Bachelor Graduation Project

Alnet (Pty) Ltd, Cape Town

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ALNET A trusted name. A tested reputation

Exploration on the functioning of a material requirements planning at a knitting department

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ALNET

UNIVERSITY OF TWENTE.

Management Summary

Introduction

This research is performed at Alnet situated in Cape Town, South Africa. Alnet is a manufacturing company for shade cloths. The company uses High Density Poly Ethylene (HDPE) polymers as the raw materials to produce their nets. The nets have multiple purposes, amongst others they are used for shade, crop protection and fishing. The value creating steps in the factory are represented by the production of extremely thin yarns out of polymers. Subsequently, these yarns are wound on bobbins. In the next department the yarns are rewound on beams and in the last production stage a shade cloth is constructed by knitting these yarns according to a certain pattern. The nets are mainly packed into packages of 25 or 50 meter rolls and sold all over the world.

Problem description

Alnet suspects that the value of semi-finished products in the Raw Material Stock (RMS), Work-In-Process (WIP) and 'floor stock' is in excess of 70% of the average monthly turnover. Despite this relatively large percentage, Alnet has often found that the needed partly manufactured materials are not available. The result is that the knitting process waits for materials - which makes the manufacturing process longer than it should be. We found that about 15% of the total available time in the knitting department is not used, caused by unavailability of materials. Many components in stock implies that a lot of money is represented by goods. We found that the current WIP-level fluctuates around ZAR 4.5 million which is approximately EUR 450,000[1]. For Alnet is essential to reduce this high WIP-level.

Research Question

Work-In-Process includes all unfinished parts or products that have been released to a production line (Hopp, Spearman, 2001). Since Alnet wants to reduce the WIP-level we focused on the material requirements planning (MRP) in the factory. Precise timing of materials flows to meet production requirements is the principle behind MRP (Ballou, 2004). In other words the research is on the subject of material flows within a factory and tends to improve the production planning of Alnet with a lower WIP-level as a result. Given this approach, this research tries to answer the research question: "*How can Alnet's material requirements planning be designed to make sure that the WIP-level is reduced and the right semi-finished products are manufactured?"*

Design of the customized MRP

During the analysis we discovered that Alnet currently uses two separated production plannings for a sequential production process. The extrusion production planning and raschel production planning are separately executed. The planning for extrusion should be based on the raschel production planning, but at the moment they are not connected in the right way. The average throughput is taken as the input for calculating the dependent demand, i.e. demand based on the next sequential production processes. This is not correct, and results in the buildup of a large stock in between the two departments as well as idle time in the raschel department. Therefore a customized MRP is designed to allocate the materials to one of the production processes and with that decrease the volume stored in the buffer. The customized planning links the sequential departments and furthermore it has a changed planning frequency, time bucket and planning horizon. The planning frequency means how often the production planning is updated. Depending on the reliability of the production process, the planning is updated

[1] 1 EUR = 9,73734 ZAR d.d. 22-07-2011

more or less frequent. A time bucket is the unit of time on which the schedule is constructed and is typically daily or weekly. Small time buckets lead to a more flexible production planning. The planning horizon is how far to plan forward, and is determined by how far ahead demand is known and by the lead times through the entire production process (Richards, 1996). We decided to change the planning attributes to be able to proactively schedule in case capacity problems occur (longer planning horizon), create more flexibility (shorter time bucket), and it helps to get insight in the exact timing for requirements in the production departments (higher planning frequency). Therefore the planning frequency, time bucket and planning horizon has changed in the customized planning to respectively, twice a week, a day and two weeks.

Conclusions & Recommendations

Basically Alnet used a incorrect demand for calculating the needs in the various departments, which has led to a very high WIP-level. The customized MRP is used to decrease this level. As already mentioned, the main changes are the correct linkage of independent and dependent demand and furthermore the planning frequency, time bucket and planning horizon have changed. It is taken into account that the manufacturing of non-required components is avoided as much as possible. By the removal of unused components we expect the WIP to decrease with about 55% to a level of about EUR 200,000. In other words, the products which are currently stored in the buffer in between the extrusion and warping/stretching department can be heavily reduced.

The unavailability of components also lead to waiting times in especially the knitting department, the department where the final product is constructed. The customized planning also has a positive influence on the waiting times. Because more overview is created, the planning department is better able to react on events happening in the rolling planning. Therefore we expect the idle time to reduce with about 5%, to 10% idle time due to unavailability of materials. Due to a little unbalance in the line it is likely that the machines cannot be supplied with materials to its full potential.

Further research

Currently, set-up times in the knitting department are quite large. A possibility to reduce the total set-up time of the machines is to combine the set-up of raw materials (the yarns wound on beams) on the machines. Therefore the length wound on these bobbins in the warping and stretching department should be adapted. If the length is adapted the beams will run out simultaneously and we expect the set-up times to reduce. Further research should investigate our expectation. Another subject for investigation is to create a link with our main supplier, to give insight in our supply chain activities in order to improve the delivery of raw materials, so called supplier integration. Furthermore the safety stock levels are assumed as a percentage of the monthly throughput, a more sophisticated research could be performed in order to set the value of the internal safety stocks right.

Implementation

To make the implementation successful a stepwise approach is recommended. During the period I stayed with Alnet, there was insufficient time to test the model properly. The next step before implementation is a final validation of the model on the Alnet 80% Green knitting machines. The model is first tested on a small range of products, to expand the model some products with properties close to the production process of Alnet 80% Green are suited to test the model. When the model is fully tested it is wise to expand to other production processes as well. The model can be expanded in the following order: first to agricultural shade cloths (similar product category), secondly to the complete range of shade cloths and finally to all products (including ropes and fishing nets).

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List of abbreviations

BOM	Bill of Material
CEO	Chief Executive Officer
CFO	Chief Financial Officer
ERP	Enterprise Resource Planning
FGS	Finished Goods Store
HDPE	High Density Polyethylene
MPS	Master Production Schedule
MRP	Material Requirements Planning
PLT	Planning Lead Time
RMS	Raw Material Store
UV	Ultraviolet
WIP	Work-in-process
ZAR	South African Rand
cm	centimeter
m	meter
mm	millimeter
i.e.	it est

Preface

This report is written as a part of my graduation project for my bachelor Industrial Engineering and Management at the University of Twente. Part of the education is to do research in the business environment. Alnet (Pty) Ltd gave me the chance to do a research on improving their production process. For a 3-months period, I stayed in Cape Town to perform this study. For me this was a fantastic opportunity. The knitting market has to deal with severe competitions, particularly entrants from the eastern part of the world. With this report I want to contribute to Alnet's production planning, which results in lower working capital and lower production costs. In this way Alnet can better compete in their market. I would like to thank everyone involved in this project. Special thanks goes to:

Alnet (Pty) Ltd.

Martijn Apello – Chief Executive Officer

Desigan Govender – Factory Manager – Project Supervisor

Alan Herringer – Member of Management Committee

Norton Holmes – Manager Production Planning

Jeff Redeker – Manager Operations Raschel Department

Annie Jacobs – Manager Raschel Department

Martin Burke – Manager Operations Extrusion

Katie Speelman – Manager Quality and Inspection

University of Twente

Dr. M.C. van der Heijden – Primary Supervisor

Dr. J.M.G. Heerkens – Secondary Supervisor

The South African experience was a perfect opportunity for me to develop as a person. Going abroad was a big challenge. It was a great opportunity to implement the knowledge I gained at university in a professional organization. An international working experience was great fun. What really surprised me was the hospitality of the South African culture. It really was a warm welcome and I would love to experience it again one day.

Enjoy reading my final report!

Tom Blankendaal

Enschede, August 2011

Chapter 1: Introduction of the company

This research takes place at Alnet (Pty) Ltd., a net and rope manufacturing company seated in Cape Town, South Africa. This chapter shortly introduces Alnet (Pty) Ltd. in terms of its background. In addition, the company activities and the involved departments are outlined. Henceforth, Alnet (Pty) Ltd. will be referred to as Alnet.

1.1 Background

As a net- and rope manufacturing company seated in Cape Town, Alnet wants to be leading in its branch. Their products are distributed all over the world. Alnet was founded in the 1960's by Dutch people. Its name originates from Apeldoorn Lighthouse Net & Twine. Apeldoorn Lighthouse Net & Twine was established in 1965 for the purposes of the manufacturing and sale of commercial fishing nets by Apeldoornse Nettenfabriek of Holland, that was the major supplier of anchovy and pilchard netting to South Africa and Namibia (then South West Africa) at that time (Fibre 2 Fashion, 2010).

The company is medium sized with an annual turnover of more than 100 million ZAR, which is approximately 10 million EUR[2]. About 70% of Alnet's products are knitted shade nets for agricultural and crop type use and a second category are 'decorative' or industrial nets. Most industrial nets have the purpose to provide shade; these nets have a higher shade percentage compared to agricultural nets. The other 30% of Alnet's products are mainly ropes, braids and twines, for a variety of applications – fishing and sport type nets, and ropes for general usage. At present, about 380 people are employed in the factory. The estimated design output of finished products is approximately 250 tons a year.

Alnet's plant is situated on the outskirts of Cape Town. Furthermore, there are a several distribution/sales branches throughout South Africa and Namibia. These branches are seated in Cape Town, Johannesburg, Durban, Port Elizabeth, Walvis Bay and St Helena Bay. Figure 1 presents an overview of domestic distribution areas.

[2] 1 EUR = 9,73734 ZAR d.d. 22-07-2011

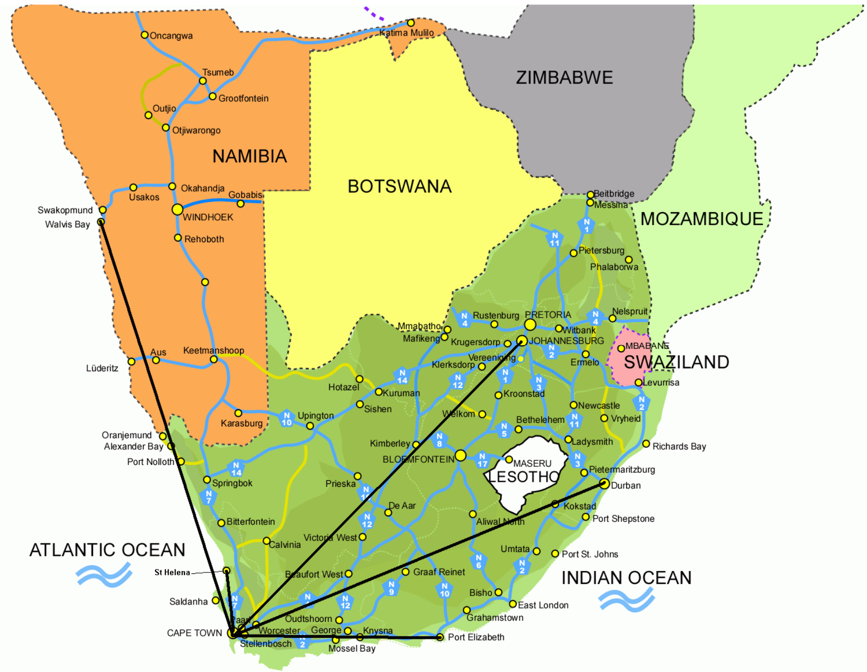

Figure 1 – Domestic distribution areas of Alnet

Although Alnet is an international operating company which distributes shade nets all over the world, their biggest market is South Africa. About 80% of their manufactured products are sold in their own country. The products are transported to distribution centers in the six cities mentioned above. From these distribution centers the largest parts of South Africa and Namibia are served. The share of Alnet in the South-African shade cloths-market is roughly estimated at 50-55%. The market share in ropes is estimated at about 35%.

1.2 Company activities and organization

Figure 2 presents an overview of the organizational structure. Alnet's organization exists out of four departments; a production department led by a factory manager, a finance department led by the CFO, a national sales department led by a national sales manager, and an export sales department led by an export sales manager. These departments are managed by the managing director of Alnet. This research takes place at the production department of the organization. The production department is divided into four areas. Technicians , Manufacturing, Quality inspection and Planning together make sure that the final products are made. Furthermore, the manufacturing department consists of Extrusion, Raschel and Cordage. The planning department plans all activities for manufacturing. My activities will be within the production department and consist of a combination between a manufacturing analysis and the planning part for manufactured products. A description of the technical details of the manufacturing department follows in chapter 3.

