence. These SKUs represent 20% of the yearly obsolescence costs, i.e. € 60.000. Despite the items are C-items, the obsolescence should be prevented, as the production cycles are shorter than the shelf lives.

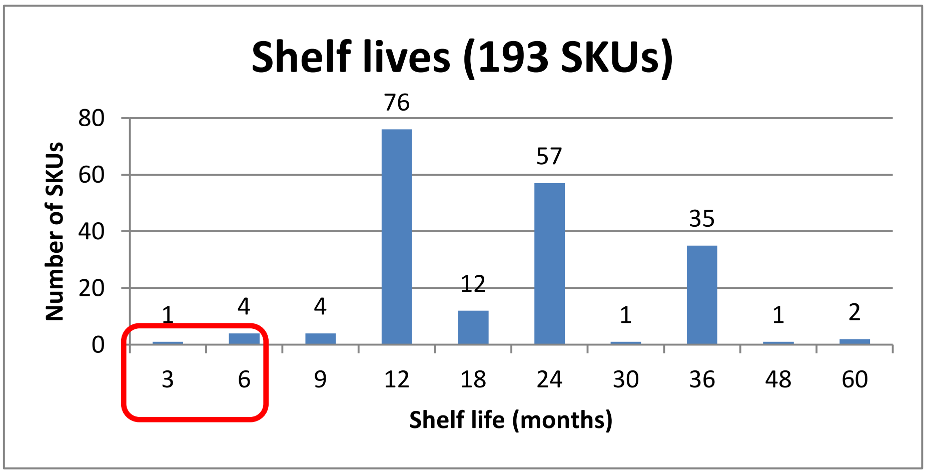


Figure 3.4 - SKU Shelf lives

Intermittent demand and non-normal demand distributions

Some raw materials are required a few times a year. Around 30 SKUs are expected to be used 6 times or less during 2014. This means that the raw materials are used once per 8.7 weeks on average. Appendix D presents the amounts of SKUs sorted on the number of weeks per year that the SKUs are required.

3.5 Performance and current inventory

To provide a reference point for the current situation versus the future situation, the current performance needs to be assessed. There are several figures indicating that the current inventory control of raw materials can be improved. Officially, the performance of the purchasers is not assessed with so-called *key performance indicators*. Therefore, I provide some figures representing the current situation myself.

Performance in Figures

I. **Stock value**
   i. During April 2014 the average raw material stock value amounted € 23.000.000
   ii. The official safety stock is worth €1.200.000 (19% of total raw material stock)

II. **Amount of pallet locations occupied**
   During April 2014, on average 6050 pallets with raw materials were kept in stock.
   i. A pallet remains on average 54.3 days or 7.8 weeks in stock.
   ii. Therewith, we estimate the yearly *storage costs* at €315.000, i.e. €1 per pallet per week.
   iii. The official safety stock concerns 705 pallets. This equals to storage costs of €36.400 per year and a material value of approximately €1.200.000.

III. **Obsolescence costs (excl. the unnecessary holding costs made)**
   In 2013, the costs caused by obsolescence of raw materials amounted to €315.000 (this is by chance the same amount as the storage costs).
   i. 55% concerns product specific ingredients, which is not used due to cancellation
   ii. 25% concerns stock without demand; lack of out phasing procedure
   iii. 20% concerns SKUs with a shelf life being ≤ 6 months

Current inventory

The expected requirements for the coming year represent a value of 112 million Euros. Assuming that every SKU is being delivered once per 8 weeks, then every 8 weeks raw materials with a cumulative value of 17.2 million Euros should arrive on average. Hence, the *average* cycle stock[‡] would amount 8.6 million Euros. The official safety stock values 1.2 million Euros. During April 2014, the raw material inventory concerned around 22 million Euros. This implies that the actual safety stock is worth 13.4 million Euros[§]. That is eleven (!) times as much as the 'official' safety stock value. The difference indicates that the safety stocks either are extremely poor determined, or there is redundant inventory present, or a combination of these two possibilities.

[‡] Please remark: the more often replenishments take place, the lower the average cycle stock will be.
[§] Average stock level value – average cycle stock value = 22 million – 8.6 million = 13.4 million Euros

Delivery	Total requirements	Average Cycle Stock Value
Once per year	€ 112,000,000	€ 56,000,000
Once per 8 weeks	€ 17,200,000	€ 8,600,000
Once per month	€ 9,300,000	€ 4,700,000
Once per week	€ 2,150,000	€ 1,080,000

Table 3.10 – The amount of replenishments influence the average cycle stock

In general, replenishing more often results in a lower inventory value (see Figure 3.5). Please note that Figure 3.5 is a major simplification, because other costs can increase, e.g. transportation costs and handling costs. Furthermore, the pragmatic benefits of receiving less often deliveries play a role as well. Nonetheless, the figure makes clear how the inventory value can be reduced by replenishing raw materials more often.

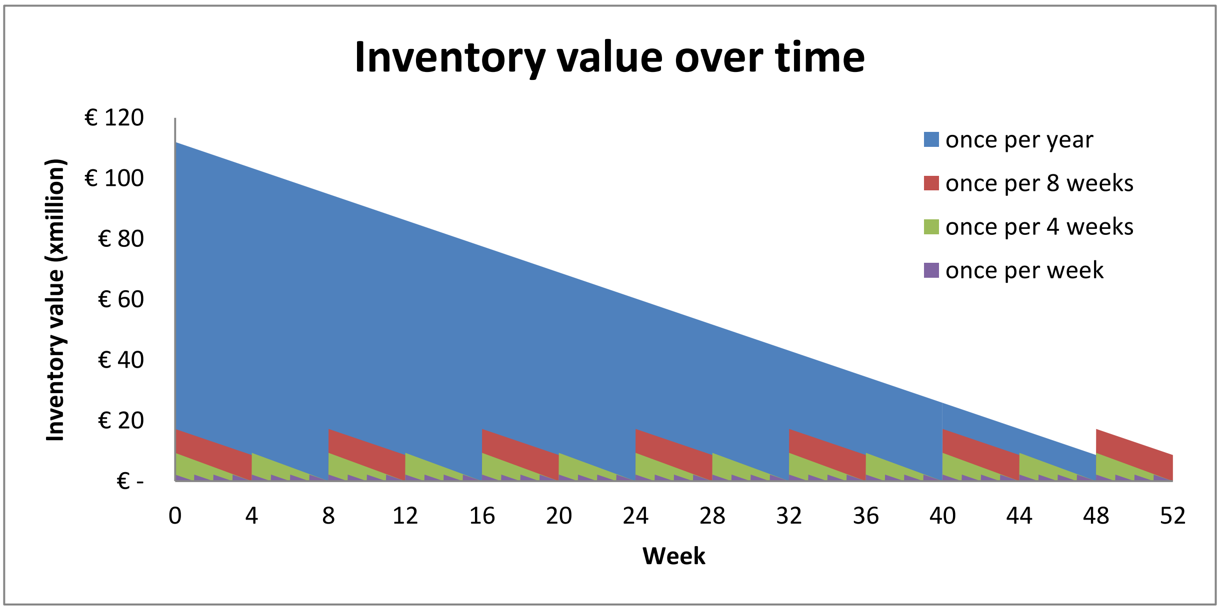


Figure 3.5 – The amount of replenishments per period influence the average cycle stock value

3.6 Conclusion

After observations and (data) analysis, it can be concluded that the current inventory policy is not optimal. A positive notification is that the unavailability of raw materials hardly causes production stops. However, Domo Beilen carries superfluous inventories and makes unnecessary costs in several ways. Hence, there is plenty of room for improvement. Table 3.11 presents the conclusions drawn in this chapter.

1	**The current performance of purchasing (or replenishing) raw materials falls short**		**Section**
	i	By purchasing three to four weeks (!) in advance, the purchasers create additional safety stocks.	3.3.1
	ii	Way more is purchased than required, considering the current (large) inventory.	3.5
	iii	There exists no termination policy for SKUs with ending demand (25% of obsolescence costs).	3.3.1
	iv	There is no awareness of the expiry dates of the inventory present.	3.3.1
2	**The input used for determining the order points and quantities is not appropriate**		
	v	The proposed inspection times for raw materials do not match reality. In general, these inspections take longer than expected.	3.3.2
	vi	Discount prices are not considered.	3.3.1
3	**The current safety stock review model is inadequate**		
	vii	The safety stocks are allocated to predictable demand variance, whereas the safety stock should be allocated to the **uncertainty** in supply and demand (forecast error).	3.3.3
	viii	The review period is not considered.	3.3.3
	ix	Disputable formulas are used. For example, the variance of the demand per week of the past six months and the forecasted six months are weighed equally, whereas the forecasted demand captures uncertainty and the actual demand (past six months) does not.	3.3.3
	x	The attendees do not support the safety stock review-model.	3.3.3
	xi	There is no counterweight present during the review meeting. Safety stock can be raised arbitrarily.	3.3.3
4	**Tihe current SKU classification is of little value**		
	xii	In the current ABC-classification also SKUs are incorporated that are not kept 'in the shelves', like RMO and whey. These 'tank-SKUs' blur the criticality of the other SKUs.	3.4
	xiiv	The allowed weeks coverage classification is not complied.	3.3.4
5	**Performance in figures**		
	xiv	The average inventory value amounts € 23.000.000.	3.5
	xv	A pallet with raw materials is kept in stock on average 7.8 weeks	3.5
	xvi	The yearly storage costs are estimated at €315.000, i.e. 6050 occupied storage locations on average per week.	3.5
	xvii	During 2013, the obsolescence costs amounted € 315.000.	3.5

Table 3.11 - Conclusions regarding the current situation

Due to uncertainties in supply and demand, it appears to be difficult to control inventories with hundreds of SKUs efficiently. As the main task of purchasers is to purchase sufficient raw materials such that no stock out occurs, they are tempted to purchase more than required.

This chapter confirmed the urgent need for an improved inventory policy for Domo Beilen. Therefore, their inventory control policy will be reorganized thoroughly. As Domo Beilen is not the only organization with valuable stocks and variable demand patterns, other organizations can learn from this approach too.

The current classification of Domo Beilen, i.e. *ABC, XYZ* and the *allowed week coverage*, is not complied properly and because it is not complied properly it does not provide any advantages for the purchasers. Therefore, it has to be decided if the current classification is the right classification for Domo Beilen.

In the next chapter, a literature review will be conducted, concerning SKU classification methods and replenishment policies. The (R,s,S) policy Domo Beilen currently uses is an appropriate policy in theory. However, the application of the policy is inadequate. Therefore, to improve the compliance of the replenishment policy also attention will be given to the determination of safety stocks and the consideration of quantity discounts.

4 Literature review

To determine how Domo Beilen should manage their (raw materials) inventories, a literature study is performed to answer Research question 2:

> *According to the literature, what* ***SKU classification models*** *and* ***replenishment policies*** *are recommended?*

In addition, special attention will be provided to (1) the consideration of quantity discounts and (2) the determination of safety stocks. In Chapter 3 appeared that the performance of Domo Beilen's inventory control could be improved on these areas as well.

This chapter provides the literature search results, whereas Appendix E describes the performed literature search. Section 4.1 summarizes the results of the literature study performed on SKU classification. Section 4.2 provides the results of the literature study on replenishment policies. Finally, Section 4.3 will conclude this chapter.

4.1 SKU classification

Production companies generally have to receive, process, and deliver hundreds or even thousands of items. In the inventory management area, items in stock are denoted as *stock keeping unit* (SKU). A SKU refers to an item of stock that is completely specified as to function, style, size, color, and, usually, location (Silver, Pyke, & Peterson, 1998). Van Kampen *et al.* (2012) suggest that differences in SKU-characteristics might result in different production and inventory policies. "As a consequence, companies those sell a wide variety of SKUs, often struggle with the control of their production and inventory systems." Therefore, the classification of SKUs provides companies guidance in decision-making for entire SKU classes rather than for each product separately (van Kampen, Akkerman, & van Donk, 2012).

In scientific literature a wide variety of SKU classification methodologies is published. World's most well-known SKU-classification methodology is the ABC-analysis (Flores, Olson, & Dorai, 1992; Chu, Liang, & Liao, 2008; Chen, Li, Kilgour, & Hipel, 2008). The ABC-analysis is developed by General Electric during the 1950s and is based on the Pareto principle, that around 20% of the people possess around 80% of the money (Guvenir & Erel, 1998). For Pareto's principle see (Pareto, 1971).

With the <u>ABC-analysis</u> a higher class (A>B>C) will be assigned a higher priority in the allocation of management time and financial resources in any decision system (Silver, Pyke, & Peterson, 1998). Its application is outlined in Section 3.5. Despite the ABC-analysis is the most well-known methodology, it has been frequently criticized (Flores, Olson, & Dorai, 1992; Guvenir & Erel, 1998; Chu, Liang, & Liao, 2008). The reason beyond is that the traditional ABC-analysis considers solely one criterion: the annual turnover at the time of classification.