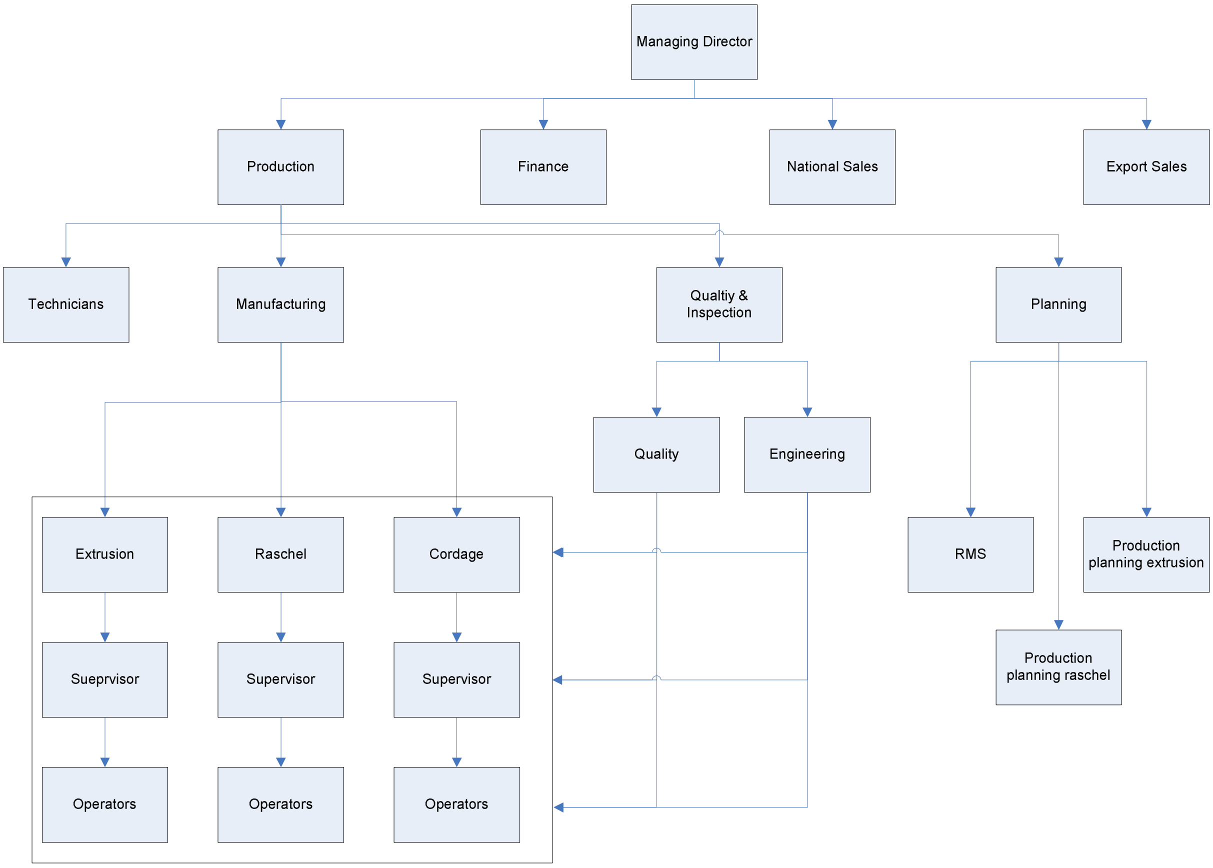

Figure 2 – Organizational Chart Alnet

1.3 The manufacturing process

To make nets, Alnet uses raw materials that are bought from external supplier. In other words, they use partly manufactured materials, add value and resell them again. Alnet basically buys polymers as their main component for the production process. The part where Alnet adds value is the production of yarns, in other words the extrusion process. The second part of the value adding process: these yarns will be wounded on beams, loaded on knitting machines and finally knitted into shade cloths. At the moment the planning is not very successful and that leads to long waiting times in different departments and a high work-in-process (WIP) level. The next chapter introduces the problem and the approach to the problem is defined. An analysis on the causes for the long waiting times and high work-in-process is presented in chapter 3.

Chapter 2: Introduction of the problem

Alnet would like to make continuous improvements on their performance. Prior to this study a problem description was formulated by Alnet. This section describes the approach to the problem and the purpose of the research. The chapter concludes with the research questions and therewith presents the foundation of the research.

2.1 Problem definition by Alnet

At the start of this research, Alnet described the problem as follows: "At the moment the value of semi-finished products in the Raw Material Stock (RMS), Work-In-Process (WIP) and 'floor stock' is in excess of 70% of our average monthly turnover – stock being at cost price of semi-finished products, turnover at selling prices. Despite this relatively large size, we often find that we do not have the partly manufactured materials to use on our knitting machines. The result is that the knitting process waits for materials – this obviously makes the manufacturing process longer than it should be. With resulting implications for planning and late completion of orders."

In this description a focus is made on the knitted products by Alnet. The reason for this is that most of the turnover is generated in the manufacturing department for shade cloths and with that the opportunities to improve are the highest. As mentioned in chapter 1, the manufacturing department consists out of extrusion, raschel and cordage. Since the research only covers knitted products, the extrusion- and raschel departments are included and the cordage department will not be taken into consideration. This is because cordage is not involved in the process to create knitted products.

2.2 Approach to the problem

Now we have a description of the initial problem it is time to focus on the causes of the arising problems. In business practice there is rarely a single problem or cause. Usually multiple and interrelated issues are involved. In order to detect the main cause of the problem I created a 'problem bundle'. In a problem bundle problems are depicted with arrows that indicate their cause-effect relationships (ABP-syllabus, 2005). Figure 3 presents this bundle, i.e. what the main problems are and which cause-effect relationships exist. In the case of Alnet the problems that are recognized are marked in yellow.

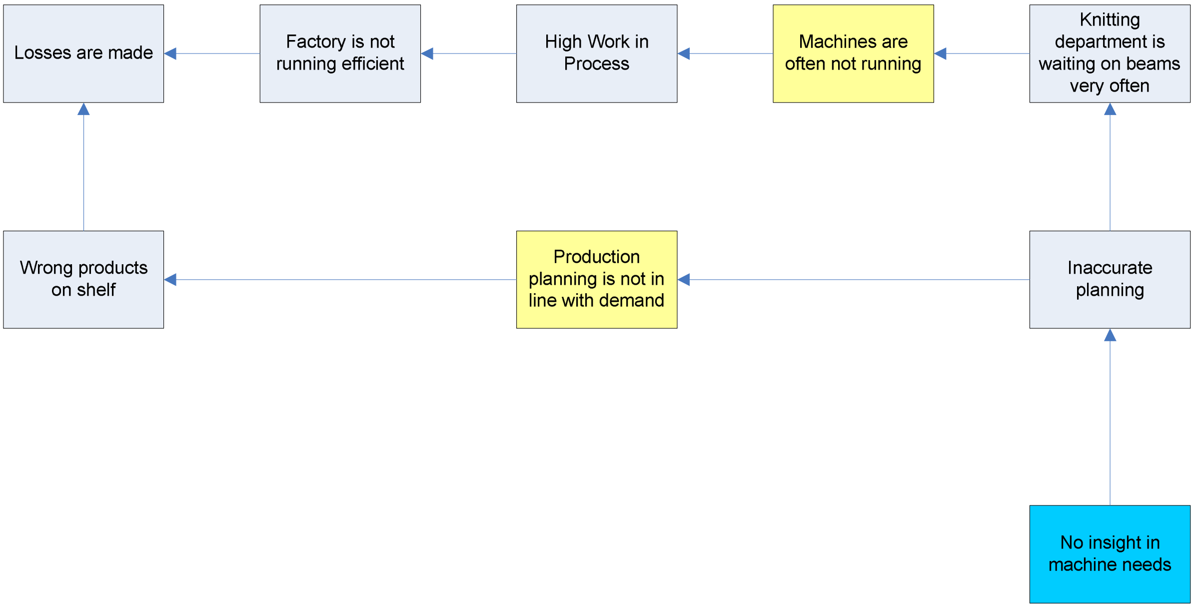

Figure 3 – Problem bundle

A translation of the initial problem statement formulated by Alnet is the foundation for further analysis in this research. The problems that machines are often not running and the existence of a gap between production planning and demand are indirectly caused by a lack of insight in the machine needs of the knitting department.

The problem bundle in figure 3 needs some more explanation. A big problem for Alnet is the negative results on the income statement for a number of successive years. Some reasons for the negative results can on the one hand be found in inefficiencies in the production process and on the other hand in the fact that demand could not always be met. The inefficiency is among others caused by a very high WIP position.

At the moment a lot of capital is represented in the on hand inventory and work-in-process (WIP). The WIP includes all unfinished parts or products that have been released to a production line (Hopp, Spearman, 2001). The company is working on reducing the total investment in the plant – in particular the warehouse for finished goods (FGS), the Raw Material Store (RMS) and WIP. One of the main underlying causes for the existing problems is a lack of insight in the machine needs of the knitting department. The visual outcome of this problem is that a lot of money is represented by components and goods. The high WIP-level is considered as not desirable by Alnet's board.

The high WIP-level is mainly caused by a big buffer between two departments. Products stay there for a long time and despite this relatively large size of stock, often is to be found that the proper semi-finished products are not available to continue the manufacturing process smoothly. This results in waiting times in the knitting process which makes the manufacturing process longer than it should be and wrong stock of semi-finished parts are hold. Long setup times for manufacturing machines make it hardly possible to change machines to manufacture other end-products on a planned machine. This makes it impossible to have a flexible production planning, and therefore the waiting times are a large problem.

According to the National Sales Manager within Alnet there were opportunities during the last year to sell more products. At the end of December 2009, Alnet closed the year with back-orders (orders for stock that Alnet could not deliver from their on-hand stock) of R9 million at the end of the peak season, which is approximately €900,000. This was due to what Alnet thought was production savings by slowing down volumes during low season, but then started too late to build up stock for the peak season (Sep, Oct, Nov and Dec). When it came to these months, production could just not cope with the volumes that had to be produced while the forecasts were already made. It was thus a combination of inaccurate planning and production not being able to meet the requirements. Although it is a huge problem, this problem is not within the scope of this research. Actually it is a separated problem which is not included in the problem bundle. It will contribute to better operations if the backlog can be reduced therefore better collaboration between the departments of sales, forecasting and production planning is necessary. We choose not to tackle this problem because first the main operations should run smoothly and when production numbers are more accurate the production can better be adapted to the required sales.

As we can see in the problem bundle both problems, the inefficiencies in the production and unmet demand, can be addressed to a lack of planning capabilities. Because of inadequate planning, machines are not running and supply and demand within the departments does not match. The reason for the inadequate planning is caused by the fact that there is no insight in the exact material needs for the production machines. Therefore this research will focus on the planning side of manufacturing for shade cloths at Alnet.

2.3 Purpose of the research

The purpose of this research is to reduce WIP through the design of a planning model that provides insight into the need in the manufacturing departments for shade cloths. To solve this problem a lot of knowledge about the production processes, variables and relationships is needed. In the previous section I already clarified the concept WIP, namely as all unfinished parts or products that have been released to a production line (Hopp, Spearman, 2001). However, the manufacturing departments still ask for clarification. Manufacturing departments include extrusion, warping, stretching and knitting. A detailed description on the technical concepts will follow in the next chapter.

2.4 Research Questions

In section 2.2 I described the causes of the problem we want to tackle. To set up a framework on how to solve this problem some research question are to be formulated. The main research question serves as a foundation for this graduation project.

Question: "How can Alnet's material requirements planning be designed to make sure that the WIP-level is reduced and the right semi-finished products are manufactured?"

The concept of a material requirements planning needs further explanation. A material requirements planning has to provide a schedule specifying when each of these materials, parts, and components should be ordered and produced (Jacobs & Chase, 2008). The required schedule gives insight in the needs of different departments.

To answer the main research question some sub-questions are necessary. First we have to get insight in the current situation of planning activities. The first research question is therefore:

RQ 1: "How is the current material requirements planning organized and where are problems arising?"

After exploring what problems are experienced by the planning department, we would like to know how the planning should be organized. A search throughout the literature will help us to get an understanding of organizing an ideal material requirements planning. With that the second research question is formulated:

RQ 2: "What does literature describe about solving a material requirement planning in a manufacturing environment?"

After reviewing literature some discrepancies in between the current planning and the desired way of organizing a material requirements planning have to be defined. The third research question is formulated:

RQ 3: "How can the current material requirements planning be improved?"

When a different planning logic is suggested we would like to know what it yields to implement this new planning logic.

RQ 4: "What is the impact of the improved material requirements planning logic?"

Since we know that problems never are the same as any other theoretical situation, we have to find a solution that adapts to Alnet's situation. Some specific conditions apply to Alnet's problem. Finally we want to implement the solution and that is covered in the last research question.

RQ 5: "How can the improved material requirements planning be implemented to Alnet's situation?"

In this report the following chapters will provide an answer to these research questions. Chapter 3 gives an answer to research question 1, it describes how the current production planning is organized. Chapter 4 continuous to describe what literature states about organizing a MRP (question 2). We expect the desirable planning logic to be different compared to the current situation, chapter 5 describes what changes are suggested to improve the current planning logic (question 3). Since we want to know what the results are when the suggested changes are implemented, chapter 6 provides an overview of the results of the improved planning logic (question 4). Finally, the last research question is described in chapter 7 and is about the implementation of the customized material requirements planning at Alnet (question 5). Some conclusions are drawn when the answers to the question are formulated, these are summarized in chapter 8. Furthermore some recommendations for further research are connected to these conclusions.

Chapter 3: Problem Analysis

In chapter 2 the main problem is defined as a lack of insight in the machine needs of the knitting department. The purpose of this research is to contribute to a better manufacturing requirements planning. This planning must ensure insight in the exact requirements of the production department and above all a lower WIP-level compared to the present WIP-level.

This chapter gives an overview how the current planning is organized, by giving a description about what is going on and where problems arise.

3.1 Material Requirements Planning

The planning department is in charge of the flow of semi-finished items and the completion of the orders. The manufacturing planning for shade cloths covers the departments of extrusion and raschel. As described before, with raschel the warping, stretching and knitting departments are meant. At the moment the planning activities on the extrusion and raschel departments are separated. The raschel planning is combined because all semi-finished products from warping and stretching are direct input for the knitting department. Before the planning activities can be explained in detail it is necessary to give some information about the manufacturing process. Explanation of some terminology is required to understand the planning activities.

Manufacturing process

To give an understanding of the value adding steps performed in the factory, a material flow chart is drawn. It describes the manufacturing process at Alnet's factory which can be seen in figure 4. The demarcated blocks, extrusion- and raschel planning, are the departments were the material requirements planning is involved.

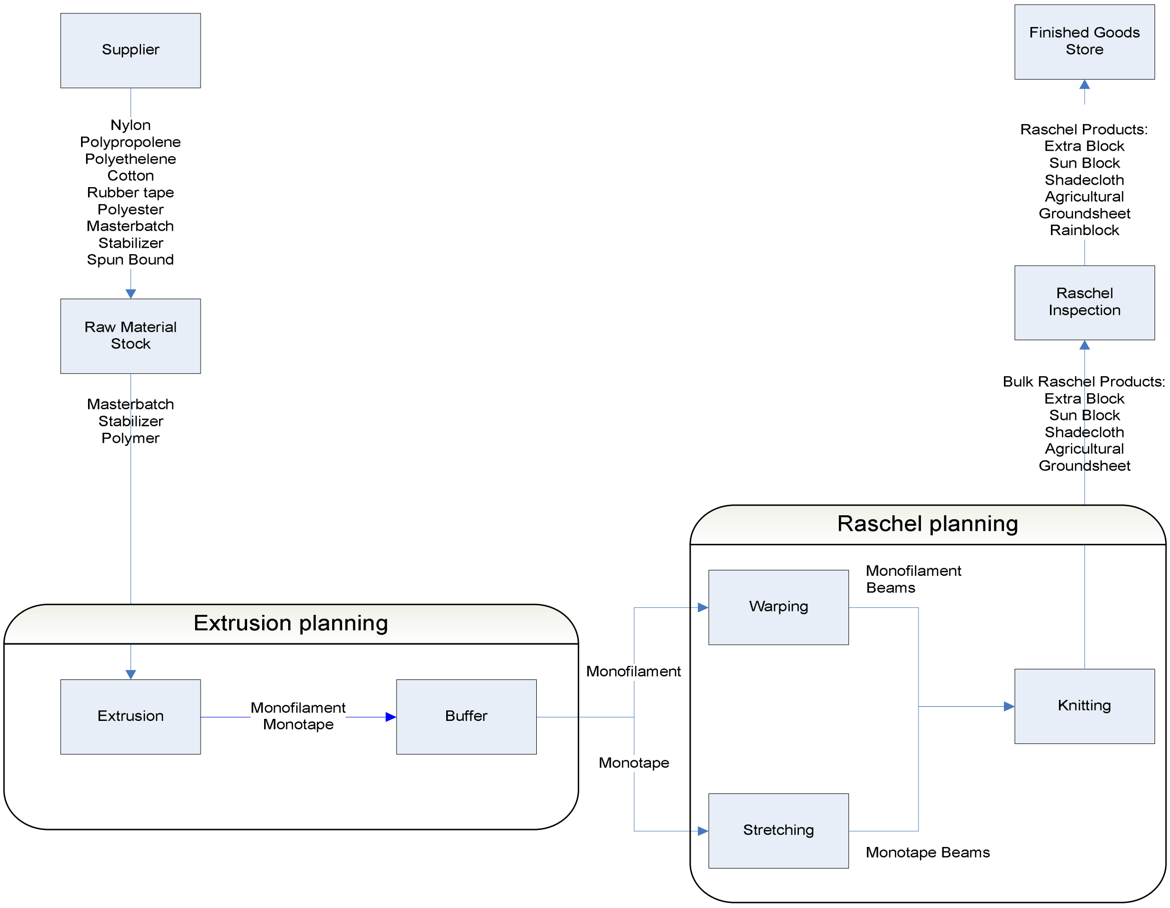

Figure 4 – Departments and material flows involved for knitted products

As one can see in figure 4, the material flowchart starts at the supplier. Raw materials for the production process – mainly High Density Polyethylene, stabilizer and masterbatch – are purchased at suppliers. These supplies are stored in the RMS and used when the production process requires one or more of these materials. The extrusion department is the first department where raw materials are used in the manufacturing process. This department is responsible for the production of bobbins with monofilament. Monofilament is a plastic yarn which is comparable to a fishing line. Another product produced by the extrusion department is monotape, which is an extremely thin and wide film which also is manufactured from HDPE. Both are wounded up on either a bobbin or a roll. The bobbins and tape rolls are temporary stored in a buffer before they are respectively used by the warping and stretching department. These departments produce big jumbo beams with a certain number of threads or ends on it. The beams are approximately one meter in width and serve as input for the knitting department. Thereafter, the jumbo beams are loaded onto the knitting machines. The beams have different colours and numbers of ends. According to a certain pattern the nets will be knitted on big rolls. These rolls are inspected by the raschel quality inspection. The inspection department will approve quality and cut, pack and label the nets into 25 or 50 meter rolls. These packed products will be stored in the finished goods store situated at the production plant. To give an indication of the components some pictures can be seen below.

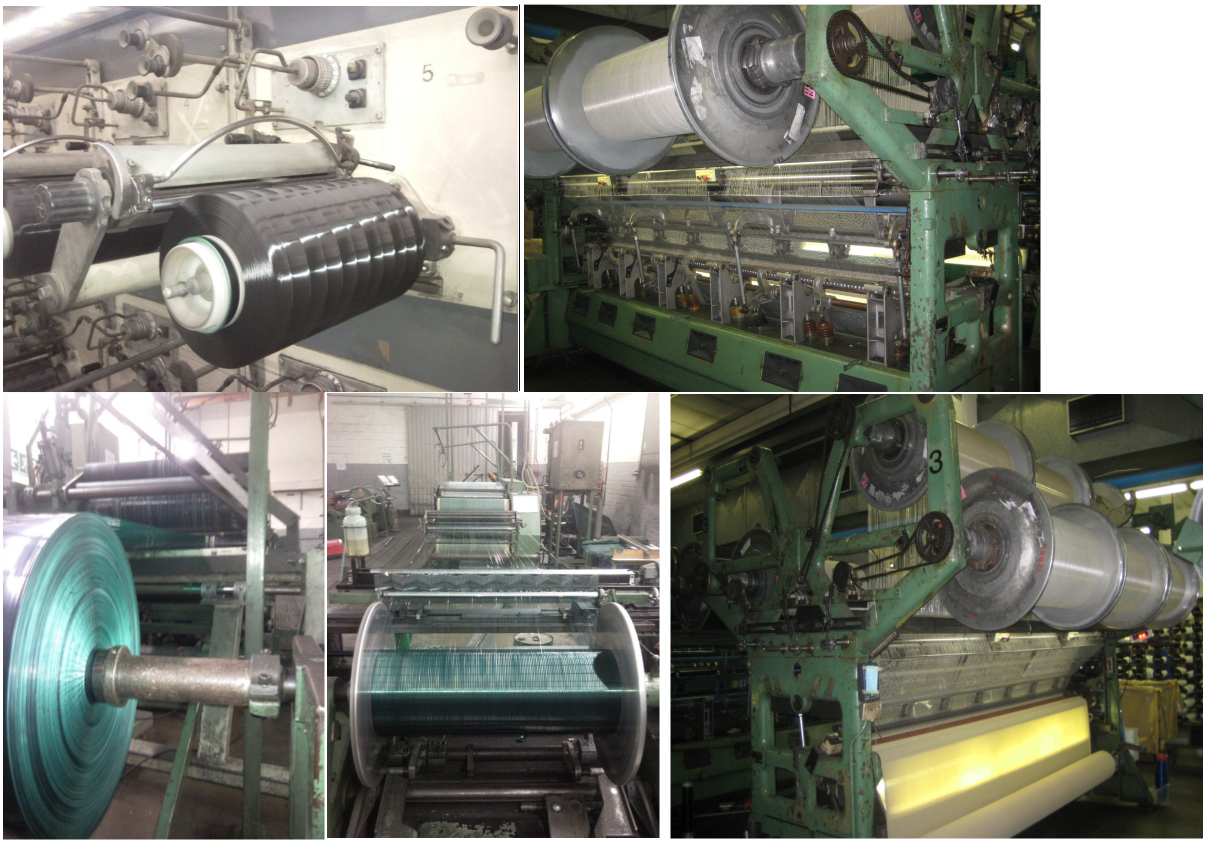

Figure 5 – (semi)-finished products; Top left – a wounded bobbin; Top right – a knitting machine with beams on top; Down Left – a wounded monotape roll being stretched; Down centre – a beam in process in the stretching department; Down right – a knitted roll being manufactured.

Alnet uses an ERP information system to store and retrieve data about the company, among others for the production planning information about product availability. Data from the system is converted by the planner into a Microsoft Access-file and this file is used to generate the production planning. Alnet applies general planning rules for the generation of the production schedule. This means that on hand inventory level at the end of week t (I_t) = on hand inventory level end of week t-1 (I_{t-1}) – forecasted sales in week t (FS_t) + planned replenishment order arrival and the end of week t (P_t). These numbers above are determined for every single product and used by the planner to generate a production schedule. The inventory position is expressed in a number of meters of end product. The planned replenishment is calculated as a result of previous planning actions, taking into account the lead time. For example, the lead time in the knitting department is one week. This implies that the planned production at the end of week t-1 is a planned replenishment for the end of week t. Details about the specific calculation of the planning method will follow in the exact description of the extrusion and raschel planning.

$$I_t = I_{t-1} - FS_t + P_t \text{ with } P_t = PQ_{t-1}$$

Some general principles to generate a production planning need some additional explanation. All production plannings are made according to certain frequencies, time buckets and time horizons. The frequency means how often the production planning is updated. A time bucket is the unit of time on which the schedule is constructed and is typically daily or weekly. The planning horizon is how far to plan forward, and is determined by how far ahead demand is known and by the lead times through the operation (Richards, 1996).

At the moment the production planning, both extrusion and raschel, is made or updated every week, the time bucket is a week and the planning is made a week in advance and does not go any further. In short, the planning frequency, time bucket and time horizon are all one week. This is a problem because the planning cannot foresee future bottlenecks, since the time horizon is so short. The lack of insight in future planning activities results in an inflexible planning and this is causing waiting times.

The planning horizon is how far to plan forward, and is determined by how far ahead demand is known and by the lead times through the operation. Most of the production planning is based on sales forecasts. The goods involved are sold by stores throughout the country. So the demand is not known exactly but it is more or less a prediction. The used lead times in the knitting department are about one week, since the minimum batch size is equal to 4000 meters duration which requires about 94 production hours. To create a set of beams in the stretching department 18 hours are required (27,500 meters stretched at 80 meters/min * 3 beams in a set, set-up times can be neglected). The preparation of a beam set in the warping department takes about 6.5 hours (37,000 meters warped at 500 meters/min * 3 beams per set with set-up time of about 2.5 hours). The longest lead time in the extrusion department is about 16 hours. A black monofilament bobbin holds 140,000 meters delivered at a speed of 150 m/min, where set-up times can be neglected again. For other colors and thickness (light green monofilament dark green tape) the lead times are respectively 14 and 12 hours. The cumulative lead time is at most 16 + max(18, 6.5) + 94 = 128 hours. Alnet produces 24 hours per day, where 21,5 hours are available for production. This means that the total lead time is somewhat less than 6 days.

As we can see in figure 4 the independent demand for final products includes the knitting department. The planning for knitted products is made in the raschel planning, therefore the raschel planning is described first. The extrusion planning is derived from the raschel planning and will follow next.

<u>Raschel planning</u>

The raschel planning is driven by the needs of the distribution stores for make-to-stock products and by customer orders for make-to-order products. The distribution stores are the retailers of the end-products. They have on hand inventory of the bulk- or fast moving products in their stores. The stores can sell products out of their stores inventory or order it at the factory. When the distribution stores need products, the products can either be on hand in the finished goods store located in the factory or be produced in the factory.

To make sure customer demand can be delivered in a reasonable time, a safety stock for the bulk products is built up. It represents inventory that protects against stock outs due to fluctuations in either demand or deliveries (Hopp, Spearman, 2001). This safety stock is kept at the FGS at the factory in Cape Town. From this distribution centre, it can be shipped to the distribution stores.

For the planning department it is important to know which products are available, where they are located and what is ordered so far. The planning system is based on the quantity allocated – already sold products –, the on hand inventory, a order-up-to-level and the planned output from the factory. To determine which products have to be produced during a certain week the current on hand inventory of every single make-to-stock product is calculated. This is done according to the following formula: $I_t = I_{t-1} - FS_t + P_t$. In the terms Alnet uses the amount of available to promise products (I_t) is equal to the on hand stock at the end of last week(I_{t-1}) – forecasted sales during this week(FS_t) + replenishment of planned products at the end of week t(P_t). The forecasted sales (FS_t) are determined based on historical data. An average of the monthly sold products are taken where the sales of last year have a higher weight in comparison to earlier years. The forecast model is developed by the sales manager of Alnet and has relation with the weighted moving average model. The most recent periods have a higher weight compared to older period.