In a reaction to the ABC-analysis, Flores & Whybark (1986) propose a <u>multiple criteria matrix</u> for a classification considering *two* criteria. A few years later Flores, Olson, & Dorai (1992) make the following remark supported by Table 4.1: "if two three-tiered criteria are used, the inventory may require nine different policies. Although it is possible to establish nine different policies, it would be a more difficult process to implement and manage these successfully." Therefore, they propose to handle the classes AB and BA, like class AA; classes CA and AC like class BB; and finally, classes CB and BC like class CC. Chen *et al.* (2008) illustrated this clearly in a table (see Table 4.3).

		Another Critical Criterion A	B	C
Dollar Usage	A	AA	AB	AC
	B	BA	BB	BC
	C	CA	CB	CC

Table 4.1 – Multiple inventory classification (Flores, Olson, & Dorai, 1992)

		CRITICALITY A	B	C
ANNUAL DOLLAR USAGE	A	X	***	**
	B	***	X	***
	C	**	**	X

Table 4.3 – Joint matrix for two criteria (Chen, Li, Kilgour, & Hipel, 2008)

Later, the awareness occurred that more item characteristics might play a role for the importance of SKUs. Flores, Olson, & Dorai (1992) suggested that other criteria may be more important than cost, e.g. lead time, obsolescence and criticality. They underline their findings with the following examples:

(1) Concerning the lead time criterion; a company had items that were classified as C-items. These items had long lead times, because they came from overseas. The long time span delayed the production process. If the items were classified considering the lead times, the items would have been A-items.

(2) Concerning the obsolescence criterion; for example, a high-tech firm holding high-value, but obsolete, inventory may incur financial losses.

(3) Concerning the criticality criterion; in the health sector, hospitals hold inventories of essential drugs and lifesaving equipment based on how critical items are to the needs of the patients and the strength of the competition.

The Analytic Hierarchy Process (AHP) is another multicriteria methodology, which helps decision-makers to rank various alternatives The AHP methodology is developed by Saaty and is applicable in many research areas (Saaty, 1980). The advantages of AHP are that (1) the method is applicable for numerous criteria and (2) the criteria might be quantitative, as well as qualitative. An important disadvantage is the subjectivity involved in the pairwise comparisons made by the decision makers (Guvenir & Erel, 1998).

There are numerous other SKU classification models. For example, Ernst & Cohen (1990) developed a statistical clustering procedure. Chu, Liang, and Liao (2008) introduced a fuzzy classification method, named ABC- Fuzzy Classification (ABC-FC). However, they will not be explained in detail here because I think that the ease of use, and therefore the reproduceability, is more important than a sophisticated classificication system.

Methodology	Authors/scholars	Advantage	Drawback
ABC-classification		Easy (based on the Pareto principle)	Solely one criteria is used to classify the inventory. This is in many cases insufficient for a proper
Joint criteria matrix	Flores & Whybark (1986)	Easy	Difficult to use for more than 2
AHP-classification	Gajpal, Ganesh & Rajendran (1994); Partovi & Burton (1993); Partovi & Hopton (1994); Flores, Olson & Dorai (1992)	It can incorporate many criteria and ease of use on a massive accounting and measurement system.	A significant amount of subjectivity is involved in pairwise comparisons of criteria.

Table 4.2 - SKU classification methodologies

4.2 Inventory control policies

Since the mid-1980s, attention for inventory management has increased (Silver, Pyke, & Peterson, 1998). The attention has been catalyzed by the Lean Management principles. The main objective of Lean Management is reducing waste. For inventory management, the reduction of waste turned mainly into reduction of inventories. Motivated by this paradigm many firms nowadays strive for effective and efficient inventory control.

Nevertheless, there is a limit on reducing inventories. In practice, firms cannot or will not function without inventories. A number of reasons why firms keep inventories are:

a. Economies of scale
b. Buffering against uncertainties in supply and demand
c. Finite supply capacity (demand peaks cannot be met by production or supply exceeds demand)
d. Shortening lead times for the customers

4.2.1 Stock types and their trade-offs

To probe further on the necessity of inventories, different functions of inventories will be denoted. Silver, Pyke, and Peterson (1998) provide a classification of functional inventories. They distinguish the following six types of inventory:

1) ***Cycle stock*** inventories resulting from ordering or producing batches
2) ***Safety stock*** inventories to buffer against uncertainty in supply and demand
3) ***Anticipation stock*** inventories obtained on time to serve an expected peak in (future) demand or to buffer against an expected decline in supply
4) *Pipeline (or work-in-progress) stock* goods in transit between adjacent work stations in a factory or between levels of a multi-echelon distribution system
5) *Congestion stock* inventories which compete for limited capacity
6) *Decoupling stock* inventories used in a multi-echelon situation to permit the separation of decision making at the different echelons

The three first mentioned stock types (**bold**) will be further explained. Instead, pipeline stock, congestion stock, and decoupling stock are not relevant for this research and will therefore not be outlined any further.

The cycle stock depends on the frequency of placing orders, and therefore the lot sizes of the replenishments. The size of a replenishment order will depend partially of the trade-off between the ordering costs and the holding costs of the purchased items, i.e. *reordering costs* versus *holding costs*.

Safety stocks are obtained to buffer against uncertainties in supply and demand. Again, a trade-off can be made, i.e. *holding costs* versus *customer service level*. Silver, Pyke, and Peterson (1998) present three measures to define customer service:

P_1 = Probability of no stockout in replenishment cycle (Cycle service level)
P_2 = Fraction of demand which satisfied directly from the shelf, thus no backorders or lost sales (Fill rate)
P_3 = Fraction of time during which the net stock (on hand – backorders) is positive (Ready rate)

The anticipation stock, as denoted by Silver, Pyke, and Peterson, concerns stocking extra materials. The necessity for extra materials could be caused by expected demand peaks, or in contrast, by expected supply declines. There is not an obvious trade-off considered. The objective of anticipation stock is simply to prevent for stockouts and therefore sufficient materials should be ordered to overcome a certain 'unusual' period.

Symbol	Meaning
A	Fixed order costs
D	Annual demand (kg)
Q	Order quantity (kg)
v_i	Unit variable cost of SKU in price class i
k	Safety stock quantity
σ_{R+L}	Std. deviation of forecast error during R+L
r	Carrying cost charge (%)
b_i	Break-even-point price class i

Table 4.3 - Parameters

Total Relevant Costs

The costs made for the different stock types can be captured in the Total Relevant Cost (TRC) function. The function is constructed from two basic components: the (re)order costs and the holding costs. The TRC is a function of Q, i.e. the (fixed) order quantity.

$$Order\ costs = fixed\ order\ costs * number\ of\ orders\ per\ year = A * \frac{D}{Q}$$

$$Holding\ costs = holding\ cost\ per\ unit * average\ inventory = rv_i * \frac{Q}{2}$$

Together, these components form the TRC function:

$$TRC = A * \frac{D}{Q} + rv_i * \frac{Q}{2} \quad \text{(Eq. 7)}$$

The TRC function is a convex function. Hence, an optimum can be determined (see Figure 4.1). For an approximately leveled demand, this optimum is known as the Economic Order Quantity (EOQ). The EOQ can be derived, by deriving the TRC function over Q. When we derive Eq. 7 over Q, we get:

$$EOQ = \sqrt{\frac{2AD}{rv}} \qquad \text{(Eq. 8)}$$

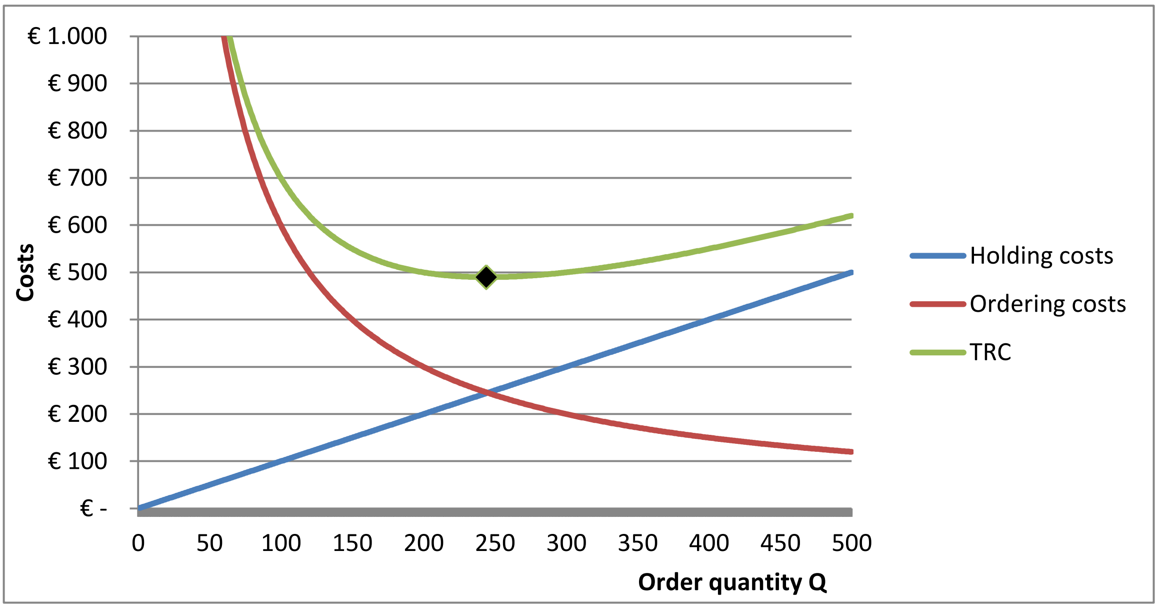


Figure 4.1 - The Total Relevant Cost function (convex function)

Discount prices discounts

In case of quantity discounts, it can be beneficial to purchase more items than the EOQ suggests, such that a discount is obtained. Considering multiple price classes, the TRC in Equation 7 has to be extended with the procurement costs. That is because different order quantities can influence the procurement costs and therefore the total relevant costs. The value v_i of a SKU is dependent of the price class i and the price class i is dependent of the order quantity Q.

$$Procurement\ costs\ = annual\ demand\ *\ unit\ value\ for\ price\ class\ i \qquad \text{(Eq. 9)}$$

$$TRC(Q, v_i) = A * \frac{D}{Q} + rv_i * \frac{Q}{2} + \boldsymbol{Dv_i} \qquad \text{, with } b_i \leq Q < b_{i+1} \qquad \text{(Eq. 10)}$$

Then, the economic order quantity is

$$EOQ_i = \sqrt{\frac{2AD}{rv_i}} \qquad \text{(Eq. 11)}$$

The optimal order quantity can be determined by applying the following steps:

1. Start with lowest price v_i (i = price class)
2. Compute for v_i the order quantity q_i^* that minimizes $TRC(Q, v_i)$ for $b_i \leq EOQ_i < b_{i+1}$
    a. Is EOQ_i if feasible; otherwise b_i
3. Compute $TRC(q_i^*, v_i)$
4. If $q_i^* = EOQ_i$ then go to step 5.
    a. Else set $i := i - 1$ and return to Step 2.
5. Select the minimum TRC. The associated order quantity is the *optimal* order quantity.

Hence, the optimal order quantity is either a feasible EOQ_i or a break point b_i.

4.2.2 Inventory control policies

The overall purpose of an inventory control system is to determine *when* and *what quantity* to order (Axsäter, 2006). Axsäter explains that the order size should not be based merely on the amount of stock on shelf. Instead, the order size should be based on the anticipated demand and different cost factors, e.g. holding costs, also. Therefore, the stock situation is defined in Equation 12. The inventory position might be negative (<0).

$$Inventory\ position = Stock\ on\ hand + outstanding\ orders - backorders - reservations$$
(Eq. 12)

There are four main types of inventory control policies for single-echelon systems. For these inventory control policies, the lot sizes will be calculated with respect to the inventory position.

	Continuous review	Periodic Review
Fixed quantity orders	(s,Q)	(R,s,Q)
Variable quantity orders	(s,S)	(R,s,S) or (R,S)

Table 4.4 - Inventory control policies

$$R = Review\ period, \quad i.e.\ the\ time\ interval\ between\ two\ reviews$$

$$s = (Re)order\ point \quad w.r.t.\ the\ inventory\ position$$

$$S = Order\ up\ to\ level$$

$$Q = Order\ quantity$$

In general, holding costs under a periodic review policy are higher than under continuous review. The reasoning beyond is that more safety stock is 'required', as the replenishment lead time increases from *delivery lead time L* to *L+R*. Therefore, the *uncertainty in the replenishment lead time* σ_{R+L} increases and thus the safety stock will increase. On the other hand, they argue that the reviewing costs and errors under continuous review are larger than under periodic review (Silver, Pyke, & Peterson, 1998). An example of reviewing costs can be allocated to track-and-tracing equipment, such as scanners, in favor of continuous inventory review.