Now we know how the inventory position is determined the next step is to determine when products should be manufactured in order to complete orders in time. In fact a simplified (R,S) inventory control system is used. Where R represents the review period, the time interval between two moments at which a replenishment order can be released. This period is equal to the planning frequency, which is one week. S represent the order-up-to-level, the level to which the inventory position is exactly increased by releasing a replenishment order, i.e. the lot sizes are not fixed (Van der Heijden et al., 1997).

Since most of the output volume of the factory consists of make-to-stock items, a safety stock is held for these products. The planned production quantities for all products are derived in the following way:

Planned Quantity = $PQ_t = S - I_t$; with $P_t = PQ_{t-1}$

For all make-to-stock products an order-up-to-level (S) is determined. This order-up-to-level serves as a safety stock to prevent against stock-out costs. The order-up-to-level is more or less a target inventory level for a certain product. The safety stock level is currently determined by the planner, but there is not a rule of thumb or a formula which is scientifically approved. A percentage of the monthly sales are taken as the safety stock level which is included in the order-up-to-level S. These figures are reviewed yearly for all products in order to keep them up to date.

The planned quantity for all products is summed and an overview of the required products is generated. Now we have calculated what the demand for production batches is, the planning department divides the required production manually over the available knitting machines. In the knitting department the available capacity is calculated as 65% of the available machine time in a week.

The required production is matched to the available capacity. According to the batch sizes that are used for individual products a calculation is made how many batches are needed to deliver the required end products. As said before batch sizes are not fixed but in general a minimum size is used to avoid excessive set-up costs.

In cases of capacity problems, the planning department does not use the planned quantity formula as a hard rule for the production of batches. This implies that the order-up-to-level is used as a flexible order-up-to-level. In the planning sheet a rule is added which compares the on hand inventory with allocated quantity. This amount is the minimum what should be manufactured to satisfy customer demand. In case of capacity problems the order-up-to-level is excluded of the planned quantity formula.

This means that a gap is created in the safety stock level. As a rule for exclusion Alnet applies the fastest moving products have the highest priority. Since expected back orders, and with that possible lost sales, on these products have the highest occurrence probability.

In case an order comes in and stock levels are sufficient to sell the product from a store or the distribution point, but no replenishment comes in, the safety stock level is not obeyed. This is only possible if the quantity on hand is large enough to cover the order size, for the inventory position this means there is not sufficient stock to cover the order-up-to-level but the on hand stock level is still positive in a period. To make sure that customers can be delivered, the planner compares the allocated quantity with the on hand inventory in a period. Since this is done all manually sometimes errors occur. This results in unsatisfied customers and backorders.

When the safety stock is left out of consideration in the production quantity plan and there is still insufficient capacity, products with the highest margins are preferred over lower margin products. Most of the times make-to-order products have a higher margin, so these are preferred above make-to-stock products. Furthermore a list is created with high volume customers, these customers have preference above single order customers. In case capacity is insufficient, the orders for these customers are produced first and other customers have to wait longer.

There are rarely problems with the capacity, but since the demand is very sensitive to seasonal influences sometimes problems with the production capacity occur. The accuracy of the seasonal forecast are of big importance to build up sufficient stock and to avoid large amount of backorders. During this peak season (especially South African summer) production is not capable to manufacture at the speed of product sales. Therefore a seasonal stock should be build up. Currently the safety stock is enlarged in the months before summer. As mentioned before the forecast accuracy is out of the scope of this research, therefore I recommend further research on the subject of forecasting.

Based on the requirements in the knitting department, the dependent demand is calculated for the warping and stretching departments. Because the knitting department needs the beams with monofilament and monotape from respectively warping and stretching the planning for these departments can be calculated by a conversion of the knitting need. The general planning principles are equal to the one used in the knitting department. The throughput of kilograms of yarn is known when a machine manufactures a certain net. When the planner decides to manufacture a product there is known what kind of semi-finished products the machine needs. The planner knows the requirements from the raschel planning. Every end product requires certain semi-finished products. The requirements are calculated by multiplying the speed of the machine with the usage of yarn per jumbo beam (kg/hour). This requirement is multiplied with 65% since the average utilization is 65%.

The dependent demands are currently calculated based on the throughput in the knitting department. The average throughput used is calculated based on a 65% utilization rate multiplied by the full capacity of the machine. The output of a machine(meters/hour) multiplied by the weight of the fabric multiplied by 65% of the available production time. For example a knitting machine manufactures 43,6 m/h * 0,45 kg/linear meter * 0,65 utilization = 12,8 kg/hour = 274,2 kg/day = 1195 kg/week. Per product is specified that this 1195 kg can be divided into percentages of semi-finished products. For example Alnet 80% Green consists of 52% black monofilament, 18% light green monofilament and 30% dark green monotape. Which corresponds with 620 kg black monofilament, 215 kg of light green monofilament and 358 kg of dark green tape per week for this machine.

The sum of the requirements for certain beams/semi-finished products is added up and is the input in the production schedule. Every beam has a certain weight and the needed amount of kilograms and the sum of requirements is translated into a number of beams. Most apparent is that there is not exactly known when the jumbo beams on the knitting machines are empty and therefore need to be changed. Therefore it is hard to determine when the semi-finished products from warping and stretching should be exactly ready. This is causing waiting times on material, since the precedence relations are not taken into account in the production schedule.

In the warping and stretching department no safety stock is held. The (expected) requirements for warping and stretching are derived from the knitting department and calculated as follows: $\mathrm{PQ_t} = \mathrm{q_t} - \mathrm{I_t}$. Where PQ_t is the planned quantity, v_t is the requirement in the knitting department and I_t is the inventory of a certain beam. As in the knitting department, the total requirements are summed and divided manually over the warping and stretching machines.

When capacity in the warping and stretching department is not sufficient to manufacture the required semi-finished products, the departments are scheduled in overtime. It sometimes happens that these departments have to work during weekends to cope with demand from the knitting department.

Extrusion planning

Since the extrusion department manufactures components for other departments its demand is dependent demand. The extrusion planning is a separate planning based on the needs of braiding-, twisting-, warping- and stretching department. In this research the needs of the braiding- and twisting department are excluded since these actions are not involved in the manufacturing process of shade cloths. Some extrusion machines in the extrusion department are specialized for manufacturing components for the departments of braiding and twisting. These manufacture other products and these are not used in the warping- and stretching departments. However, the planning principles for all these departments are similar.

To meet the production requirements a weekly production schedule is generated. The required production is determined with the following formula: $\mathrm{PQ_t} = \mathrm{S} - \mathrm{I_t} + \mathrm{q_t}$. The production schedule contains all colours and thicknesses of monofilament that should be produced in a certain week. This production schedule is matched to the capacity and capability for a certain machine. The output of the planning for the extrusion department is a number of kilograms of monofilament and a number of kilograms of monotape. The planner creates a production schedule with the requirements for every single machine. To produce the required bobbins a total bill of materials (BOM) is set up. Time slot are reserved to manufacture the required kilograms.

Data on the levels of on hand stock of bobbins is extracted from the ERP system. The Microsoft Access data sheet contains all numbers needed for setting up a weekly plan. This production schedule is presented as the need for certain products and is displayed in kilograms. The products vary in colour and thickness. At the moment this is just a rough estimation of the needs in the raschel department; the average throughput of a week production by the knitting machines. We can state that this is not the need of the raschel department. In other words products are produced while these products are not required by warping or stretching. This implies that a big buffer between the departments arises with products at the lying there at the wrong time.

The dependent demand in the extrusion department is currently calculated as the sum of the average throughput per machine in the knitting department. As in the warping and stretching planning the average throughput in the knitting department is used to calculated the requirements in extrusion. The output of a machine(meters/hour) multiplied by the weight of the fabric multiplied by 65% of the available production time.

Every knitting machine has its own throughput. The throughput depends on the product being manufactured and the speed of that particular machine. If there is known what the total expected throughput in kilograms per week is, the needs are specified into needs for extrusion. The extrusion department extrudes the requirements for the warping- and stretching department and these dependent demands are calculated for all colours and thicknesses of monofilament or monotape needed. The requirements are summarized in a ‘requirements sheet’. This is the input for the extrusion planning. On the sheet every colour and optional additives are grouped.

For the planning an average production capacity in kilograms an hour is calculated and this is the guideline for the output. The planning on the extrusion lines is based on the available hours. On average 90% of the available time output can be produced. Due to machine breakdowns, set-up times and maintenance the lines are not available for about 10% of the time.

The planning is made in excel. The planner uses a ‘capability sheet’ that displays the production capacities and capabilities for every extruder. The requirements sheet is matched to the capability sheet. The products are scheduled manually over the available time. Because the requirements from warping and stretching and the available capacity are known a week in advance, an estimation on the number of working days can be made. Most of the times this is 6 or 7 days a week, 24 hours a day.

The extrusion department consists out of 8 extrusion machines. Every machine produces monofilament or monotape according to certain standards. In figure 5 an overview of a weekly schedule is given. This schedule is created for every extrusion machine. Some terminology need explanation, denier represents the thickness of the threads. Doffs mean the number of batches of a certain quality must be produced. In other words how many times the bobbins must be changed. In this case 5 batches of beige monofilament must be produced. The total weight of the batches is estimated 2151 kg’s. The batch started at October 20th at 21:50 and ended at October 22nd at 13:25.

	DENIER	COLOUR	DOFFS	Kg.	START	TIME
1	350 d. BEIGE+UV Works Order No. :		5	2151	20-okt-10	21:50
2	350 d. WHITE+UV Works Order No. :		5	2151	22-okt-10	13:25
3	350 d. L/GREEN+UV Works Order No. :		4	1721	24-okt-10	05:00

Figure 5 – Example of production schedule for extrusion department

Every week the performance of the extrusion department is reviewed. This is done in the manufacturing meeting. Operators monitor how many kilograms of monofilament or monotape is produced and these data will be added to the ERP system. The new information is used to construct a schedule during the next week.

3.2 Challenges within the materials requirement planning

Now we know what kind of information is needed for the planning it is important to find out where the problems' origin is coming from.

Alnet started with the problem of having a very high WIP-level. The WIP-level for Alnet in the period of 1 October 2009 till May 2010 fluctuates between EUR 380,000 and EUR 740,000. On average the amount was about EUR 450,000, for details see appendix B. The fluctuation in this WIP-level seems very big, the maximum level is almost twice the minimum. A closer view on the numbers will point out that the maximum level occurred during a couple of days in the beginning of April. This must be a measurement error, it is impossible that the WIP almost doubles. When we exclude these figures the observations make clear that the total average fluctuates around EUR 450,000. Compared to a monthly turnover of about EUR 900,000 this is very high. A large part of this 450,000 is temporary stored in the buffer in between extrusion and warping/stretching. The challenge is to reduce this number by adapting the production planning.

Secondly, an effect of a bad production planning is the occurrence of waiting times. The fact that machines are not running is mainly caused by the fact they have to wait on semi-finished products to be ready. This table gives an overview of the size of this problem. The waiting time is divided into waiting on material and waiting on beams. In this table "waiting on material" is defined as the warping or stretching department have to wait on material from extrusion and when the beam on a knitting machine is empty it has to wait as well. This is because no safety stock is held between warping/stretching and knitting. The semi-finished items are only stored on bobbins, this is the output of extrusion. So when extrusion has not finished the products in time and there is no stock of semi-finished products available it implies that all succeeding departments have to wait. "Waiting on beams" is defined as the warping- or stretching department is busy making beams but it is not yet available for the knitting department. In general all products manufactured in warping/stretching are immediately used by the knitting department, a beam set of 3 beams is manufactured and loaded on a knitting machine.

Week	Waiting on material (%)	Waiting on beams (%)	Total waiting %
10	2,8%	21,4%	24,2%
11	7,7%	19,8%	27,5%
12	5,4%	2,2%	7,6%
13	3,3%	5,1%	8,4%
14	20,3%	1,7%	22,0%
15	15,0%	2,4%	17,5%
16	5,8%	8,5%	14,3%
17	12,4%	1,7%	14,1%
18	15,2%	2,9%	18,1%
19	13,9%	4,7%	18,6%
20	19,1%	0,0%	19,1%
21	14,2%	1,0%	15,2%
22	4,5%	0,8%	5,2%
23	7,9%	2,6%	10,5%
24	10,1%	0,3%	10,4%
Average waiting percentage caused by these two factors:			**15,5%**

Table 1 – Waiting times knitting machines (Downtime sheet Alnet, 2010)

Table 1 shows the waiting times caused by unavailability of materials. Waiting on materials and waiting on beams together cause a lot of delays in the production process. This sample of 15 weeks shows that about 15,5% of the available time production was not able to operate because of product unavailability. The origin of these problems arises due to inaccuracy in the planning. The lack of detailed information on the need of the knitting department is the actual cause. There is no timetable when these knitting machines will be empty. There is only a plan on how many kilograms of yarns are needed on average during the week. Also the production line is not in balance. The capacity in the different departments is not exactly equal.