(R,s,S) policy

The (R,s,S) can be explained as reviewing the inventory every R periods. If the inventory position ≤ s, i.e. the reorder point*,* then order as much as required to increase the inventory position to the order-up-to-level *S.* The formulas used to make the calculations for a (R,s,S) policy intended for SKUs with a normally distributed demand during lead time ~N($\hat{x}_{R+L}, \sigma_{R+L}$) are:

$$Safety\ Stock = k * \sigma_{R+L} \quad \text{(Eq. 13)}$$

$$Reorder\ point\ s = \hat{x}_{R+L} + Safety\ Stock \quad \text{(Eq. 14)}$$

$$Order\text{-}up\text{-}to\text{-}level\ S = Safety\ stock + undershoot + \hat{x}_{R+L} \quad \text{(Eq. 15)}$$

$$Reorder\ quantity\ Q = S - Inventory\ position \quad \text{(Eq. 16)}$$

With k denoting the safety factor and σ_{R+L} denoting the standard deviation of demand during the review period (R) and the replenishment lead time (L). $\hat{x}_{R+L}$ represents the *expected demand during the replenishment lead time and the review period*.

The safety factor k can be determined by the so-called P_1 service measure, i.e. the probability of having *no* stockout during a replenishment cycle (see Equation 17). Assume one requests a 95 % probability of having no stockout. Then,

$$k = \Phi^{-1}(P_1) \quad \text{(Eq. 17)}$$

$$= \Phi^{-1}(0.95) = 1.645$$

4.2.3 Standard deviation of the forecast error σ

Silver, Pyke and Peterson describe several measures of forecast variability. They recommend the use of one of these measures in particular. It is the Mean Square Error (MSE), which is an estimate of the standard deviation of errors of forecast of demand made for one *unit period.* A unit period is a forecast update interval.

To estimate the forecast error we need two types of information: (1) the actual observed demands, $x_1, x_2, \dots, x_n$ and (2) the one-period ahead forecasts $\hat{x}_{0,1}, \hat{x}_{1,2}, \dots, \hat{x}_{n-1,n}$ where, as $\hat{x}_{t,t+1}$ is the forecast, made at the end of period t, of demand in period $t+1$. Then the MSE is as follows:

$$MSE = \frac{1}{n}\sum_{t=1}^{n}(x_t - \hat{x}_{t-1,t})^2 \quad \text{(Eq. 18)}$$

If the MSE is calculated, the standard deviation of the forecast error σ_1 (for one unit period) can be derived with:

$$\sigma_1 = \sqrt{MSE} \quad \text{(Eq. 19)}$$

4.2.4 Lot sizing for intermittent demand

For SKUs with intermittent demand, it is more appropriate to use a decision rule based on a deterministic, time-varying demand pattern (Silver, Pyke, & Peterson, 1998). If in most periods no demand occurs, it does not make sense to use a stochastic decision rule based on shortage probabilities. That is because a shortage will not occur in a period without demand. Therefore, a decision rule based on deterministic demand makes more sense.

Most deterministic lot sizing procedure, e.g. Wagner-Whitin, Silver & Meal, or Least Unit Costs, incorporate fixed order costs[**]. However, Domo Beilen does not consider fixed order costs. Therefore, these lot sizing procedures are not applicable for Domo Beilen. The only lot sizing procedure that functions without a constant is the Lot-for-lot procedure. The procedure simply means replenish every period (if demand>0).

4.3 Conclusion

Chapter 4 served as preparation for the redesign of the inventory control policy. Section 4.1 denoted that it could be useful to distinguish SKUs on multiple characteristics, e.g. based on lead times, shelf lives or throughput values.

The *Analytic Hierarchy Process* is a useful multicriteria decision-making tool. The method has proven its success in many research areas, including inventory management. However, a major drawback is that a significant amount of subjectivity is involved in the pairwise comparisons between the criteria. As it makes the process more complex, I want to limit the room for discussion. Therefore, I suggest to set up a simple, intuitive classification method, which considers multiple, more important SKU characteristics than currently. The ABC classification will be applied on solely the *used* raw materials. Therewith, SKUs with short shelf lives become more important.

Of the service measures, the *cycle service level* P_1, i.e. the probability of having no stockout during the replenishment cycle is the most appropriate for, because Domo Beilen has a batch production process and will not produce a fraction of a planned production run. It is all or nothing. The *fill rate* P_2 indicates what fraction of demand be fulfilled. For Domo Beilen it is less important to know what fraction of the orders can be fulfilled (or not). This fraction is indicated by the service measure known as *fill rate* P_2. As explained, they are concerned preventing stockouts at all. For the ready rate P_3, concerning the period of having a positive net stock, holds the same as for P_2.

The (R,s,S) policy is the most suitable inventory control policy for Domo Beilen. The organization does not benefit from a continuous review policy. That is because (1) the lot sizes are based on demand in weekbuckets and (2) due to the weekly planning sequence, which makes that no purchase orders are submitted on Monday and Tuesday. In case of purchasing agreements, e.g. about full truckloads, the R,s,S policy can easily be adjusted to a (R,s,Q) policy.

Further, considering discount prices could result in lower total relevant costs with respect to ordering the economic order quantity (EOQ).

Concerning safety stocks, the predictable and the *un*predictable variation in the forecast error should be considered. The variation in the forecast error can be determined with the Mean Squared Error measure (explained in Section XX). Further, in Section 3.4.3 explained that the cyclic service level is not appropriate for SKUs with intermittent demand. Namely, you cannot get out-of-stock in a period

[**] See Silver, Pyke, and Peterson (1998)

that there is no demand. With the cyclic service level, safety stock is considered also for the *no demand*-periods as well.

Using the information discussed in this chapter, in Chapter 5 the inventory control policy will be rearranged.

5 Redesign inventory control policy

This chapter translates the literature discussed in the preceding chapter into an applicable solution for Domo Beilen's inventory control problem. Section 5.1 describes the SKU classification. Section 5.2 explains how the safety stocks should be determined. Section 5.3 explains how discount prices should be considered. Section 5.4 provides a tool for anticipating on expiring inventories. Finally, Section 5.5 concludes this chapter.

5.1 SKU classification

Section 4.1 outlined that multiple scholars suggested that a SKU classification can improve the inventory control policy and that multiple relevant SKU characters should be considered, for example lead time or risk of obsolescence.

The goal of the SKU classification is twofold. First, SKU classification could help to distinguish the most critical SKUs, if the classification characteristics are determined thoroughly. Second, it could be helpful to assign different inventory control policies to different SKU classes. For example, Silver, Pyke and Peterson explained that SKUs with intermittent demand require another kind of safety mechanism, than a safety stock based on the probability of having no stockout during a replenishment cycle.

Therefore, two *independent* classifications will be made. One to assess the importance of the SKUs and one for the practical use of determining proper safety stock levels.

5.1.1 Importance classification

The importance of the SKU will be determined based on the throughput value, using the ABC-analysis. As extension, the SKUs with a shelf life of six months or less receive also the label of highest importance (A).

One of Domo Beilen's goals for the future is to reduce the obsolescence costs. Therefore, the SKUs with short shelf lives will receive additional attention. Also, Domo Beilen wants to know what the impact of the SKU's inventories is on the working capital. The most important items (A-items)

Shelf life

SKUs with a short shelf life carry more risk to become obsolete. Items that have a shelf life of 6 months or less require special attention. The FIFO way of working will be monitored actively and large demand changes will be researched. These raw materials should be ordered in small quantities, such that the risk of obsolescence will be minimized.

Throughput value

SKUs with a high throughput value influence the inventory value heavily. Therefore, especially the inventories of these SKUs will be controlled closely. Nonetheless, the overall goal of the inventory control policy is to minimize inventories, while preventing for stockouts. The SKUs with the highest throughput value deserve more attention, because they represent a significant amount of the working capital.

In May 2014, 180 SKUs are used actively. These raw materials will be distinguished on the following characteristics.

Class	Criterium	Number of SKUs	Treatment
A-class	SKUs with highest throughput values cumulated 80 % of total throughput value.	16	Focus on minimizing inventory (while preventing for stockouts)
A-class	Shelf life ≤ 6 months	4	Actively check on FIFO processing.
B-class	Cumulated throughput value; next 15%	30	Variable order quantity
C-class	Cumulated throughput value; lower 5%	134	Fixed order quantity

Table 5.1 - Classification relevant for the replenishment policy

5.1.2 Safety stock classification

Concerning the safety stock determination, it is important to differentiate between intermittent demand and non-intermittent demand.

<u>Demand pattern; Intermittent or non-intermittent</u>
SKUs with the expectation of having six or less times demand in the coming year will be considered at intermittent demand-SKUs. On average these SKUs are required at most once every 8 weeks. Domo Beilen considers the SKUs required six times or less as specialties. According to the literature, these SKUs do not benefit from a safety stock policy as Domo Beilen is used to, because in most periods they cannot even have a stock out, as there is no demand. Therefore, another inventory policy will be developed for this class of SKUs.

The SKUs with intermittent demand, currently 27 SKUs, will be ordered two weeks in advance, to buffer against planning shifts (see Table 5.2). The production of *specials* shifts at most one week. However, if the production is scheduled for Monday, there exists a possibility that the raw materials have to be weighed on Sunday. As in the weekends no deliveries are received, it should be there earlier. It does not make sense to carry safety stock over the *entire* replenishment cycle while the SKU is required once in eight weeks. The remainder of the SKUs gets a safety stock based on the safety stock model which will be outlined in the next section.

Class	Criterium	Number of SKUs	Treatment
Intermittent demand	≤ 6 times required per year (for special products)	27	2 weeks safety time
Non-intermittent demand	> 6 times required per year	153	Calculated safety stock level

Table 5.2 - Classification relevant for the safety stock determination

5.2 Safety stock

Not every raw material benefits from a general replenishment policy. As explained in 4.2.4 the determination of a safety stock using a P_1- service level, is not appropriate for raw materials with intermittent demand. In addition, the calculations currently used for the safety stock determination are not appropriate to cover the real risks. This subsection provides new formulas, which will result in safety stock levels being more accurate. Therewith, a distinction will be made between several SKUs based on the classification criteria outlined in Section 5.1.

Please recall from chapter 3, that the current safety stock model considers…

1. Predictable variance of the demand per week
2. No review period
3. No realistic inspection periods
4. Unusual calculations

5.2.1 Unpredictable variance in demand

As explained in Section 4.2, safety stock is required to buffer against uncertainties in supply and demand. Uncertainty in demand can be measured by the variability of the forecast errors.

With a number of observations, the variability of the forecast error can be computed. Silver, Pyke, and Peterson (1998) recommend the Mean Squared Error (MSE) measure for computing the *standard deviation of the forecast error.*

First, the standard deviation of the forecast error for *one unit period* has to be derived. A unit period is a forecast update interval, i.e. for Domo Beilen this is one week. The forecast error is determined by observing the period *beyond* the lead time (see Figure 5.1). For example, if we order today, we have to order the material that is required *after* the SKU's lead time. Assume a lead time of six weeks and an inspection of two weeks. Then, the product should be available after eight weeks. Hence, we need to estimate what we require *after* eight weeks.

Subsequently, this standard deviation will be converted to a standard deviation over the total replenishment lead time, including the review period.

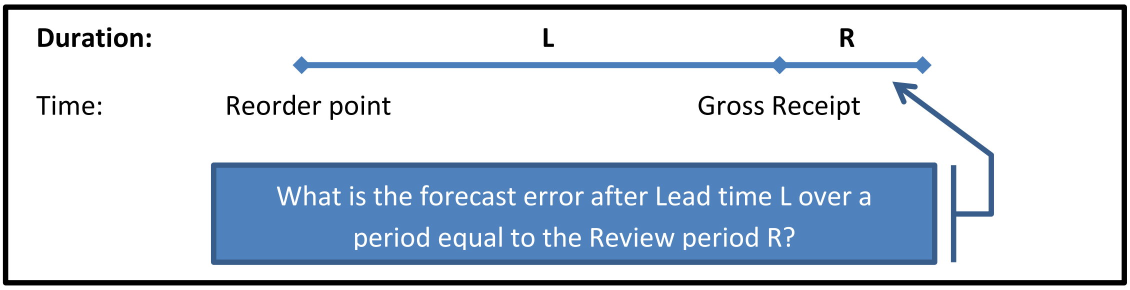


Figure 5.1 - Illustration of the relevant forecast error

The standard deviation of the forecast error of demand over one unit period will be computed with the MSE measure based on the demand data. In Subsection 4.2.3 is explained that we need (1) the actual observed demands, $x_1, x_2, \dots, x_n$ and (2) the one-period-ahead forecasts $\hat{x}_{0,1}, \hat{x}_{1,2}, \dots, \hat{x}_{n-1,n}$ where $\hat{x}_{t,t+1}$ is the forecast, made at the end of period t, of demand t+1. Herewith, we are able to determine the MSE.

$$MSE = \frac{1}{n}\sum_{t=1}^{n}(x_t - \hat{x}_{t-1,t})^{2} \qquad \text{(Eq. 20)}$$

Once the MSE is established, the standard deviation of the forecast error over a unit period σ_1 can be derived.

$$\sigma_1 = \sqrt{MSE} \quad \text{(Eq. 21)}$$

Now, the standard deviation of the forecast error of the demand over one unit period is computed, under the assumption that the demand during the lead time is normally distributed[††]. This standard deviation can be converted to the standard deviation of the demand forecast error over the *total replenishment period and the review period* σ_{L+R} .

$$\sigma_{L+R} = \sqrt{(L+R) * \sigma_1^2} \quad \text{(Eq. 22)}$$

With the standard deviation of the forecast error during the lead time and the review period σ_{L+R} we have an essential input for the safety stock model. In the next subsection, the *total* lead time will be outlined.