At the moment a weekly material requirements plan is made. This weekly plan gives insight in which products will be produced. It is known which semi-finished products are needed to make a certain end product. But there is a lack of knowledge on which days these products are required. So products will be made somewhere in the week but it is possible that the production happens in an incorrect sequence. The sequence is not resulting from logic due dates, but it is almost a random order in which the products are scheduled. The availability of semi-finished products is checked, and whether or not available a production batch is scheduled. Because of the large time bucket, when semi-finished products still have to be manufactured, it sometimes happens that materials are not ready yet. Prioritising production batches is only a result of experience of the planner and the priority of production is not determined by a standard procedure. Because the planner decides manually when semi-finished products are manufactured it is hard to include fixed priority rules, which do not lead to waiting times in the production. It is even harder when two separate plannings are used. It often happens that material is needed on a knitting machine, which should be delivered by the warping- or stretching department, but is not available (yet). It is often the case that these beams are still in the process, resulting in long waiting times for the knitting machines. This is not caused by a lack of capacity but caused by a lack of insight in the exact time for requirements in the departments.

Due to long set-up times for changing quality in the knitting departments, the machines run batches with a minimum of about a week. This makes it impossible to run a flexible manufacturing schedule.

Most of the products are continuously manufactured on one knitting machine. Therefore the moment for raw material needs can be known but the knowledge is currently absent.

Another problem is the conversion of the throughput in kilograms. On average the weekly throughput in kilograms will be about the same. But because beams are running on different speeds it can occur that a lot of beams of the same raw material run out simultaneously. This is also caused by a lack of overview on the needs for the knitting department.

Conclusions

1. The planning of material flows is currently separated into a raschel- and extrusion planning.
2. At the moment the production planning is updated weekly, the time bucket and the planning horizon are a week.
3. Most apparent error in the planning is that the demand in the extrusion department is calculated by taking the average throughput in the knitting department. It should be dependent on the requirements in warping/stretching departments, which in its turn can be calculated through applying the general planning principles. This error causes wrong products at the wrong time in the buffer between extrusion and warping/stretching and therefore a relatively high WIP position.
4. The current WIP-level is on average about ZAR 4.5 million.
5. The waiting time in the knitting department caused by waiting on materials is currently about 15% of available production time.
6. The new planning should include a good connection between the extrusion and raschel planning, which takes into account precedence relations.
7. The so called independent demand should be the input for the production process, the dependent demand can be derived from the independent demand. A lot of production information can be extracted from the raschel planning and should serve the extrusion planning to improve the planning logic and reduce non-required production runs and waiting times.

Chapter 4: Theoretical Review

In the last section of chapter 3 the key problems are mentioned, the challenges are to reduce waiting times and to reduce the current high WIP-level. A literature review will be done to discover how other researcher solved a comparable problem. In this chapter an investigation is done on the possibilities of introducing a MRP for Alnet. A description about critical components to design a good MRP is given. This chapter answers the second research questions: *"What does the theory describe about solving a material requirement planning in a manufacturing environment?"*

The key in a production planning model is the flow of goods. The purpose of a model is to simplify the reality to ensure that human beings can visualize and understand a system. To understand the production system and the interrelationships in a system the bill of materials (BOM) is used. This BOM is one of the inputs for MRP. It gives an overview how an end-product or level-zero item is built up into its components or lower-level items. Using MRP is a nice tool to calculate how and when products flow in between departments. The purpose of a MRP, from a logistics viewpoint, is to avoid, as much as possible, carrying items in inventory. Theoretically, inventories do not need to be created when the amount and timing of the end-product requirements are known. Offsetting by the lead time the request part, materials, and supplies, the end-product requirements can be met at the time they develop. Precise timing of materials flows to meet production requirements is the principle behind material requirements planning (Ballou, 2004).

In other words a material requirements planning is a plan to keep the machines running by feeding them at the right time with the right resources. Unfortunately there exists variability in production systems. All production systems have to cope with this variability; variation can either be controllable or random (Hopp, Spearman, 2001). Controllable variation occurs as a direct result of decisions. This part of variability has to do with for example planning. In most cases it is predictable what happens to a production system if a decision is made to extend a production batch in a certain department. It will either disturb or favour the production process.

On the other side there is random variation what is a consequence of events beyond our immediate control. For example, the times between customer demands are not generally under our control. Another example is that the breakdown of machines is a stochastic process. We do not know in advance when the machine will break down due to for example broken parts in a machine. But we only know that on average it will happen once every period of a certain months or weeks. This is a source that cannot be influenced and therefore is not in the scope of this research.

Using a MRP will reduce controllable variability. A planning model can be used to forecast the needs for the different departments within Alnet. When we would like to set up a batch in the knitting department, we would like to know what the requirements are for the other departments to complete that production. A level-zero item (net) has a bill of materials (BOM) which translates it into its constituent components. It connects the independent demand with the dependent demand. Hopp and Spearman (2001) determined two different types of demand; independent- and dependent demand. Independent demand includes all demand for final products and possibly some demand for components. Dependent demand is demand for components that make up independent demand products.

A production control system is based on some variant of statistical reorder points. The production of a part is triggered by inventory for that part falling below a specified level (S). Demand for components is known as a function of a final product. There are a few variants to control inventory levels. First of all (s,Q)- and (s,S) policies are used in continuous review policies. In the current production system a periodic review is applied. We can either choose between a (R,s,Q) or (R,S) policy.

The symbols are defined by (Van der Heijden and Diks, 1999) as:

"R : Review period, the time interval between two moments at which a replenishment order can be released. In a continuous review policy, the value of *R* is always zero and therefore excluded.

S : Order-up-to level, the level to which the inventory position is exactly increased by releasing a replenishment order. In these control systems, the lot size is not fixed.

s : Reorder point; additional products are only ordered if the inventory position falls below the reorder point. This variable is not relevant for the (*R,S*) control policy. In that case, every *R* time units a replenishment order is released with a size that brings the inventory position to the level *S*.

Q : Fixed lot size. If a replenishment order is released, it has size Q or an integer multiple of Q. Such a fixed lot size often represents a pallet, a box or some other standard packaging. If multiple lots may be ordered simultaneously, we indicate this as *nQ*. If the inventory position is below the reorder point s, a (variable) multiple *n* of lots Q is ordered such, that the inventory position is raised above the level *s*."

Since we want the new planning to be in line with the current way of working, the production planning of shade cloths can be best controlled by a (R,S)-policy. We always would like to have a certain inventory position for the make-to-stock items. Therefore every review period R we want to have an inventory position of at least S. This rule is already applied by the planning department and is considered as useful and should be maintained in the customized planning.

To meet dependent demand production should be scheduled so as to explicitly recognize its linkage to production to meet independent demand. A MRP works backward from a production schedule of an independent demand item to derive schedules for dependent demand components. MRP adds the link between independent and dependent demand that is missing from statistical reorder point systems. Therefore a MRP is called a push system since it computes schedules of what should be started or pushed into production based on demand (Hopp, Spearman, 2001).

Now we know the basic principles of a MRP system we focus on how to generate such a MRP for Alnet. The input for a MRP comes from a master production schedule (MPS). A MPS contains gross requirements, the current inventory status known as on-hand inventory, and the status of outstanding orders (both purchased and manufacturing) as known as scheduled receipts. This MPS is based on the demand for end products. MRP works with both finished products, or end times, and their constituent parts, called lower-level items.

To create a MRP the following steps have to be taken:

1. Netting: Determining net requirements by subtracting on-hand inventory and scheduled receipts from gross requirements. The gross requirements for level-zero items come from the MPS, while those for lower-level items are the result of previous MRP operations.

2. Lot sizing: Divide the netted demand into appropriate lot sizes to form jobs.

3. Time Phasing: Offset the due dates of the jobs with lead times to determine start times.

4. BOM explosion: Use the start times, the lot sizes, and the BOM to generate gross requirements of any required components at the next level(s).

5. Iterate: Repeat these steps until all levels are processed (Hopp, Spearman, 2001).

The basic inputs to MRP are a forecast of demand for end items, the associated bills of material, and the current inventory status, plus any data needed to specify production policies. These data come from three sources:

(1) the item master file; a file containing all item master records for a product, product line, plant, or company. E.g. which machine is capable of producing a certain type of monofilament.

(2) the master production schedule; the sum of demand for end products

(3) the inventory status level (Hopp, Spearman, 2001).

The planning lead time (PLT) is used to determine job start times. In MRP, this procedure is simple: The start time is equal to the due date minus the PLT. Thus, if the lead times were always precisely equal to the PLTs, MRP would result in parts being ready exactly when needed (i.e. Just-In-Time). However actual lead times vary and are never known in advance. But for the MRP average production times are assumed.

In section 3.1 the concepts of time bucket, frequency and time horizon are already explained. Orlicky (1973) describes that a more flexible planning system can be generated by using small time buckets. In order to keep the inventory and requirements data up to date. In the article the author states that the time bucket for the on hand inventory should not be longer than one day. For the requirements it should not be longer than a week.

When for example daily changes occur in the MPS, which is the input for the MRP, the production schedule must be very flexible. The frequency of scheduling is better to be high. In contrary, when few changes in MPS are made the frequency can be lower.

Conclusions

9. A material requirements planning is used to prevent controllable variability.
10. By linking the dependent demands to the independent demand, the production needs can be calculated (netting).
11. The demand for components is known as a function of a final product. Therefore the extrusion planning can be derived from requirements for higher level items and should be linked to the raschel planning since it is a sequential production process.

12. The policy to control inventory position can be best described as a (R,S)-policy.
13. The use of two separated production plannings should be avoided. It is confusing and is the source of multiple errors in the production planning. One planning system with equal rules for every department is desirable.
14. The production planning should have a short time bucket in order to create a more flexible planning. A time bucket of a day increases flexibility and clarifies exact timing of requirement for components.
15. The planning frequency used in the planning is dependent on the number of orders coming in for the on-going planning. It would be wise to update the planning twice a week, in quiet times when utilization rates are stable the planning can be updated once a week.
16. The time horizon of the production planning should have at least the length of the sum of the lead times of the involved production departments. Currently the time horizon is only one week, to create a better overview and ability to react on future events the planning horizon should be enlarged to at least two weeks.

Chapter 5: Design of a customized Material Requirements Planning

In chapter 4 the ideal situation according to the MRP theory is described. Diverse authors agree on a few concept within the theory: netting, explosion and offsetting. In this chapter the customization on the planning are presented. The theory combined with the practical situation describes how Alnet should organize their MRP.

As described in chapter 3, currently the dependent demand is based on the average throughput in the knitting department. As stated the dependent demand of warping, stretching and extrusion should be derived from the independent demand (the knitting requirements). If we want to improve the performance of the planning department we should formulate the need for the different departments correctly. The new planning is based on the MRP rules described in chapter 4. The required output in amount of meters of net should be the starting point of the production planning. This net consist of various components and the components should be available at the time required. Therefore stock levels on lower level items should be checked and if not available a batch should be scheduled. Based on the net requirement for end products the planning for lower level items can be derived from the zero-level items. The changes, compared to the current way of working, in the planning are described in this chapter.

For the customized production planning the parameters time bucket, frequency and planning horizon have changed. Because the planning for lower level items changes quite frequent, we change the time bucket into a day. Currently often is found that materials are still in production while the materials are already required in a successive department, this is caused by a lack of insight in the needs in the knitting department. When a time bucket of a day is used, the planning will give insight in the requirements of knitting machines that run out per day. For simplicity of the model, the planning ensures that materials are available at last at the beginning of the day they are needed in the next sequenced department. This prevents waiting on materials in adjacent departments. Adapting the time bucket into a smaller parameter will erase/reduce waiting times because batches are planned and every component is allocated to a successive level in the production.

The frequency of updating depends on the reliability of the production process. The accurateness of the planning process in its turn relies on the accurateness of the estimation of the utilization rate and the frequency of production entries for the rolling planning. At the moment the utilization rate in the raschel department are fluctuating quite heavily, therefore it is better to update the planning twice a week. When the uncontrollable variability is low, i.e. the production process is stable, the frequency can also be lower.

The planning horizon is how far to plan forward, and is determined by how far ahead demand is known and by the lead times through the operation. Most of the production planning is based on forecasts. The goods involved are sold by stores throughout the country. So the demand is not known exactly but it is more or less a prediction. The used lead times in the knitting department are about one week, in warping, stretching and extrusion respectively 6.5, 18 and 16 hours. This means the total lead time is somewhat less than 6 days and implies that the planning horizon should at least cover 6 days. Therefore we changed the planning horizon into a period of two weeks.

Currently a big buffer exists between the extrusion department and warping- and stretching department. Figure 6 illustrates what happens when the current two separate plannings are used. The extrusion department keeps producing while the adjacent departments do not need the produced materials.