5.2.2 Replenishment lead time

In Subsection 3.3.2 is outlined that the currently considered lead time is unrealistic. A realistic lead time is essential, as it is used for important decisions. Except that the lead time is required for the material requirements planning, it is also used to determine the safety stock levels. At Domo Beilen the lead time is composed of two parts, i.e. the delivery lead time and the inspection duration.

$$Total\ lead\ time\ =\ delivery\ lead\ time\ +\ inspection\ duration \quad \text{(Eq. 23)}$$

Domo Beilen experiences most problems with the inspection periods. In practice, the inspections often take longer than expected and the variability over the durations is large. Instead, Domo Beilen experiences little problems with the deliveries. However, this could be the result of the high *additional* safety stock, created by ordering four weeks in front.

Most entrance inspections are subject to improving analysis methods, higher quality standards, or changing suppliers. Therefore, it is helpful to monitor recent inspection results periodically, and adjust the planning parameters where necessary.

Because most inspections take longer than expected, the inspection durations should be updated. Just as in the previous model, the replenishment lead time will be handled as a deterministic value. That is because I have confidence in the projects that are initiated to make the inspection lead times more reliable. The reason beyond is that a project is initiated to improve the inspection procedures and to reduce the variability in durations. The difference for the considered lead time will be that the average (actual) inspection duration is considered now, instead of the prescribed inspection duration, which falls short regularly.

In Chapter 3, I have analyzed the inspection durations. An overview of the inspection duration excess is provided. For the analysis, I separated the inspection characteristics for each SKU as well. Hence, the new formula to determine the realistic lead times is:

$$Realistic\ lead\ time = Delivery\ lead\ time + inspection\ duration_{avg.\ actual} \quad \text{(Eq. 24)}$$

[††] The consequence is that the safety stocks will be tight, because the normal distribution allows negative values for demand as well.

SKU	Planned Deliv. Time (days)	Planned inspection duration (days)	Average inspection excess (days)	Number of inspections	Realistic Lead time (days)	Realistic Lead time (weeks)
1	35	14	-3.3	12	45.7	6.5
2	35	21	8.6	5	64.6	9.2
3	42	21	16.2	6	79.2	11.3

Table 5.3 - Realistic lead times

5.2.3 Intermittent demand

Silver, Pyke, and Peterson (1998) indicate that a decision rule based on a deterministic, time-varying demand pattern is more appropriate for SKUs with intermittent demand. That is because during periods without demand no stock-out could occur. In other words, these 'no demand' periods will bias the decision.

Nonetheless, the past shows that the **timing** and **quantities** of the production orders can change with respect to the forecasts. As we still want to prevent production stops due to lacking raw materials, the raw materials have to be available timely. It is possible that the planned production is advanced one or two weeks. Therefore, a safety time will be considered meaning replenishing two weeks earlier than is asked. Two weeks are considered, because the production planning can be advanced.

5.3 Cycle stock

The *cycle stock* is the result of ordering or producing in batches. We assume that there is one active purchase order per replenishment cycle. If a SKU has no quantity discounts and no fixed ordering costs, the optimal lot size Q will be based on the expected demand during the lead time of the SKU. Then, the objective is to remain the inventory as low as possible. Assuming there may be one active purchase order at the time and the demand for the SKU is approximately uniform distributed, the average inventory level will equal Q/2.

For SKUs with discount prices it is slightly different. With these SKUs financial benefits can be attained by purchasing more, such that a lower price per item or kilogram can be attained. Ordering larger lot sizes can save purchasing costs, but will increase the inventory level and therefore increase the carrying costs. How to compute the optimal lot size, while considering discount prices, will be outlined in the next subsection.

SKUs with discounts prices

Currently, around 80 SKUs have quantity discounts. Section 4.2.1 explained that the savings realized with a discount price should be weighed against the additional holding costs. This trade-off is captured in the Total Relevant Cost factor.

Suppliers do not charge Domo Beilen fixed prices for submitting a purchase orders. These fixed ordering costs are included in the material price per kilogram and are therefore variable to the order size. Hence, it becomes a linear function:

$$TRC(Q, v_i) = rv_i * \frac{Q}{2} + Dv_i = v_i * (D + r * \frac{Q}{2}) \qquad \text{(Eq. 25)}$$

Figure 5.2 shows a graph of the total relevant costs depending on the order lot size. The lowest cost is made by replenishing 1000 kilograms of this SKU every time. Note: by purchasing more kilograms the carrying costs increases slightly. Nonetheless, the cycle stock *and* the safety stock have to be consumed, before the shelf life expires. Otherwise, obsolescence costs will be made as well. Therefore, there is a limitation:

$$Safety\ stock\ +\ order\ quantity\ \leq\ Demand_{shelf\ life} \qquad \text{(Eq. 26)}$$

Hence, the maximum order quantity is:

$$Maximum\ order\ quantity = \ Demand_{shelf\ life} - Safety\ stock \qquad \text{(Eq. 27)}$$

However, there are some reasons to consider not the expected demand during the *entire* shelf life. First, recipes can be changed, which influence the demand for a certain raw material. Secondly, suppliers are allowed to deliver raw materials with 75% of the shelf life remaining. Based on these two arguments it is decided there may not be more stock, than is expected to be used within 6 months.

$$Maximum\ order\ quantity = \ Demand_{6\ months} - Safety\ stock \qquad \text{(Eq. 28)}$$

To determine the optimal order quantity, first the maximum allowed order quantity needs to be determined (see Eq. 28). The nearest break point being smaller than the maximum order quantity will be the optimal order quantity. For example, consider Figure 5.2 and assume the demand during six months is 1150 kilograms and the safety stock amounts 250 kilograms. Then, the maximum order quantity is 900 kilograms. The optimal order quantity is the lower bound of the price class, where the proposed order quantity belongs.

Priceclass	Lower bound		Price per kg		TRC[‡‡]
1	50	KG	€	32.80	€ 33,611
2	100	KG	€	20.87	€ 21,485
3	250	KG	€	13.36	€ 13,944
4	500	KG	€	11.02	€ 11,763
5	750	KG	€	9.52	€ 10,388
6	1.000	KG	€	8.79	€ 9,800

Table 5.4- Break points and their Total Relevant Costs

Just as for the SKUs without discount prices, the average inventory level will equal Q/2, assuming that their demand is approximately leveled during the replenishment cycle. However, the optimal lot size Q now depends on the corresponding total relevant costs. In Chapter 6 the total attainable savings will be determined.

[‡‡] According to Equation 25 with r = 0,19.

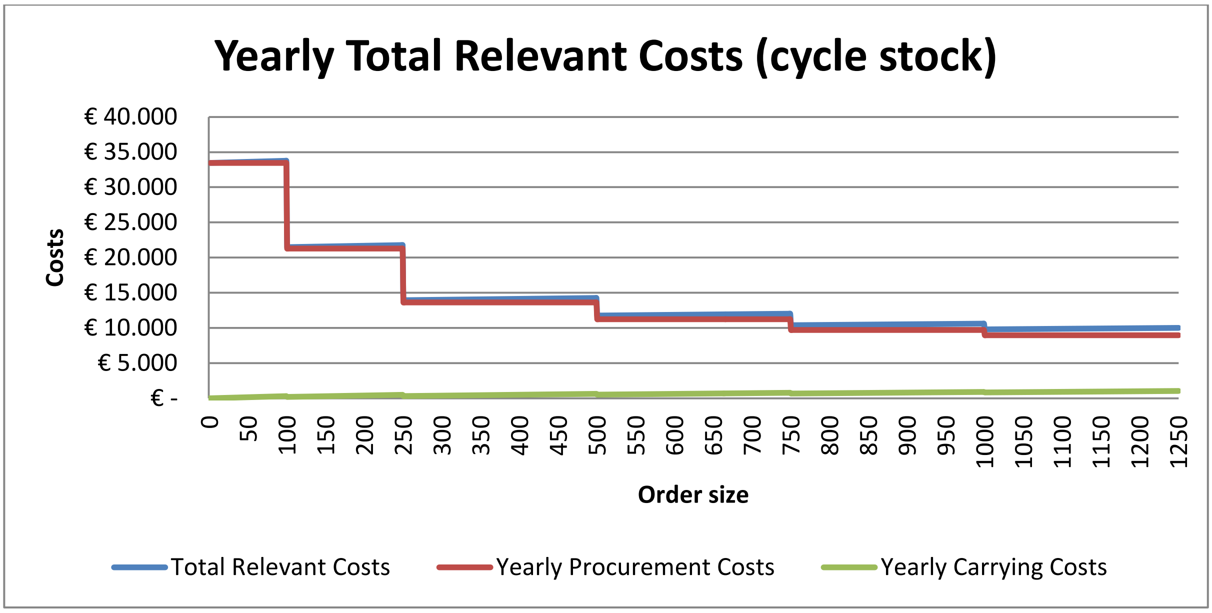


Figure 5.2 - Yearly Total Releavant Costs

5.4 Anticipation on expiring inventories

Expiring inventories in combination with an uncertain demand pattern can cause additional complexities in replenishing. For example, the expiry date could limit the amount of goods to order. Therewith, the possibility exists that the inventory perishes and the investment made becomes unprofitable. During my research, I noticed that the purchasers were not aware of raw materials' oncoming obsolescence. Besides, SAP does not warn for expiration.

Because Domo Beilen's raw materials concern nutrition, the SKUs are obliged to have an expiry date. Every batch and every SKU has expiration date tag in SAP. SAP is programmed to change the usage status automatically to blocked inventory if the expiration date is passed. Then it is destined to be scrapped.

The automatic status changes cause problems, if the purchasers are not aware of its appearance. It is not attainable for SAP to give a warning for future expiration. It will cost a lot of computational power, because then for every planning adjustment, each expiration date has to be checked. However, given the materials, their shelf lives and the demand patterns, expiration can be prevented. With a little effort, Domo Beilen is able to anticipate on expiring inventories.

Therefore, I have constructed a tool that lists every batch that will expire within the near future, if the SKUs are not processed anymore. Herewith, Domo Beilen is able to recognize the batches that are close to obsolescence. The angle covers a period of 15 weeks, such that we have enough time to attain additional raw materials. The 15 weeks is enough to cover 87% of the raw materials. A second angle covers more weeks, especially for the raw materials with a very long lead time (up to 21 weeks).

The angle includes information about the batch content, its location, and its shelf life expiration date. The information could be extracted from SAP with Every Angle and subsequently be compared with the scheduled requirements. In this manner, it can be determined if additional orders have to be sent.

Hence, with these *angles* Domo Beilen can anticipate on future obsolescence, such that they will not be surprised by its occurrence. A side effect of this tool it also makes clear if the materials are processed first in, first out (FIFO). Once the raw materials are not processed FIFO, the observer should alert the departments involved to prevent for additional failure costs. Further, it provides a starting point for retrieving causes for possible obsolescence.

Appendix B provides an example of a completed Shelf Life Expiration Date-form.

5.5 Conclusion

This chapter used the reviewed literature to improve Domo Beilen's inventory control policy. First, it is helpful to distinguish the SKUs on importance. The importance of the SKUs will help to control the working capital captured in the inventory, given that there is sufficient inventory to meet the service level. For determining the safety stock it is recommended to distinguish the SKUs on demand pattern, i.e. is the demand intermittent or not?

Class A	Class B	Class C
• Most important SKUs • 80% of total annual usage value • SKUs with shelf life ≤ 6 months	• Moderate important SKUs • 15 % of total annual usage value	• Non-critical SKUs • 5 % of total annual usage value

Figure 5.3 - SKU classification on importance

Intermittent	Non-intermittent
• Specialties • ≤ 6 times per year required (is once every 7.8 weeks on average)	• Regulars • > 6 times per year required

Figure 5.4 - SKU classification for determining safety stocks

Section 5.2 outlined what needs to be improved about the current safety stock review model. In essence, the model is rebuilt comprehensively. Only the fundamental idea of allowing a certain possibility of having a stock-out remains intact. The following adjustments will increase the reliability of the safety stock model:

1. The forecast error estimation and the elimination of predictable variability
2. The consideration of realistic replenishment lead times and the review period
3. The distinction between intermittent and non-intermittent demand

Section 5.3 explained how the quantity discounts could be used to attain more cost effectiveness with replenishing. With the quantity discounts minimum order quantities can be determined, which always should be weighed against the expected demand during the SKU's shelf life.

Finally, Section 5.4 provided a tool with which the purchasers can anticipate on oncoming shelf life expirations. This is a useful tool for several reasons, for example:

1. The purchasers now know if additional orders are required.
2. The purchasers can intervene if inventories appear not to be processed according to the FIFO-principle.
3. It forms a starting point to find the cause of possible obsolescence.

In the next chapter, the accompanying savings of the provided approach will be outlined.

6 Savings and contributions

This chapter outlines the benefits of the solutions that improve Domo Beilen's inventory control. Section 6.1 outlines the attainable savings. Section 6.2 describes two tools that help controlling the inventories.

6.1 Savings

The potential savings with the improvements described in Chapter 5 can be divided in three categories.

1. Working capital invested in raw material inventories
2. Obsolescence costs
3. Quantity discount savings

Carrying cost

In this paper is spoken about the storage costs of one Euro per pallet per week. These costs represent solely a occupied picking location. It excludes the entry and removal costs of pallets and the opportunity costs. Hence, the total carrying costs are not defined yet. The carrying cost rate r captures (1) the capital costs, i.e. bank loans, (2) the risk to various threats, e.g. as obsolescence or handling damage, and (3) storage costs for the warehouse and handling equipment and personnel.

The capital cost rate is estimated on 8%, which is a common weighted average cost of capital. The risk is estimated to be 1%, as 1% of the total current inventory is unusable due to obsolescence and handling damage. The storage costs are estimated on 10% existing from large cost components representing the warehouse, the handling and storage equipment, and the personnel involved in the SKU handling. Hence, the carrying cost rate is determined to be 19%.

6.1.1 The working capital

The working capital captured in the raw material inventories can be reduced to approximately 14.4 million Euros. Compared to the current inventory of 22 million Euros, this is a saving of 7.6 million Euros on working capital. Assuming a carry cost rate of 19%, this will save yearly 1.4 million Euros.

The target cycle stock is based on the expected and proposed order quantities Q and the expected demand of the coming year. In case of SKUs with discount quantities, a lot size Q is proposed (see subsection 6.1.2 later). For SKUs without discount quantities, the lot size Q is the expected demand during the replenishment lead time, assumed they have a levelled demand during the lead time. Hence, the average target cycle inventory equals $\sum_i Q_i/2$ with for all SKUs i.

The average target cycle stock is worth 5.2 million Euros; two weeks of inventory for the purpose of inspection, being worth 4.3 million Euros, and a safety stock with a service level of 99%, being worth 4.9 million Euros.

$$Average\ (target)\ cycle\ stock \qquad \approx\ 5.200.000\ Euros$$

$$Average\ actual\ inspection\ duration\ \approx\ 112\ /\ 52\ *2 \qquad \approx\ 4.300.000\ Euros$$

$$Safety\ stock\ (P1\ =\ 99\%) \qquad \approx\ 4.900.000\ Euros$$

$$Target\ inventory \qquad 14.400.000\ Euros$$

$$Attainable\ saving = (22.000.000 - 14.400.000) * 0.19 \qquad \approx\ 1.400.000\ Euros$$

6.1.2 Quantity discount savings

I have collected all purchase orders of 2013. For every SKU the optimal order quantity is determined using the procedure discussed in 4.2.1. If the raw materials were bought according to the optimal order quantities, 250.000 Euros less would be spended on procurement costs. The additional carrying are considered in the working capital, outlined in the previous subsection.

Table 6.1 to 6.3 provides an example of a certain SKU. Table 6.1 concerns the price classes and quantity limits. Table 6.2 shows the actual orders sent in 2013. Table 6.3 shows to optimal order sizes, where the least procurement costs for attaining the same amount of raw materials. The possible saving for this specific SKU amounts 3.590 Euros (= 48.729 – 45.139).

Priceclass	Lower bound	Price per kg
1	100 KG	€ 15.10
2	250 KG	€ 11.38
3	500 KG	€ 10.19
4	750 KG	€ 9.48
5	1000 KG	€ 9.29
6	2000 KG	€ 8.73

Table 6.1 - Price classes

Actual Orders	Order size	Price per kg	PO Value
1	1.600 KG	€ 9.29	€ 14,864
2	500 KG	€ 10.19	€ 5,095
3	500 KG	€ 10.19	€ 5,095
4	500 KG	€ 10.19	€ 5,095
5	1.000 KG	€ 9.29	€ 9,290
6	1.000 KG	€ 9.29	€ 9,290
Totals	**5.100 KG**		**€ 48.729**

Table 6.2 – Actual costs of purchasing this SKU during 2013

Optimal Orders	Order size		Price per kg		PO Value
1	2.000	KG	€	8.73	€ 17,460
2	2.000	KG	€	8.73	€ 17,460
3	1.100	KG	€	9.29	€ 10,219
Totals	**5.100**	**KG**			**€ 45.139**

Table 6.3 - Optimal order sizes

6.1.3 Obsolescence savings

The obsolescence costs can be reduced heavily. First, the new inventory control policy should be complied and second, Domo Beilen should make agreements with customers about rejecting their forecasts or reducing their orders.

55% of the obsolescence costs are caused by the cancellation of forecasts and planned orders. In the so-called service level agreements are the obligations of Domo Beilen to the customer and vice versa defined. The SLA also captures also the allowed forecast changes and lead times. If Domo Beilen holds its customers to comply with the SLAs, no SKUs have to be kept in stock purposeless or even have to expire.

Sudden replacements or endings of certain ingredients cause 25% of the obsoleted raw material value. Currently, Domo Beilen uses *hard* terminations and replacements. Subsequently, the SKUs are not cleared, but remain in stock until their shelf life expires. This percentage could be reduced by a *soft* replacement or improved communication about the phasing out of the material.

The remaining 20% of obsoleted material is caused by SKUs with a short shelf life. Regarding their usage and their lead time the material does not have to expire. To prevent for obsolescence the inventory control policy provided in this paper should be complied.

By developing a phasing out procedure, complying to the new inventory control policy and by reviewing the SLAs with the customers a minimum of 75% cost reduction should be attained.

6.2 Other contributions

This section outlines two contributions of this research, which do not save money in the first place, but provides insight in the actual performance of the production support processes. Herewith, they form a basis to improve the production supporting activities.

6.2.1 Overview planning adjustments

The masterplanners construct the production planning for the end products. Then, SAP computes the requirements for each raw material based on the bill of materials (BOM). Subsequently, the purchasers order the required raw materials.

If the production planning changes, it has consequences for dozens of raw materials. If the planned production for one end product is delayed, another end product will probably be brought forward.

However, the master planners do not see the difficulties in raw materials and on their turn, the purchasers do not see the causing production planning adjustments.

It has never made clear where the raw materials difficulties caused by demand or production changes come from. Whereas SAP is MRP-based, it captures for every SKU a bill of materials (BOM). Because the planning is adjusted regularly, it is difficult to determine the right cause.

With Microsoft Excel I have developed a pivot table, which provides a clear overview of the weekly production planning shifts. In SAP, it can be found for which products a certain raw material can be used. Subsequently, the relevant article numbers can be entered and the desired production or planning weeks. Herewith, Domo Beilen is able to create an overview of the planning changes per end product.

The planning changes could concern changes in timing and quantity. Both types of changes are made visible with the overview generated in Excel. Subsequently, the causes of these changes and the impact of these changes can be analyzed. If it is required, corrective action can be taken to prevent for problems in the future.

Benefits of the planning overview

1. Provides insight in the changes made on end product production planning
2. Provides suggestions for over stock or under stock for certain raw materials, if this is cause by production planning changes
3. With the BOM the impact on the inventory control of raw materials can be determined
4. Once the changes are known, their causes can be analyzed more effectively. Subsequently, actions can be taken to prevent for unnecessary or undesired changes in the future.

Please remember that planning adjustments are caused by (1) constraining, due to internal issues or (2) by the customer.

Please consider Table 6.4. The columns, named 2014-… show the release of a new masterplan. The rows show the actual scheduled quantities for the production per week. The green cells are the actually produced quantities. The orange cells are unexpected quantity increases (for the Business Office). The red demarcated area, shows a very extreme increase within the period of 4 weeks.

Production week	Planning 2014-11	2014-12	2014-13	2014-14	2014-15	2014-16	2014-17	2014-18	2014-19	2014-20	2014-21	2014-22	2014-24	2014-25
17				23.990	23.990	23.990	23.990							
18		11.470	23.985											
19		12.864	26.754	26.749	26.749	26.749	26.749	26.749	13.374					
20	60.503	26.754				370	370	370	13.745	2.139				
22		30.599	50.003	6.300	31.223	14.054	14.058	17.908	17.908	17.908	17.908	17.908		
24	48.300			31.500	54.328		38.578	38.578	34.780	35.103	35.103	35.103	35.103	
25						38.578								
26		48.300	48.300	16.800	33.600		16.800	24.300	16.612	16.800	16.740	14.640	14.640	14.640
27						16.800				14.695				
28	52.518			31.500	31.500	3.225	14.695	14.695	14.695		14.695			
29						11.470						39.995	51.325	
30		52.518	52.518					17.485	25.200		25.200		55.439	128.857
31										25.200		54.700	48.179	21.876
32				36.768	36.768	31.139	31.135	32.550	25.200	25.200	25.200	35.200	11.470	22.940
33														11.470

Sum	65.095	129.895	166.413	185.143
	100%	200%	256%	284%

Table 6.4 - Planning overview tool

6.2.2 Insight to inspection durations

This research showed that the inspection durations are considerable larger than presumed. Since the inspection duration is an eminent part of the lead time, it plays an important role in the material requirements planning. Therewith, it should influence the safety stock levels as well as the safety stock should buffer against the uncertainties during the lead time.

Partly motivated by this research the interest for the importance of the inspection raised. It is important that representative parameters are embedded in SAP, because the complete production planning and material requirements planning is based on these parameters. Subsequently, a proper material requirements planning is important for the raw material purchasers.

A more fundamental question is: "What is the necessity of inspecting all raw material batches?" It appears that many raw material batches never were disapproved. If the supplier meets the agreed specifications every time, laboratory analysis costs and holding costs could be saved, for example by inspection on random sampling. Advancing the recommendations of this research, Domo Beilen initiated a project to improve the raw materials inspection policy.

7 Implementation

This chapter provides an approach to implement the proposed inventory control policy. Section 7.1 provides the approach. Section 7.2 outlines the actions that could be executed immediately. Finally, Section 7.3 describes how the quality of the inventory control policy should assured.

7.1 Implementation approach

Figure 7.1 - Implementation of reorganized inventory control policy

This research and particularly the conclusions and recommendations will be presented to the executive board of Domo Beilen by the author of this thesis. The author of this research is blessed to implement the new way of working himself. Subsequently, the findings and recommendations will be presented to the purchasers. It is the researcher's duty too, that there will not be an unjustifiable stockout. The main goal is to create compliance to the new inventory control policy. The purchasers will see that the safety stock levels with the new model are significant higher than with the former model. Hence, no more purchase orders have to be sent earlier than required.

The purchasers will be trained in updating the inventory control policy. Finally, the performance of the purchasers and other departments (FIFO working) will be evaluated.

7.2 Ready to use

Domo Beilen can benefit immediately from some improvements. During this research, several parameters are reassessed and these will be adjusted directly in the master data of SAP.

1. Importance of the SKUs
2. Minimum order quantities
3. Inspection durations

Further, the SLED-monitoring tool is successfully in use already. With the planning-monitoring tool the changes in production plans of the end-products can be illustrated. Herewith, causes for changes in the raw material requirements are more easily to retrieve.

7.3 Quality assurance

To maintain the quality of the inventory control policy the used data should be up-to-date. Domo Beilen is used to review the safety stocks every three months, and this is an acceptable interval. The following actions should be executed every quarter, except for the SLED monitoring. The latter is better to perform weekly, due to the high amount of planning changes. For every action a work instruction will be developed, that step-by-step explains how to perform the procedure.

1. SKU classification (denoting the SKUs importance)
2. Minimum order quantity determination (w.r.t. the discount prices)
3. Safety stock determination, considering
    a. Reassessment of *SKU classification*, concerning the demand pattern
    b. Reassessment of the *forecast errors*
    c. Reassessment of the *actual lead times*
4. SLED monitoring (weekly)

8 Conclusions and recommendations

In the final chapter of this paper the conclusions and recommendations are provided. Section 8.1 outlines the conclusions of each research question. Section 8.2 lists the recommendations based on the analysis and literature review performed. Section 8.3 describes some limitations of the research. Finally, Section 8.4 provides some directions for further research.

8.1 Conclusions

In the following five subsections, the conclusions of the research questions will be discussed.