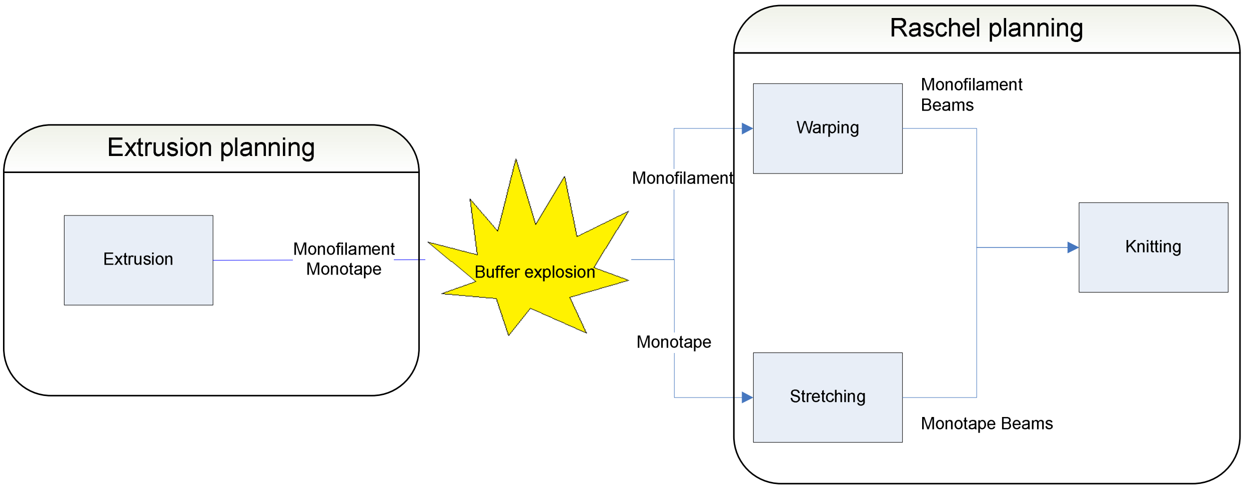

Figure 6 – buffer explosion in the production process

By using the MRP rules this buffer will decrease because the BOM prescribes what products should be produced to complete an end product. The lower level items are derived from the level-zero items in the first step (netting) of the MRP. In this section a description of the exact calculations are described.

A sales forecast is made for every month, customer orders are coming in, the current inventory and future planned shipments are known. With these numbers the available to promise can be calculated. The available to promise in the current action bucket is calculated through beginning inventory + MPS shipment until the arrival of the next replenishment order – customer orders before next replenishment. Based on the available to promise level and the sales forecast we can determine the size of the production for a certain period. The determination of production is calculated first for the end products, i.e. level-zero items. Taking into account the order-up-to level a planned quantity for all products can be calculated. The order-up-to level is taken over from the current production planning. Currently it is a percentage of the monthly sales. This is a subject for further research to adapt the levels of safety stock/order-up-to level.

$$\mathrm{PQ_t} = \mathrm{S} - \mathrm{I_t}$$

Where S is the order-up-to-level, I_t the inventory position at the beginning of week t. As mentioned in chapter 3, currently the planned quantity is calculated in a correct way. In the customized planning, this procedure has not changed. The total requirements are scheduled over all available knitting machines.

The next step is to monitor the availability of semi-finished products, i.e. the amount monofilament and monotape on jumbo beams, on the knitting machines. This step is currently lacking in the planning. The customized planning model forecasts on which day the machine runs out of material. This forecast model is the input for the first-level production, i.e. the warping and stretching planning. It determines the due date for completion of the previous operation. The net requirement for end products can only be produced in time when first-level items are available.

From the scheduled items and monitoring in the knitting department a gross requirement for first-level items (beams) is derived per day, this is possible because it can be forecasted when a machine will be empty and needs a beam change. This is the gross requirement for the first-level items. Now we have to determine how many beams should be produced to satisfy the requirements in the knitting department. The planned quantity is calculated as follows:

$$\mathrm{PQ_t} = \mathrm{S} - \mathrm{I_t} + \mathrm{v_t}$$

Where PQ_t represents a number of beams, which can be translated into a number of kilograms of monofilament or monotape. Where S is the internal safety stock level for semi-finished products, I_t the inventory at the beginning of the period and v_t represents the gross requirements from the knitting department, all these values are expressed in a number of beams. This calculation is made for all varieties of semi-finished products. In the warping and stretching department the minimum lot size is equal to a beam set, consisting of 3 beams. This implies warping and stretching always need to manufacture a multiple of 3 beams to feed the knitting department. To warp or stretch a certain amount of kilograms, the start-time for a job can be calculated by using the throughput time and utilization rate of the used warping- or stretching machine. E.g. a beam has a weight of 250 kg, the warper runs at a speed of 500 meter/min and the weight of the material is 350 grams per 9000 meters (350 deniers). When 160 ends per beam are used the throughput is equal to 160 * 500 * 0.35/9000 = 3,1 kg/min. It will approximately take 250 / 3.1 = 80 minutes to warp a single beam, excluding set up times to attach bobbins to the creel and assuming 100% utilization. On average it takes 2.5 hours to prepare the machine for the production of a beam set. The average utilization is about 65% in the warping and stretching department. Taking this into account leads to a throughput time in the warping department of $\frac{3*80}{0.65} + 150 = 519\ minutes$, or approximately 8,5 hours for a new beam set.

In the model the first-level items are linked to the second-level items (monofilament and monotape). Finally, for the second level items the gross- and net requirements can be calculated in a similar way as for first-level items. Namely, $\mathrm{PQ_t} = \mathrm{S} - \mathrm{I_t} + \mathrm{v_t}$. In the extrusion department the batch sizes are predefined and start times can be determined by using the throughput time and utilization rate and required amount of kilograms. Now step 5 of the planning logic, the iteration of the process, is completed. This results in an overview of the demand for the involved departments with known due dates for production.

This method is shown using Alnet 80% Green as an example. Figure 5 represents the best sold end product Alnet 80% Green and its components. This product is on average manufactured on 4 of the 35 knitting machines. To manufacture this net the knitting department gets beam sets with black and light green monofilament from the warping department. And a set of 3 dark green tape beams from stretching. The warping and stretching get their materials in its turn from the extrusion department. Figure 7 gives an illustration of the BOM of Alnet 80% Green.

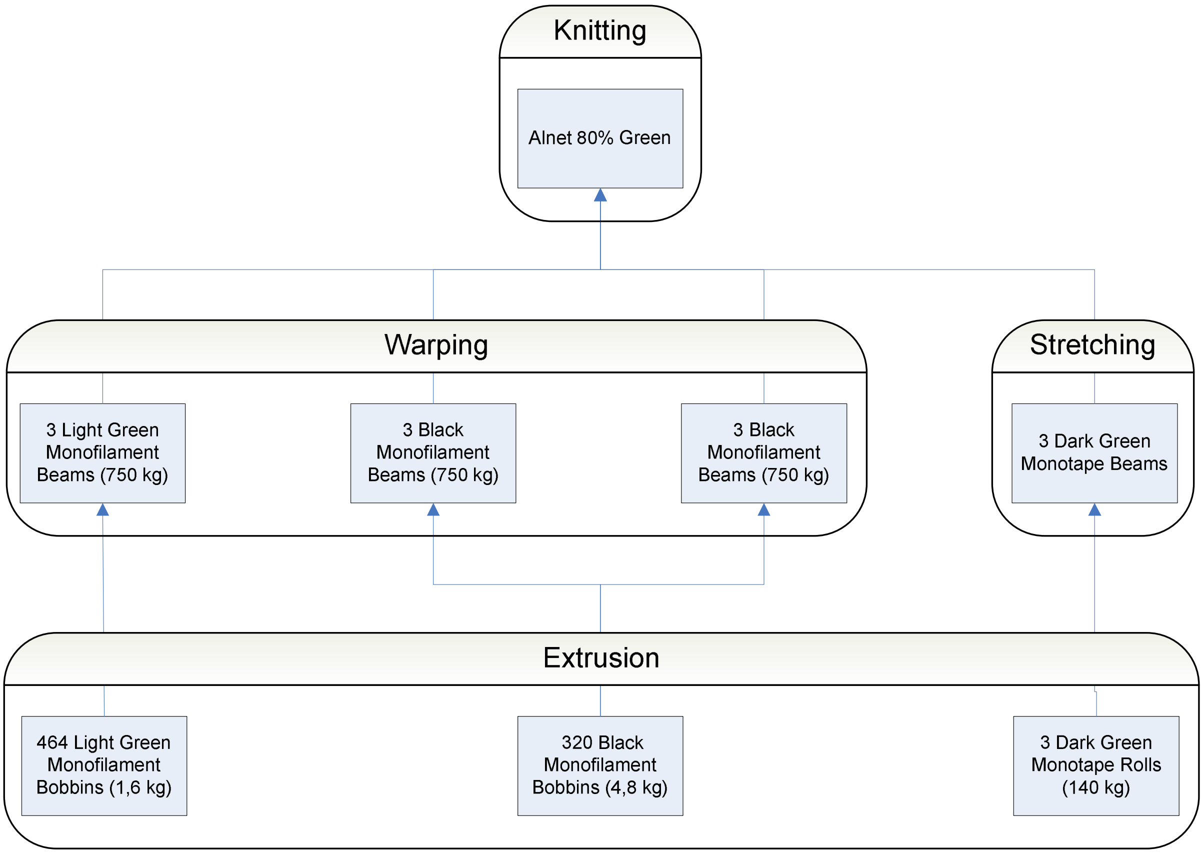

Figure 7 – Alnet 80% Green and its components

The model is programmed in way that the lot sizes are predefined with a minimum batch size. The batches can only be greater or equal to the predefined minimum. This batch size is added as a scheduled receipt. The planner has some influence on the planning, it is possible to add, remove or unite batches manually. Step 3 of MRP, the time phasing is programmed automatically. When a certain job has to be ready on a date there is calculated what the last start time of the machine can be according to the job size, average throughput time and utilization rate of the machine. The calculated starting time is used in the iteration process for the lower-level items.

Because of long setup times in the knitting department the minimum batch size for a knitted product is 4000 meters, this is determined by Alnet. 4000 meters corresponds for a Alnet 80% Green net with about 4000(m) / 43,6(m/h) = 91,67 production hours. This is about a week of production without any disturbances in the production. The manufacturing speed of a product depends on the number of stitches per inch. Because in general products with less shade have less stitches per inch they can be manufactured at a higher speed. The manufacturing speed varies from 40,7 till 68,8 m/h. Most agricultural products are manufactured at a speed of about 45 m/h. To avoid high set-up costs in the knitting department the production on a knitting machine can only be changed once a week. This is more or less in line with the frequency of the planning.

The described method can also be found in appendix C. First, the planner can use this schedule to determine how many machines are needed to produce the required meters of end products. In the next phase the production of beams can be determined. The model gives insight when new beams are needed and when warping or stretching should complete a batch. Finally the requirements for the extrusion department are given.

Conclusions

17. In the customized planning we created a link between all independent- and dependent demands to avoid a built up of unnecessary semi-finished products. This ensures a lower WIP-level and furthermore it takes into account precedence relations. Based on the requirements in the knitting department, the other department have to make sure semi-finished products are available at the right moment in the right quantity, which will decrease waiting times on materials.
18. The planning frequency, time bucket and planning horizon have changed in the customized planning to respectively, twice a week, a day and two weeks. These planning elements have changed to increase the insight in exact requirements of all involved production departments and to enlarge the ability to react on changes in the rolling planning.
19. The planning principles for determining the planned quantity of the current planning are correct and are applied to the customized planning.

Chapter 6: Results of the model

The previous chapters resulted in a description for the use of a customized MRP in the production planning of Alnet. This chapter describes what the developed model will yield. The purpose of the research, stated in chapter 2, is to reduce waiting times and WIP-level. This chapter shows the improvements and measures the effects of the customized planning.

The approach to measure the results is to use the forecast from some low- and high demand months. These requirements per month are executed with the customized planning model. On average 4 knitting machines are set to manufacture the Alnet 80% Green shade cloth, most of the time the production configuration fluctuates between 3 and 5 machines for this product. When the production requirements are plugged into the planning the amount of material in the system can be measured. The total sum of material released to the production system is used to determine the level of the WIP. Since Alnet 80% Green has a throughput volume of 25% of the factory, the WIP-level for this product is used and extrapolated to estimate the total required WIP.

Furthermore the waiting times on the long term can be measured when the required time for producing semi-finished products, the required capacity, is compared to the available capacity. An estimation of the waiting times can be made when the required capacity is exceeding the available capacity for a certain percentage of throughput of that product.

As mentioned in chapter 2 Alnet closed the year 2009 with back-orders with a value of ZAR 9 million. This high back-order level is can hardly be a result of capacity problems. Alnet usually manufactures about 93 hours per week, for the capacity calculations we use a utilization rate of 65%. Furthermore Alnet 80% Green is manufactured at a speed of 49.1 meter/hour. This implies that the current four machines are capable of manufacturing about 50,000 meters/month. This is more than sufficient to cover the demand and does not indicate any capacity problems. Furthermore, Alnet assumes and calculated that the production line is more or less in balance. It seems more a matter of bad forecasting because in peak season the demand transcends the 50,000 meters/month. It is of huge importance to build the seasonal stock timely.

Under the assumption that there is no capacity problem, the down times can be reduced to set-up times and stochastic variability as for example machine breakdown. Waiting on materials and waiting on beams can be reduced to a minimum since the planning indicates exactly when material is needed. The problem of a lack in insight in the material needs is resolved by our customized planning. The needs in the knitting department can exactly be monitored and therefore the planning for lower-level items can be scheduled without disturbances. In addition, there is a safety stock in case a beam set is required earlier in time due to for example a higher utilization.