8.1.1 Current situation

Inspections and planning adjustments formed many uncertainties for the purchasers in ordering raw materials. The inspection durations took longer than agreed. The safety stocks were determined with an inadequate model, considering for example predictable variance in demand. No review period was considered. These uncertainties resulted in large inventories, being worth 23 million Euros. Further, the purchasers were surprised by expiring inventories. This caused problems in replenishing the raw materials timely. Discount prices were not used actively to determine economic order quantities. Finally, the SKU classifications, i.e. ABC, XYZ, and Weeks coverage, were not of any relevance to the purchasers.

8.1.2 Solutions

Regarding the SKU classification, the letters A, B, and C will indicate the importance of SKUs. The safety stock model is fundamentally changed. Now, the review period is considered (L+R); the inspection durations are realistic now; the variance solely concerns the unpredictable variance, i.e. the variance of the forecast error; and the safety stock model is solely intended for the SKU with a non-intermittent demand pattern. The SKUs with an intermittent demand pattern will make use of a *safety time*, meaning that they are ordered two weeks in advance, to buffer against planning shifts or inspection duration excess.

8.1.3 Savings and contributions

The major saving will be attained in reducing the working capital captured in the current inventories, namely 1.2 million Euros on yearly basis. By using the quantity discounts in determining the order sizes, another 250.000 Euros could be saved. The obsolescence costs are estimated to be reduced with 75%, meaning 235.000 Euros per year.

The SLED anticipation tool will help to reduce the need for planning changes and obsolescence through non-FIFO working. The planning overview tool will help to trace back difficulties with raw material requirements. Required actions can be deployed if the root causes are known.

8.1.4 Implementation

Support for the implementation is gathered with presentations for the Executive board of Domo Beilen and the purchasers. The required MRP-settings, i.e. inspection durations, safety stocks, and minimum order quantities will be adjusted in SAP. Work instructions will be available and the purchasers will be trained carefully to make the inventory control policy their responsibility.

The quality of the inventory control policy will be maintained by updating the inventory characteristics and MRP-settings every quarter. The SLED-anticipation will be executed every week.

8.2 Recommendations

1. **<u>Make use of the new safety stock model as soon as possible</u>**
   This research delivered an improved safety stock model, buffering against realistic uncertainties. This model provides the purchasers a hold in replenishing efficient quantities.

2. **<u>Make use of the quantity discounts</u>**
   It will save easily tens of thousands Euros per month. Compute the economic order quantities and compare them to the expected requirements and the shelf life. This value can be captured in SAP as *minimum order quantity.*

3. **<u>Distinguish SKUs on importance</u>**
   The current SKU classifications are not supported and due to inclusion of bulk articles irrelevant. Therefore a SKU classification is provided, which makes it easier to control a large group of SKUs. Class A denotes the most important SKUs and Class C denotes the SKUs with the least material value and importance.

4. **<u>Comply with the new inventory control policy</u>**
   Complying with the new inventory control policy will reduce the current inventory heavily, namely with 6.5 million Euros. Due to the rules, there is more clarity for the Domo Beilen's entire supply Chain, which creates rest. Further, less obsolescence costs will be made.

5. **<u>Use the SLED anticipation tool awareness of the oncoming shelf life expiration dates</u>**
   Domo Beilen will not be surprised anymore by possibly expiring inventories. Obsolescence costs can be reduced with at least 75%.

6. **<u>Reassess the safety stocks, inspection lead times, minimum order quantities every three months.</u>**
   The competition in the IFT nutrition market is high, which causes regularly changes in the production plans and forecasts, i.e. new customers. This will influence the requirements for raw materials. Hence, it is important to keep the parameters up-to-date.

7. **<u>Monitor and adjust if necessary the inspection lead times.</u>**
   It is important for determining the (re)order point, but also to determine adequate safety stocks.

8. **<u>Use the planning insight tool</u>**
   With this tool causes for planning nervousness can be retrieved. Possibly, the shifts can be prevented in the future which will benefit Domo Beilen's entire supply chain

8.3 Research limitations

The supplier reliability is not incorporated in the safety stock model or in the SKU importance. That is because the supplier reliability is not assessed properly yet and the purchasers do not experience issues with the suppliers. However, due to the high inventories, the differences in timing and quantities became unimportant and the difference became accepted. As illustration; during 2014 there was one supplier that could not deliver in time.

The financial impact of the non-availability of raw materials is not known. If a raw material occasionally is not available, the production planning can be adjusted such that production stops are prevented. Due to the inspections, the raw materials have to be in stock days before the production is planned. Hence, Domo Beilen knows when the unavailability tends to cause difficulties. It is not known what the financial impact is of these planning adjustments caused by the occasionally non-availability of raw materials. The financial impact can be a reason to increase the safety stock.

8.4 Further research

Currently, the sudden phasing out of raw materials causes a large part of the obsolescence costs. The communication around these out phasings can be improved. It is recommended to construct a procedure for phasing out raw materials, including responsibilities and time frames, such that every relevant person knows what is coming and that redundant costs are minimized.

Domo Beilen could benefit from a tighter collaboration with its suppliers. With for example Efficient Consumer Response a better alignment of needs for both stakeholders can be reached. One of the questions to ask is: how many information would we share with our supplier?

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Appendix A – Organizational chart

Figure A.1 implies the location in the organization where this research is initiated.

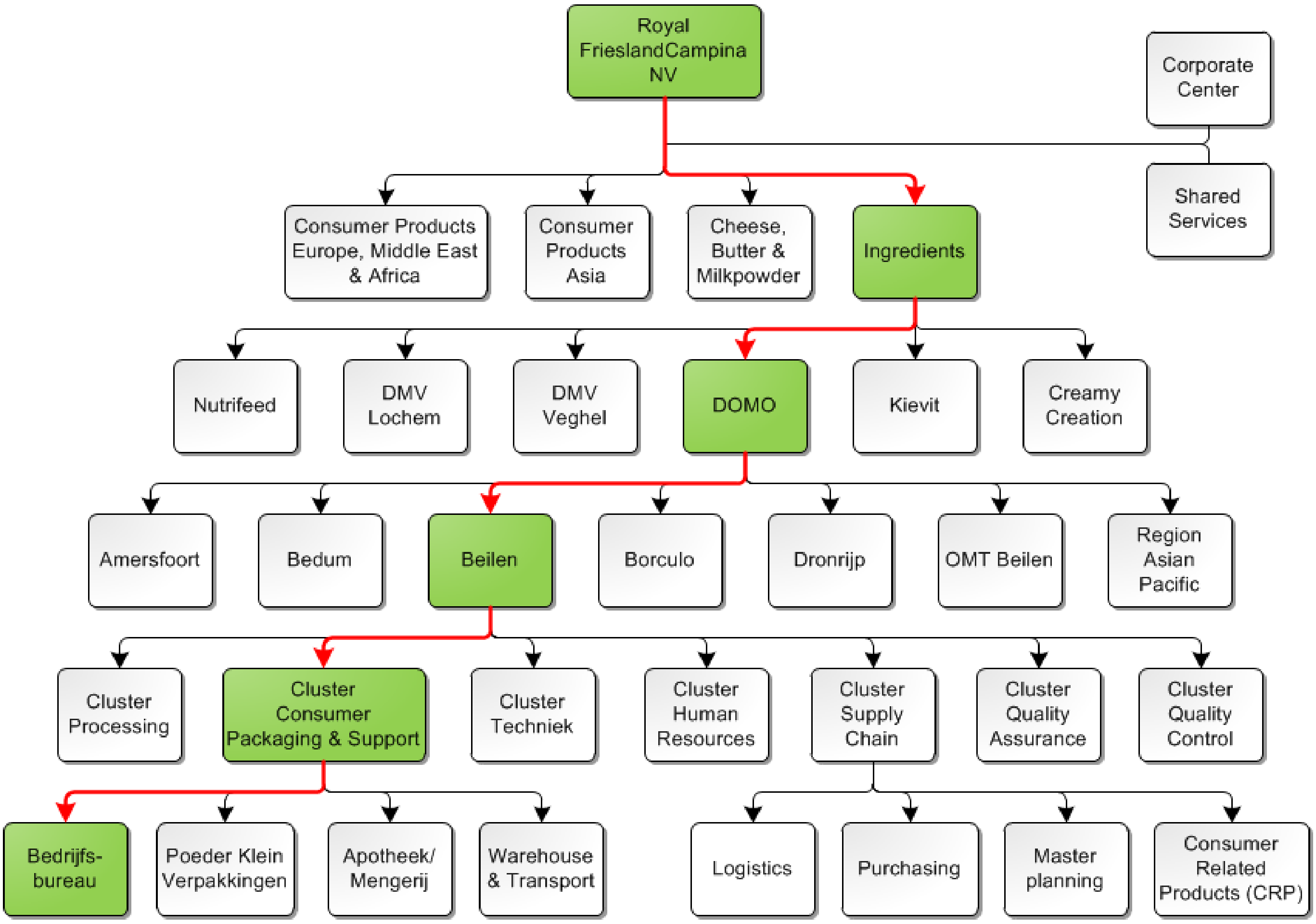


Figure A.1 - Organizational chart of FrieslandCampina (constricted)

Appendix B – SLED anticipation

kgs	62 batches	Material	Description	Quantity	Material value	Obsolescence costs	Expected demand next 30 days (Material plant)	Stock quantity available (Material plant)	Batch	Stock status	Warehouse Number (Material warehouse)	Repl. lead time	Order in wee	Total shelf life	Period Ind. for SLED (Material)	Date first needed	Week	SLED/BBD (Batch)	=SLED - Date first needed
47	kg over THT + besteld	J		46,616	€ 188,33	€ 188,33	119,985	2566,616	20414595-1	Unrestricted	210 (Magazijn SPB)	9	3	12,0	2 (Month)	14-Apr-14	12	20-Mar-14	-25
1520	kg over THT + besteld	J		1520,0	€ 6.140,80	€ 6.140,80	119,985	2566,616	20414595-1	Unrestricted	217 (DC De Rijk)	9	3	12,0	2 (Month)	14-Apr-14	12	20-Mar-14	-25
77	kg over THT + besteld	A		76,628	€ 10.421,02	€ 10.421,02	103,54	256,628	57021792-1	Unrestricted	210 (Magazijn SPB)	6,3	7	6,0	2 (Month)	09-Apr-14	13	24-Mar-14	-16
16	kg over THT + oke	C		15,99	€ 412,70	€ 412,70	168,0	2865,99	20419400-1	Unrestricted	210 (Magazijn SPB)	7,3	6	12,0	2 (Month)	31-Mar-14	13	26-Mar-14	-5
27	kg over THT + oke	D		27,078	€ 192,52	€ 192,52	0,0	1527,078	20416078-2	Unrestricted	210 (Magazijn SPB)	9	4	12,0	2 (Month)	05-May-14	13	26-Mar-14	-40
	Shelf life wordt aangepast	R		211,154	€ 948,08		386,431	1211,154	57003872-1	Unrestricted	210 (Magazijn SPB)	7,7	5	24,0	2 (Month)	20-Mar-14	13	28-Mar-14	8
16	kg over THT + oke	F		15,516	€ 84,56	€ 84,56	0,0	4455,516	20416077-1	Unrestricted	210 (Magazijn SPB)	9	4	12,0	2 (Month)	05-May-14	13	28-Mar-14	-38
420	kg over THT + oke	F		420,0	€ 2.289,00	€ 2.289,00	0,0	4455,516	20416076-1	Unrestricted	217 (DC De Rijk)	9	4	12,0	2 (Month)	05-May-14	13	28-Mar-14	-38
420	kg over THT + oke	G		420,0	€ 2.289,00	€ 2.289,00	0,0	4455,516	20416077-1	Unrestricted	217 (DC De Rijk)	9	4	12,0	2 (Month)	05-May-14	13	28-Mar-14	-38
	komt deze kant op	S		25,0	€ 100,00		160293,116	368675,0	389863	Unrestricted	211 (IMS Veendam)	5	8	12,0	2 (Month)	22-Mar-14	13	28-Mar-14	6
	Shelf life wordt aangepast	V		1000,0	€ 4.490,00		386,431	1211,154	57031547-1	Unrestricted	217 (DC De Rijk)	7,7	5	24,0	2 (Month)	07-Apr-14	13	29-Mar-14	-9
449	hoort niet op Jelles Purch. Gr.	E		449,0	€ 628,60	€ 628,60	1560,677	449,0	583753	Unrestricted		0	14	30,0	(Day)	13-Apr-14	14	03-Apr-14	-10
	moet op gaan (uit. week 15)	H		10,0	€ 155,90		1209,377	2801,804	57029299-1	Unrestricted	210 (Magazijn SPB)	9	6	3,0	2 (Month)	18-Mar-14	15	06-Apr-14	19
	moet op gaan (uit. week 15)	H		7,212	€ 112,44		1209,377	2801,804	57029300-2	Unrestricted	210 (Magazijn SPB)	9	6	3,0	2 (Month)	18-Mar-14	15	06-Apr-14	19
	moet op gaan (uit. week 15)	H		399,592	€ 6.229,64		1209,377	2801,804	57030592-1	Unrestricted	210 (Magazijn SPB)	9	6	3,0	2 (Month)	18-Mar-14	15	06-Apr-14	19
	moet op gaan (uit. week 15)	H		270,0	€ 4.209,30		1209,377	2801,804	57032733-1	Unrestricted	213 (Koelveem, Leeuwarden	9	6	3,0	2 (Month)	31-Mar-14	15	06-Apr-14	6
	misschien zoek?	T		1,0	€ 16,23		12614,805	32762,862	57006982-1	Unrestricted	210 (Magazijn SPB)	13,3	2	9,0	2 (Month)	18-Mar-14	15	07-Apr-14	20
	moet op gaan (in week 12/13)	T		71,862	€ 1.166,32		12614,805	32762,862	57014263-2	Unrestricted	210 (Magazijn SPB)	13,3	2	9,0	2 (Month)	18-Mar-14	15	07-Apr-14	20
	moet op gaan (in week 12/13)	T		80,0	€ 1.298,40		12614,805	32762,862	57006985-1	Unrestricted	217 (DC De Rijk)	13,3	2	9,0	2 (Month)	21-Mar-14	15	07-Apr-14	17
	moet op gaan (in week 12/13)	T		320,0	€ 5.193,60		12614,805	32762,862	57006986-1	Unrestricted	217 (DC De Rijk)	13,3	2	9,0	2 (Month)	21-Mar-14	15	07-Apr-14	17
	moet op gaan (in week 12/13)	T		660,0	€ 10.711,80		12614,805	32762,862	57014263-2	Unrestricted	217 (DC De Rijk)	13,3	2	9,0	2 (Month)	22-Mar-14	15	07-Apr-14	16
	gaat op (24.03; 404161)	C		7,795	€ 475,50		178,901	299,215	57018391-1	Unrestricted	210 (Magazijn SPB)	8	7	12,0	2 (Month)	24-Mar-14	15	08-Apr-14	15
1000	kg over THT + oke	G		1000,0	€ 1.409,00	€ 1.409,00	0,0	1000,0	57011827	Unrestricted	217 (DC De Rijk)	4	11	6,0	2 (Month)	19-Oct-14	15	10-Apr-14	-192
169	kg over THT + besteld	W		328,353	€ 3.493,68	€ 1.794,66	320,561	1128,353	20418896-2	Unrestricted	210 (Magazijn SPB)	8	7	12,0	2 (Month)	24-Mar-14	15	11-Apr-14	18
682	kg over THT; weer vraag versch.	D		850,0	€ 21.938,50	€ 17.602,42	168,0	2865,99	20422505-1	Unrestricted	217 (DC De Rijk)	7,3	10	12,0	2 (Month)	31-Mar-14	17	22-Apr-14	22
454,2	kg over THT + oke	M		477,03	€ 4.269,42	€ 4.065,36	22,8	977,03	20419905-2	Unrestricted	210 (Magazijn SPB)	7	10	12,0	2 (Month)	31-Mar-14	17	25-Apr-14	25
40	kg over THT; weer vraag versch.	F		40,0	€ 134,40	€ 134,40	0,0	1629,4	20388784-1	Unrestricted	210 (Magazijn SPB)	5,3	12	24,0	2 (Month)	04-May-14	17	26-Apr-14	-8
	moet op gaan (9.04; 638944)	X		17,45	€ 193,35		127,875	417,45	57024004-2	Unrestricted	210 (Magazijn SPB)	10	8	12,0	2 (Month)	09-Apr-14	18	02-May-14	23
	waarom niet verbruikt?	AC		125,0	€ 385,88		466707,07	88450,0	57026140-4	Unrestricted	210 (Magazijn SPB)	2	18	10,0	2 (Month)	25-Mar-14	20	11-May-14	47
385	geen vraag	B		385,427	€ 782,42	€ 782,42	0,0	1385,427	20368926	Unrestricted	210 (Magazijn SPB)	4	16	24,0	2 (Month)	31-Dec-99	20	12-May-14	-2916694
	moet op gaan	H		915,0	€ 14.264,85		1209,377	2801,804	57034390-1	Unrestricted	213 (Koelveem, Leeuwarden	9	11	3,0	2 (Month)	06-Apr-14	20	12-May-14	36
	moet op gaan	H		1200,0	€ 18.708,00		1209,377	2801,804	57035116	Quality inspectio	213 (Koelveem, Leeuwarden	9	11	3,0	2 (Month)	27-Apr-14	20	12-May-14	15
	gaat op (5.05); vraag naar achter	K		900,0	€ 4.905,00		0,0	4455,516	20423107-1	Unrestricted	217 (DC De Rijk)	9	11	12,0	2 (Month)	05-May-14	20	16-May-14	11
900	vraag naar achter	K		900,0	€ 4.905,00	€ 4.905,00	0,0	4455,516	20423108-2	Unrestricted	217 (DC De Rijk)	9	11	12,0	2 (Month)	02-Jun-14	20	16-May-14	-17
	geen vraag	Q		11,018	€ 1.358,41		0,0	51,018	20421617-2	Unrestricted	210 (Magazijn SPB)	8	12	12,0	2 (Month)	31-Dec-99	20	17-May-14	-2916689
76	kg over THT	A		180,0	€ 24.479,10	€ 10.398,18	103,54	256,628	57026958-1	Unrestricted	213 (Koelveem, Leeuwarden	6,3	15	6,0	2 (Month)	13-Apr-14	21	19-May-14	36
	niet FIFO	S		325,0	€ 1.300,00		160293,116	368675,0	B15706	Unrestricted	210 (Magazijn SPB)	5	16	12,0	2 (Month)	22-Mar-14	21	21-May-14	60
356	kg over THT + besteld	Y		500,0	€ 5.270,00	€ 3.748,86	85,654	1000,0	20425520-4	Unrestricted	217 (DC De Rijk)	8	13	12,0	2 (Month)	24-Mar-14	21	23-May-14	60
500	kg over THT + uitzoeken	Y		500,0	€ 5.270,00	€ 5.270,00	85,654	1000,0	20425521-1	Unrestricted	217 (DC De Rijk)	8	13	12,0	2 (Month)	18-Aug-14	21	24-May-14	-86
	moet op gaan	U		4,498	€ 269,34		14954,467	25059,971	57018606-1	Unrestricted	210 (Magazijn SPB)	14	8	9,0	2 (Month)	18-Mar-14	22	26-May-14	69
	moet op gaan (12.05)	L		97,546	€ 683,80		40,4	597,546	20424037-1	Unrestricted	210 (Magazijn SPB)	6,3	16	12,0	2 (Month)	07-Apr-14	22	27-May-14	50
	komt deze kant op	U		10,0	€ 598,80		14954,467	25059,971	57023680-1	Unrestricted	217 (DC De Rijk)	14	8	9,0	2 (Month)	22-Mar-14	22	27-May-14	66
	moet op gaan	U		1495,473	€ 89.548,92		14954,467	25059,971	57023682-1	Unrestricted	210 (Magazijn SPB)	14	8	9,0	2 (Month)	18-Mar-14	22	29-May-14	72
	moet op gaan	U		1200,0	€ 71.856,00		14954,467	25059,971	57023682-1	Unrestricted	217 (DC De Rijk)	14	8	9,0	2 (Month)	22-Mar-14	22	29-May-14	68
	moet op gaan	U		2800,0	€ 167.664,00		14954,467	25059,971	57025367-1	Unrestricted	217 (DC De Rijk)	14	8	9,0	2 (Month)	23-Mar-14	22	29-May-14	67
	moet op gaan	U		6800,0	€ 407.184,00		14954,467	25059,971	57025368-1	Unrestricted	217 (DC De Rijk)	14	8	9,0	2 (Month)	24-Mar-14	22	29-May-14	66
4	kg over THT	AA		27,18	€ 2.679,40	€ 431,78	5,673	87,18	20422511-2	Unrestricted	210 (Magazijn SPB)	8	14	12,0	2 (Month)	24-Mar-14	22	29-May-14	66
39	kg over THT (5.05; 402612)	O		500,0	€ 3.555,00	€ 277,29	0,0	1527,078	20425311-2	Unrestricted	217 (DC De Rijk)	9	13	12,0	2 (Month)	05-May-14	22	31-May-14	26
	moet op gaan (29.05; 400346)	R		18,985	€ 1.603,66		0,0	58,985	20427282-2	Unrestricted	210 (Magazijn SPB)	8	15	12,0	2 (Month)	29-May-14	23	06-Jun-14	8
	moet op gaan (24.03)	Z		7,869	€ 89,04		162,5	1867,869	574786-001	Unrestricted	210 (Magazijn SPB)	10	13	18,0	2 (Month)	24-Mar-14	23	07-Jun-14	75
	moet op gaan (7.04)	Z		100,0	€ 1.131,50		162,5	1867,869	577106-001	Unrestricted	210 (Magazijn SPB)	10	13	18,0	2 (Month)	24-Mar-14	23	07-Jun-14	75
500	geen vraag	AB		500,0	€ 5.750,00	€ 5.750,00	0,0	500,0	20383648-2	Unrestricted	217 (DC De Rijk)	14,3	10	24,0	2 (Month)	31-Dec-99	24	08-Jun-14	-2916667
68	geen vraag	P		67,971	€ 971,53	€ 971,53	0,0	3067,971	20425759-1	Unrestricted	210 (Magazijn SPB)	12	12	12,0	2 (Month)	31-Dec-99	24	10-Jun-14	-2916665
72	kg over THT + bestellen in w.17	N		155,456	€ 1.994,50	€ 921,53	28,748	155,456	20428863-1	Unrestricted	210 (Magazijn SPB)	8	17	12,0	2 (Month)	31-Mar-14	25	17-Jun-14	78
	moet op gaan	S		850,0	€ 3.400,00		160293,116	368675,0	576729	Unrestricted	210 (Magazijn SPB)	5	20	12,0	2 (Month)	16-Mar-14	25	19-Jun-14	95
	moet op gaan	S		1925,0	€ 7.700,00		160293,116	368675,0	579650	Unrestricted	211 (IMS Veendam)	5	21	12,0	2 (Month)	22-Mar-14	26	23-Jun-14	93
	moet op gaan	S		950,0	€ 3.800,00		160293,116	368675,0	579651	Unrestricted	211 (IMS Veendam)	5	21	12,0	2 (Month)	22-Mar-14	26	23-Jun-14	93
	moet op gaan	T		400,0	€ 6.492,00		12614,805	32762,862	57014264-2	Unrestricted	210 (Magazijn SPB)	13,3	13	9,0	2 (Month)	21-Mar-14	26	24-Jun-14	95
	moet op gaan	T		1740,0	€ 28.240,20		12614,805	32762,862	57014264-2	Unrestricted	217 (DC De Rijk)	13,3	13	9,0	2 (Month)	23-Mar-14	26	24-Jun-14	93
	moet op gaan	T		260,0	€ 4.219,80		12614,805	32762,862	57016217-1	Unrestricted	217 (DC De Rijk)	13,3	13	9,0	2 (Month)	23-Mar-14	26	24-Jun-14	93
	moet op gaan (5.05; 400772)	I		89,636	€ 785,21		0,0	409,636	20375060-1	Unrestricted	210 (Magazijn SPB)	7,3	19	24,0	2 (Month)	05-May-14	26	26-Jun-14	52
49	kg over THT (2.06; 402612)	O		500,0	€ 3.555,00	€ 348,39	0,0	1527,078	A0348555-2	Unrestricted	217 (DC De Rijk)	9	17	12,0	2 (Month)	30-Jun-14	26	28-Jun-14	-2
					Prognose	81.457,35 EUR													

Appendix C – Current safety stock review model

For the current model, the actual demand of the past six months and the expected demand for the coming six months is used. Further, a list with SKU characteristics is used. Table C.1 presents all used and calculated SKU characteristics. The latest column presents how the data is derived. Here, a distinction is made between (1) input, (2) calculations or intermediate results, and (3) output.

Character	Description	Derivation
1	Article name	Input
2	Material value (Euros)	Input
3	Procurement lead time (days)	Input
4	Inspection lead time (days)	Input
5	Length statistical period (weeks)	Input
6	Safety stock current situation	Input
7	Current safety stock	Input
8	Cost of current safety stock (Euros)	Calculation
9	* [§§] Demand over 6 months (in weekbuckets)	Input
10	* Cumulative demand over 6 months	Calculation
11	* Average demand per week	Calculation
12	* Std. dev. demand per week	Calculation
13	* Coefficient of variance of demand per week	Calculation
14	Total demand	Calculation
15	Turnover (euros)	Calculation
16	Percentage of total throughput	Calculation
17	Cumulative percentage	Calculation
18	Total lead time (days)	Calculation
19	Std. dev. demand during statistical period	Calculation
20	Average demand per week	Calculation
21	ABC-classification	Output
22	XYZ-classification	Output
23	Week coverage proposition	Output
24	Safety factor	Output
25	New safety stock level	Output
14	Cost of new safety stock	Output

Table C.1 - SKU characteristics used for the Safety Stock Review

The attribute article name [1] speaks for itself. The material value [2] is the price per kg. The procurement lead time [3] en [4] are periods in days. The statistical period [5] always equals 52 weeks. The current safety stock [6] is expressed in kilograms. The last data input is the demand. Currently, the actual demand over the past six months is captured in week buckets. Further, the expected demand for the coming six months is incorporated.