In chapter 3, we showed that currently 15% of the available production time in the knitting department is lost due waiting on materials. We would like to know what the savings are of solving the lack of insight in the needs by using the customized planning model. Therefore we need to know what the operational time is to create batches in the involved departments.

Department	Set/Batch	Color	Required processing time
Warping	Beam set	Black	6.5 hours
Warping	Beam set	Light green	8.5 hours
Stretching	Beam set	Dark green	18 hours
Extrusion	Batch (1250 kg)	Black	16 hours
Extrusion	Batch (375 kg)	Light green	7 hours
Extrusion	Batch (290 kg)	Dark green	4 hours

Using these processing times in the scheduling of the jobs does not lead to problems in the simulation of the model. Unfortunately some days, 9 beams are required, which implies that (more than) the entire capacity is used to produce black monofilament for Alnet 80% Green machines. There are 31 other knitting machines and it is likely that these machines require black monofilament as well, since this is the semi-finished product which is used the most frequent. Advantage of this planning model is that we can react on events we foresee. The days before the 'peak demand' for black monofilament nothing is requested, so we can easily shift the production.

When the model runs a couple of times the average requirements of the capacity are as follows:

Department	Material	Required % of capacity
Extrusion	Black monofilament	21%
Extrusion	Light green monofilament	11%
Extrusion	Dark green monotape	9%
Warping	Black monofilament	36%
Warping	Light green monofilament	16%
Stretching	Dark green monotape	27%

The total throughput volume of Alnet 80% Green is about 25%. As one can see warping of black monofilament and stretching dark green tape requires more time than the 25% of the available capacity. Therefore it is likely that the warping of black monofilament and stretching of dark green tape results in waiting times on material. When approximately 12% of the black monofilament won't be ready in time, it results in an average waiting time of 1 hour (0,12 * 8,5 hours processing time). When 2% of the dark green monotape is late it results in an average waiting time of 0,4 hour (0,02 * 18 hours). Currently the waiting time is about 15%, which is equal to 14 hours production hours. This means that the use of the customized planning can reduce the waiting time with about 12.5 hours in the knitting department.

A higher utilization rate in the knitting department requires more material, while especially warping and stretching are already struggling with the material which is required. So a reduction of 12.5 hours is a little too optimistic, but a reduction of waiting times with 5% (4.65 hours) is very realistic since demand is known and the planning department is better able to foresee problems due to a smaller time bucket. This additional required time might be planned during weekends. A 5% decrease of waiting time should lead to a production increase of 228 meters per week per machine.

The sales of the nets (and forecasts) are all expressed in meters, while production of the semi-finished products is mostly expressed in kilograms. Currently the measurement devices which are used in extrusion and warping/stretching are quiet unreliable, therefore it is not possible to express the materials in all departments in meters. To be able to control the material flows, all the semi-finished products are weighted. Since the weight of the material (density) is more or less constant, it is a reliable way to express the amount of materials in kilograms. A few samples of Alnet 80% Green are taken to audit the accuracy of weight of the product, in almost all cases 50 meters of net weighted 22.5 kg. This means a linear meter of Alnet 80% Green weights 450 grams, which is in line with the data on the specifications sheets. Therefore the WIP-level in all departments is converted to a number of kilograms of semi-finished products. The cost price of the material is about 30 ZAR per kilogram. This price is currently used to determine the value of the WIP and will also be used to make a comparison with the current situation. On average the WIP-level for all products at Alnet in the period of October 2009 till May 2010 fluctuates around ZAR 4.5 million.

To determine the WIP in order to complete all requirements for Alnet 80% Green, a summation of the WIP per station is used to approximate the total WIP-level. The WIP is split into the different components of the final product. An overview of the WIP per station is presented below. Besides we made some assumptions to calculate the WIP-level on Alnet 80% Green.

- The calculations are based on a 65% utilization in the knitting department.
- Production of Alnet 80% Green on four knitting machines (output 49,500 meters per month, which is the about the monthly average based on a complete production year For Alnet 80% Green, the forecasted sales for the period between June and December 2010 (peak season) were between 38,000 and 62,000 meters per month.).
- Safety stocks in the warping and stretching department are equal to a beam set per required beam type on a machine (i.e. double amount of black monofilament, since it is used twice on a machine for Alnet 80% Green).
- Safety stock in extrusion is equal to two beam sets per required beam type. These semi-finished products can also be used for other net types.
- The planning horizon is two weeks, with five production days per week.
- $WIP_{Raschel}$ is material in process at warping/stretching, safety stock of warped/stretched beams and the loaded material on the knitting machines.
- $WIP_{extrusion}$ is the safety stock in between extrusion and warping/stretching and material in process in extrusion.

The customized MRP monitors how much material is left on the knitting machines. Therefore we can determine how much material is left in the knitting department. Based on the requirements in the knitting department, dependent demand in kilograms is determined. All materials in the process are traceable in the planning and summed per type. The average over the planning horizon of two weeks is taken to determine the average WIP-level. The symbol LG, B and DG represent the colors of the semi-finished products, respectively light green, black and dark green. Based on the aforementioned assumptions, for Alnet 80% Green, we found an average WIP of:

$WIP_{Extrusion,\ LG}$ = 1725 kg

$WIP_{Extrusion,\ B}$ = 3525 kg

$WIP_{Extrusion,\ DG}$ = 1044 kg

$WIP_{Raschel,\ LG}$ = 2662 kg

$WIP_{Raschel,\ B}$ = 2629 + 2674 = 5303 kg

$WIP_{Raschel,\ DG}$ = 1559 kg

Total sum of the WIP is 1725 + 3525 + 1044 + 2662 + 5303 + 1559 kg = 15,818 kg for the production process of Alnet 80% Green. The value of the WIP is calculated based on the cost price of the stock. This is about ZAR 30 / kg per kg HDPE. Using the customized planning, this means the total WIP for Alnet 80% Green is about ZAR 474,540. The safety stock represents quite a big percentage of the WIP (8055 kg $\approx 51\%$), while more products are fabricated out of similar semi-finished products. This means that on average the safety stock will be relatively smaller when we convert the WIP for Alnet 80% Green to a WIP for all products within Alnet. Since we can keep a smaller percentage of safety stock when more items use a similar semi-finished product. Assuming that Alnet 80% Green represents about 25% of the sales, and thus about a similar requirement of WIP in the factory, it means that a WIP position of about 4 times 474,540 is reasonable to produce all items. This means expanding the customized planning to all products might lead to a WIP-level of about 2 million ZAR. This is a reduction of 2.5 million or 55%.

The accuracy of getting the right components at the right time at the right place reduces the WIP-level. Another important side effect for Alnet: goods are translated into money, which will improve the cash position with about 2.5 million ZAR when all unnecessary items in mainly the buffer are used for production. As in chapter 2 is described, Alnet had the idea that the WIP-level was unnecessary high. Using the theory of applying MRP in a production environment we revealed that the current WIP-level is far too high compared to the current production level. Therefore I recommend to start using the customized production planning and rapidly expand to other products as well.

Conclusions

20. The application of the MRP theory on the production planning, resulted in a reduction of the WIP-level with about 55%, to a level of about EUR 200,000.
21. The model forecasts the waiting times to reduce with 12,5 hours, compared to the current situation of 14 waiting hours in the knitting department. This is somewhat unrealistic and a reduction of 5% (4,65 hours) would be more realistic.

Chapter 7: Implementation plan

In chapter 5 a description of the developed model is given. To implement a new model successful, an implementation plan is written and its outlines are described in this chapter. Which steps have to be overcome to make use of the new model?

Change in working procedures often lead to resistance. So the first hurdle to take is change the way of working for the planner. How can we make sure that the decision maker is going to use the model? In my opinion the best way of managing change is to show participative leadership. Therefore, I tried to involve the production planning department as much as possible during the research. Their opinion is very important and therefore they should have the feeling of being involved in the development of the new planning model. Prevention of resistance against the model is the key for successful implementation. More arguments to convince the planning department are the benefits of the model. The financial benefit is the biggest driver. Next to a reduction in holding cost for inventory a benefit in better service to the customer can lead to a revenue increase. Because the developed model has a longer planning horizon, determination for product manufacturing can be improved.

During my stay with Alnet I collected lots of data and processed this data into the customized production planning in MS Excel. During the last week of my stay, I tried to start off with the implementation. The model is introduced during a presentation to the management committee and planning department. Furthermore, every Friday afternoon a knowledge sharing session is held at Alnet. The second way of introduction was at the last day of presence, the model was introduced to all the employees who were interested in joining the knowledge sharing session.

The second step of implementing the model were a couple of meetings with the planner. I explained what variables should be alternated to use the model successfully. Furthermore I have written a manual if any support is needed to work with the model. The manual is shown in appendix D.

For the final stages of implementation I recommend a stepwise implementation approach to Alnet. Since the period for development was not sufficient to fully implement the model, these guidelines can be used to successfully take the last few hurdles.

- Final validation of the model, starting a pilot at Alnet 80% machine(s)
- Period of use and reporting experiences with the model, careful monitoring of waiting times and WIP-level
- Optimize the model, adapt variables in the model if necessary
- Expand model to agricultural product range
- Expand model to all shade cloths
- Expand model throughout factory, including rope making department

A detailed description on these six steps follow in the coming sections. The model is developed using specification sheets on material composition and usage. These specifications are available for every end product and contain data on the BOM and the amount of raw material used by the knitting machines. Together with the employees of Alnet the parameters on these specifications are checked on correctness. The parameters on the specifications are used as input for the model. The parameters used in the model are averages of the specifications that were found during measurements in the factory.

In literature a lot of research is done on the subject of MRP. Previous research to MRP proved that the concept is effective and drastically reduces waiting times and WIP-levels. Based on that assumption, the expectation is that the model reduces WIP-levels at Alnet as well. To make sure that the model will not disappear in the dust bin it should be validated. The model should be run a couple of times to investigate of all parameters in the model are set correctly.

The next step is to start with a pilot of the model at one of the Alnet 80% Green, to verify if the parameters are set correct. Alnet 80% Green is the most suitable option because this product is almost in continuous production on the knitting machines and therefore very reliable to do a pilot on. If the output of the model is successful and correct, the model can be used to plan production on all the Alnet 80% Green knitting machines. During this period of use experiences should be reported and WIP-levels and waiting times must be measured very precisely. After this pilot the model can be evaluated and outcomes compared to the current performance.

Most probably after the implementation on the Alnet 80% Green experiences with the model give opportunities for improvement. Some ideas for improvements are for example parameters that can be changed, i.e. machines use more or less semi-finished materials, safety stock is different, utilization rate is different, etc. Furthermore, other raw materials can be added to the model, more machines can be added to the model, etc.

Conclusions

23. Once the model is configured correctly and the use is experienced as positive, the model can be expanded to other products as well.
24. Because the programming will take some time it is recommended to do it stepwise.
25. The expansion to the agricultural product range and other shade cloth types is quite easy because the process is similar to a great extent.
26. The expansion to the rope making process involves other machines types, this requires more programming knowledge because the model parts cannot be copied.

Chapter 8: Conclusions & Recommendations

8.1 Conclusions

In the second chapter we formulated the research questions which serve as the foundation of this research. In this chapter we shortly summarize the conclusions as stated in the chapters. These conclusions give an answer to the research questions. In the end, an answer to the main research question is formulated.

RQ 1: "How is the current material requirements planning organized and where are problems arising?"

1. The planning of material flows is currently separated into a raschel- and extrusion planning.
2. At the moment the production planning is updated weekly, the time bucket and the planning horizon are a week.
3. Most apparent error in the planning is that the demand in the extrusion department is calculated by taking the average throughput in the knitting department. It should be dependent on the requirements in warping/stretching departments, which in its turn can be calculated through applying the general planning principles. This error causes wrong products at the wrong time in the buffer between extrusion and warping/stretching and therefore a relatively high WIP position.
4. The current WIP-level is on average about ZAR 4.5 million.
5. The waiting time in the knitting department caused by waiting on materials is currently about 15% of available production time.
6. The problem in the current planning is an incorrect connection between the extrusion and raschel planning. The independent demand is not linked correctly to the dependent demand.

RQ 2: "What does literature describe about solving a material requirement planning in a manufacturing environment?"

7. A material requirements planning is used to prevent controllable variability.
8. By linking the dependent demands to the independent demand, the production needs can be calculated (netting).
9. The demand for components is known as a function of a final product. Therefore the extrusion planning can be derived from requirements for higher level items and should be linked to the raschel planning since it is a sequential production process.
10. The policy to control inventory position can be best described as a (R,S)-policy.
11. The use of two separated production plannings should be avoided. It is confusing and is the source of multiple errors in the production planning. One planning system with equal rules for every department is desirable.
12. The production planning should have a short time bucket in order to create a more flexible planning. A time bucket of a day increases flexibility and clarifies exact timing of requirement for components.
13. The planning frequency used in the planning is dependent on the number of orders coming in for the on-going planning. It would be wise to update the planning twice a week, in quiet times when utilization rates are stable the planning can be updated once a week.
14. The time horizon of the production planning should have at least the length of the sum of the lead times of the involved production departments. Currently the time horizon is only one week, to create a better overview and ability to react on future events the planning horizon should be enlarged to at least two weeks.