Then a sequence of calculations follows. The cost of the current safety stock [8] is the multiplication of the current safety stock [7] and the material value [2]. From both demand data sets, i.e. actual and

[§§] Holds for actual demand (past six months) and the expected demand (coming six months) expected demand, the average demand per week [11], the standard deviation of the demand per week [12] and the coefficient of variance of the weekly demand [13] is calculated.

The coefficient of variance of the weekly demand [13] is calculated over the average demand per week, by dividing the standard deviation of the demand per week by the average demand per week:

$$CV = \frac{\sigma}{\mu}$$

The turnover [15] is calculated by an addition of the actual demand of the past 6 months and the forecasted demand of the coming six months. The turnover is calculated to determine the SKUs their ABC-classes. Subsequently, the percentage of the turnover is computed, w.r.t. the cumulated turnover of all SKUs. Then, the list is sorted on the turnover values from high to low values. Consecutively, the turnover percentages are accumulated one at the time. Based on these figures the ABC-classification is determined. Domo Beilen labels the top 80% as class A, the next 15% as class B, and the remaining 5% as class C.

The XYZ-class are allocated based on the coefficient of variance (CV) values of each SKU. The thresholds Domo Beilen uses are $CV \leq 0.3$ for class X, $0.3 < CV \leq 0.7$ for class Y, and $CV > 0.7$ for class X. Hence, class X concerns the steadiest demand and class Z concerns the lumpiest demand.

Then, the total lead time [18] is required is required to determine the *allowed weeks coverage* [23] and more important: the *new safety stock level*. The sum of the procurement lead time [3] and the inspection lead time [4] expressed in days and is assumed to be deterministic.

Subsequently, the standard deviation of the demand volume [19] concerns the *average* of the *standard deviation of the actual demand* and the *standard deviation of the forecasted demand*. Again, no distinction is made between *planned* variance and *uncertainty.* Likewise is the average demand per week [20] the sum of the *actual demand order average* and the *expected demand order average* divided by two.

Then there is an *allowed weeks coverage* limit. However, the allowed weeks coverage period is not complied. If the rules are not complied, the rules are redundant or their importance has to be made clear. Though, as explained, the *allowed weeks coverage* is a result of three attributes, namely the ABC-class, the XYZ-class and the total lead time (or replenishment lead time). The allocation is assigned via a table, as depicted in Table C.2.

Finally, the safety stocks will be computed. Therefore, a safety factor is assigned to each SKU. The safety factor [24] is also based on the coefficient of variance of the demand per week (average of the CVs of the actual and forecasted demand per week). The safety factors used are 1.282 for X-class items; 1.64 for Y-class items; and 3 for Z-class items. A safety factor of 1.282 implies a probability of 90% of having *no* stockout during a replenishment cycle; a safety factor of 1.64 offers a probability of 95%; and finally, a safety factor of 3 result in a probability of 99.9 % of *not* having a stockout during a replenishment cycle (see also Section 4.3).

If the safety factor is assigned, the new safety stock [25] is calculated by:

$$Safety\ Stock = k * \sigma_L$$

Again, I have to make a remark. The review period is not considered while calculating the safety stock. The review period should be incorporated, because we will buffer against uncertainties during this week as well.

<u>All remarks on the current safety stock model are listed in Subsection 3.3.4.</u>

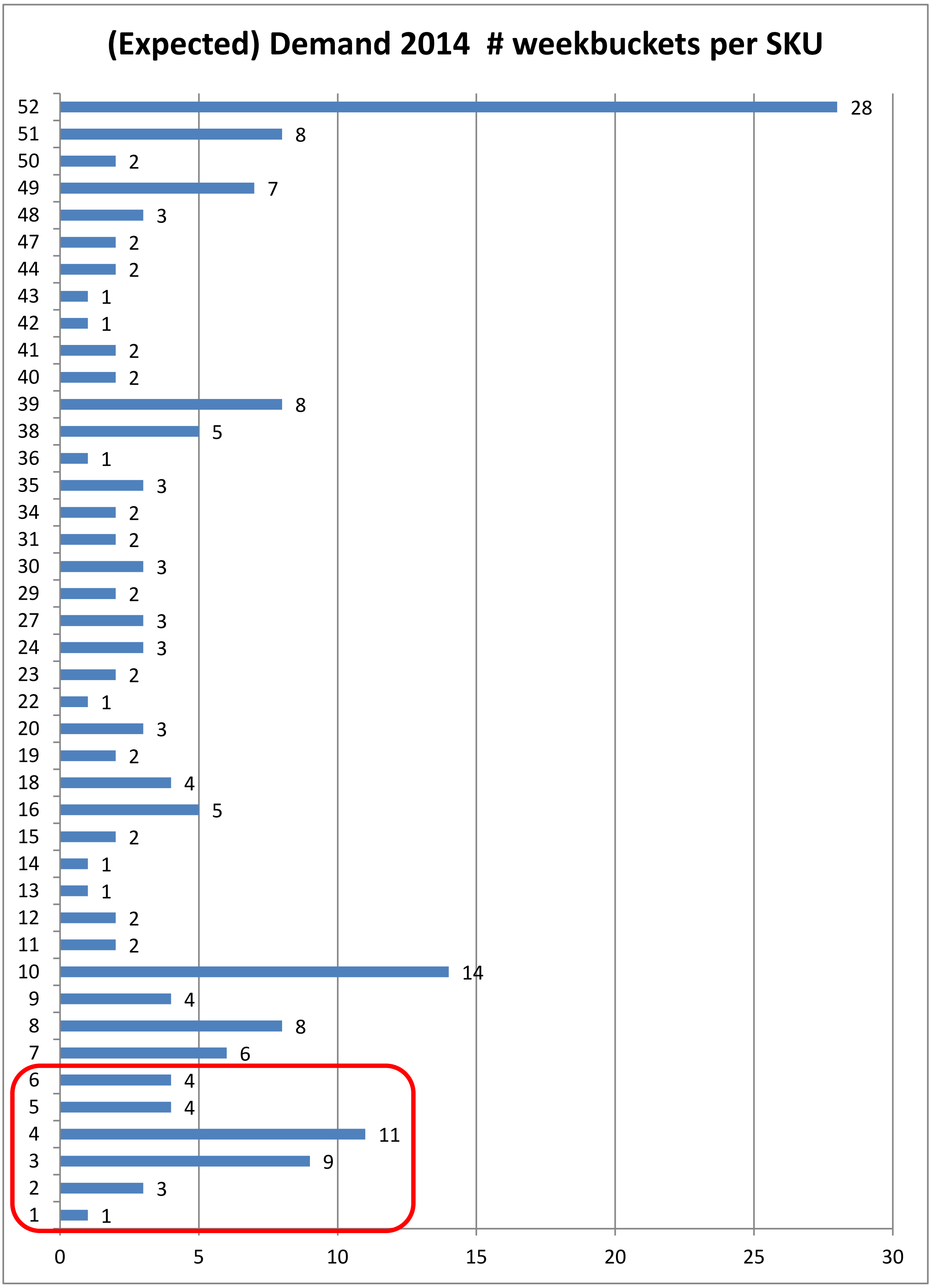
Table C.2 shows the table used to allocate the allowed weeks coverage value.

ABC classification	XYZ classification	Lead time (days)	Allowed weeks coverage
A	X	L < 28	6
A	X	28 < L < 56	8
A	X	L > 56	16
A	Y	L < 28	6
A	Y	28 < L < 56	8
A	Y	L > 56	16
A	Z	L < 28	8
A	Z	28 < L < 56	16
A	Z	L > 56	16
B	X	L < 28	6
B	X	28 < L < 56	8
B	X	L > 56	16
B	Y	L < 28	8
B	Y	28 < L < 56	16
B	Y	L > 56	16
B	Z	L < 28	16
B	Z	28 < L < 56	16
B	Z	L > 56	16
C	X	L < 28	8
C	X	28 < L < 56	16
C	X	L > 56	16
C	Y	L < 28	8
C	Y	28 < L < 56	16
C	Y	L > 56	16
C	Z	L < 28	16
C	Z	28 < L < 56	16
C	Z	L > 56	16

Table C.2 - Allocation of Allowed Weeks Coverage value

Appendix D – Number of weeks with expected requirements

In 2014, 32 SKUs are in six weeks or less required. This indicates that between their production runs is at least 8 weeks (52/6 = 8.67).



Appendix E – Literature search

For the literature review, the search is divided in two parts. Firstly, the literature is searched regarding *SKU classification* and secondly, the literature is searched concerning *inventory models*. The scientific literature used is mainly attained via Scopus (www.scopus.com). Scopus is the largest abstract and citation database of peer-reviewed literature (Elsevier B.V., 2014). Articles which are not accessible via Scopus are searched via Google Scholar (scholar.google.com).

The search queries determine which articles are shown by Scopus. Scopus will show all articles containing the entered key words. Though, there are some features to enlarge the chance for success. By entering the word 'AND' one can search for articles which consider both topics. The word 'OR' could be used to include substitutable words. For example, scholar A uses the word *categorization* and scholar B prefers the word *classification*. Therefore, it is helpful to enter the most common substitutes as well. For example, the search query '*SKU OR product'* will result in articles containing the word *SKU* and articles containing the word *product*. Besides, scholar A could talk about categori<u>z</u>ation (US spelling), as scholar C talks about categori<u>s</u>ation (UK spelling). Hence, it is very helpful to determine the search queries carefully.

For attaining the relevant knowledge the articles should cover at least the topics SKUs, classification, and inventories. Figure E.1 shows the building blocks for the used search query. These building blocks are combined into the following search query:

SKU OR product AND class* OR categor* AND inventory OR inventories

Topic	Search keys	Possible hits
SKU	SKU OR product	SKU, SKUs, product, products
Classification	class* OR categor*	Class, classes, classification, classifying, category, categories, categorization, categorisation
Inventory	inventory OR inventories	Inventory, inventories

Table E.1 – Key words used in literature search

Our search query matched 1691 results. To narrow the review, a journal selection is applied. The articles, and therefore the journals, have to be related to the subject areas of production, operations research or operations management. This limitation yielded 505 articles. Subsequently, the publications are assessed on relevance by scanning the titles first and if necessary by reading the abstract. 12 articles where interesting. A forward and backward search on these articles resulted in 11 additional articles. In the end 33 articles were studied to find a useful classification method for Domo Beilen.

For the replenishment policies the books of Silver, Pyke and Peterson (1998) and Axsäter (2006) are used. These books are well-known in the field of inventory management and provide a comprehensive overview of inventory management and production planning topics.

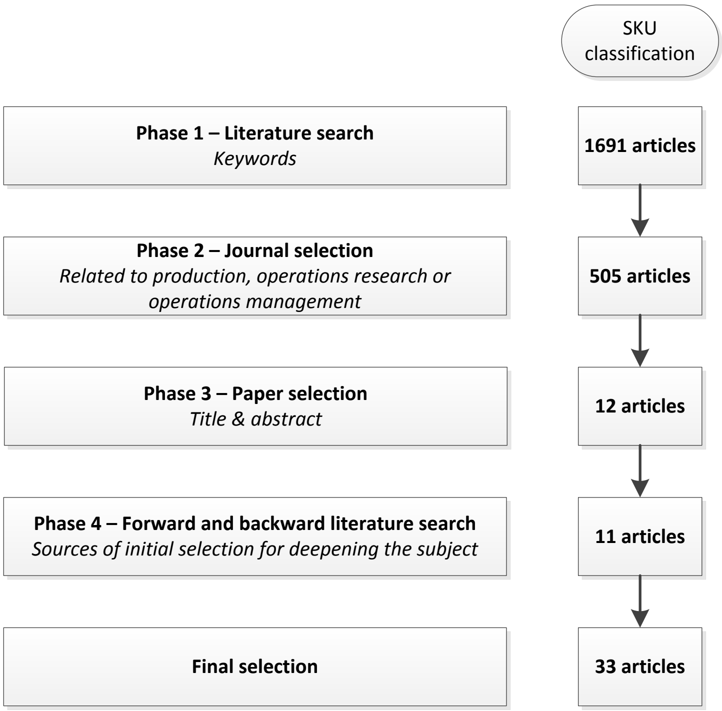


Figure E.1 - Literature search methodology (SKU classification)