RQ 3: "How can the current material requirements planning be improved?"

15. In the customized planning we created a link between all independent- and dependent demands to avoid a built up of unnecessary semi-finished products. This ensures a lower WIP-level and furthermore it takes into account precedence relations. Based on the requirements in the knitting department, the other department have to make sure semi-finished products are available at the right moment in the right quantity, which will decrease waiting times on materials.
16. The planning frequency, time bucket and planning horizon have changed in the customized planning to respectively, twice a week, a day and two weeks. These planning elements have changed to increase the insight in exact requirements of all involved production departments and to enlarge the ability to react on changes in the rolling planning.
17. The planning principles for determining the planned quantity of the current planning are correct and are applied to the customized planning.

RQ 4: "What is the impact of the improved material requirements planning logic?"

18. The application of the MRP theory on the production planning, resulted in a reduction of the WIP-level with about 55%, to a level of about EUR 200,000.
19. The model forecasts the waiting times to reduce with 12,5 hours, compared to the current situation of 14 waiting hours in the knitting department. This is somewhat unrealistic and a reduction of 5% (4,65 hours) would be more realistic.

RQ 5: "How can the improved material requirements planning be implemented to Alnet's situation?"

20. Once the model is configured correctly and the use is experienced as positive, the model can be expanded to other products as well.
21. Because the programming will take some time it is recommended to do it stepwise.
22. The expansion to the agricultural product range and other shade cloth types is quite easy because the process is similar to a great extent.
23. The expansion to the rope making process involves other machines types, this requires more programming knowledge because the model parts cannot be copied.

Main Research Question: "How can Alnet's material requirements planning be designed to make sure that the WIP-level is reduced and the right semi-finished products are manufactured?"

In the problem description it is described that currently a lack of insight in the production requirements is causing a lot of waiting times and a high WIP-level. Taken into consideration all the answers on the sub questions a combination of the answers has lead to the development of a new planning model. In the model a description based on MRP of a single end product is made. The model connects the lower-level items with the end product. The chosen time bucket is 1 day, the time horizon is two weeks and frequency can be once or twice a week. For every level the 5 steps of the MRP concept are executed. This ensures that all semi-finished products are connected to the required end product and it avoids the manufacturing of non-required items. Therefore the WIP-level is expected to decreases to EUR 200,000. Moreover, the waiting times are likely to decrease to an idle time of 5%.

8.2 Recommendations

- <u>Use of similar measurement variables in production planning.</u>

  Currently different measurement variables are used in one system. To simplify and avoid errors similar measurement variables must be used. Sales forecast are displayed in meters/month while the production planning is displayed in weeks. This is confusing, it is easier to convert the sales forecast in a parameter similar to the one used as the time bucket.

Nets are always sold per meter or a multiply of meters. In the factory some departments use kilograms or tons as their quantity, while others measure in meters. This makes it more difficult to compare the results of the different departments. When errors in volumes of products occur it is hard to communicate in between departments. One operator is talking about meters the other operator about tons. A nice change is to change measurement scale to one measurement variable.

- <u>Adapt beam lengths to reduce setup times</u>
  Some products are manufactured almost continuously. Every knitting machine holds three or four beam sets. These beam sets rotate on different speeds, so to manufacture 1 meter of net for example the length of beam set 1 is reduced by 2.25 meter, set 2 by 4.03 meter, set 3 by 2.27 meter and set 4 by 3.89 meter. The change of beams on a knitting machine takes a lot of time. Adapting the distance of monofilament or tape on a beam to the speed of that particular spindle, there can be reached that beams will run out simultaneously. When these beam sets are empty simultaneously they can be changed simultaneously and this will yield shorter set up times. Smart set up of production will reduce the time involved for setting up a machine.
- <u>Investigate the loss of semi-finished products</u>
  In the current model no loss of semi -finished products is included. When a net is manufactured and the beams are nearly empty the machine will be stopped to change the beams. But still a small amount of material is left on the beams. This is thrown away and recycled where possible. When a beam is manufactured out of material from bobbins there is a loss of material as well. A small amount of material is left on the bobbin. To increase the accuracy of the model an investigation should be done on the percentage that is left on either bobbins or beams. When this percentage is known it can be included in the model.
- <u>Expand model to other product ranges</u>
  The model is developed for the agricultural product range within Alnet. Alnet also manufactures other types of shade cloths like rain block or sun block, ropes and fishing nets. The model can be expanded to these products as well. The concept of MRP is clearly explained, only some manufacturing details should be gathered and it can be duplicated to these products as well.
- <u>Connect raw materials to model</u>
  At the moment the model can only be used for the manufacturing side within the factory. To start up the production in the extrusion raw materials are needed from third parties. A link between Alnet's first production process in extrusion and the requirements for raw materials can be added. Very long delivery times from the supplier and the time horizon of this model make it somewhat harder to implement. The raw material (HDPE) is coming from Johannesburg and is transported by truck. The lead time of HDPE is about three weeks, implementation of this requires the planning horizon to be enlarged by at least three weeks. Since Alnet is only a small customer at the supplier of HDPE, they are very dependent on the supplier. A cooperation with the supplier (supply chain integration) to give insight in the exact needs for HDPE might be one of the future researches.
- <u>Perform a study on appropriate safety stock levels</u>
  Currently a rough estimation is made on the level of the safety stock. In the customized planning model some safety stock is installed in between the warping/stretching and knitting department. A further investigation on the safety stock levels could yield either a better utilization of the production machines or some additional decrease of the WIP-level.

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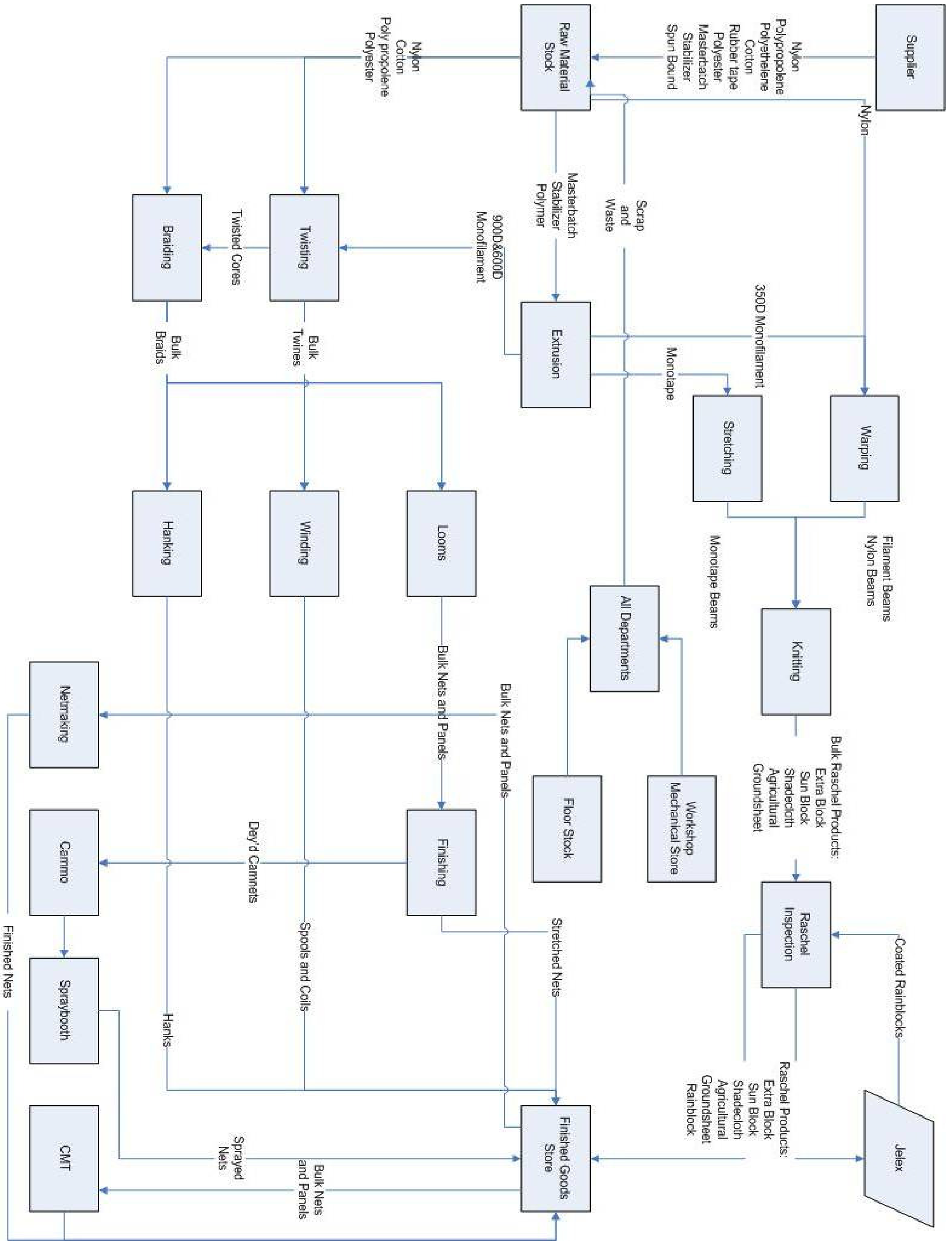
Appendixes

Appendix A – Factory Material Flow



Appendix B – Level of WIP

Date	WIP	Date	WIP	Date	WIP
1-Oct-09	R 4.150.368,23	25-Nov-09	R 4.222.386,39	23-Feb-10	R 4.513.782,14
2-Oct-09	R 4.205.678,43	26-Nov-09	R 4.414.129,19	24-Feb-10	R 4.376.774,19
5-Oct-09	R 4.190.038,23	27-Nov-09	R 4.310.711,62	25-Feb-10	R 4.523.449,51
6-Oct-09	R 4.177.088,64	30-Nov-09	R 4.498.136,09	26-Feb-10	R 4.649.004,84
7-Oct-09	R 4.203.076,02	1-Dec-09	R 4.077.776,15	2-Mar-10	R 4.266.722,50
8-Oct-09	R 4.233.043,11	2-Dec-09	R 4.179.528,47	3-Mar-10	R 4.126.164,05
9-Oct-09	R 4.178.683,00	3-Dec-09	R 4.183.620,16	4-Mar-10	R 4.223.517,09
12-Oct-09	R 4.580.024,69	4-Dec-09	R 4.085.811,67	5-Mar-10	R 4.182.589,86
13-Oct-09	R 4.604.562,95	7-Dec-09	R 4.413.017,75	9-Mar-10	R 4.259.039,36
14-Oct-09	R 4.653.173,00	8-Dec-09	R 4.618.564,75	10-Mar-10	R 4.008.236,81
15-Oct-09	R 4.442.522,32	9-Dec-09	R 4.449.233,09	11-Mar-10	R 4.168.998,17
16-Oct-09	R 4.468.175,50	10-Dec-09	R 4.286.903,18	12-Mar-10	R 4.559.347,33
19-Oct-09	R 4.241.138,55	11-Dec-09	R 4.153.200,00	15-Mar-10	R 4.203.778,02
20-Oct-09	R 4.262.312,19	14-Dec-09	R 4.344.050,93	16-Mar-10	R 4.218.263,77
21-Oct-09	R 4.470.932,00	15-Dec-09	R 4.396.057,72	17-Mar-10	R 4.285.389,38
22-Oct-09	R 4.430.637,99	19-Dec-09	R 4.620.723,92	18-Mar-10	R 4.290.166,64
23-Oct-09	R 4.587.432,05	19-Jan-10	R 4.620.723,92	19-Mar-10	R 4.646.273,90
26-Oct-09	R 4.480.114,52	20-Jan-10	R 4.415.350,82	23-Mar-10	R 4.441.411,91
27-Oct-09	R 4.833.465,09	21-Jan-10	R 4.397.641,36	24-Mar-10	R 4.245.250,26
28-Oct-09	R 4.560.371,61	22-Jan-10	R 4.372.320,11	25-Mar-10	R 4.403.808,58
29-Oct-09	R 4.652.328,92	26-Jan-10	R 4.392.393,06	26-Mar-10	R 4.985.588,76
30-Oct-09	R 4.574.818,87	27-Jan-10	R 4.362.380,87	29-Mar-10	R 4.304.123,22
2-Nov-09	R 4.923.791,60	28-Jan-10	R 4.354.723,09	30-Mar-10	R 3.847.084,34
3-Nov-09	R 4.390.840,60	29-Jan-10	R 4.251.134,15	31-Mar-10	R 3.872.520,00
4-Nov-09	R 4.592.281,64	1-Feb-10	R 4.643.274,48	1-Apr-10	R 3.861.379,68
5-Nov-09	R 4.662.866,84	2-Feb-10	R 4.868.707,69	6-Apr-10	R 4.103.954,35
6-Nov-09	R 4.634.820,07	3-Feb-10	R 4.347.471,38	7-Apr-10	R 7.109.933,96
9-Nov-09	R 4.905.127,26	4-Feb-10	R 4.600.994,29	8-Apr-10	R 7.186.753,92
10-Nov-09	R 4.634.820,07	5-Feb-10	R 4.916.414,50	9-Apr-10	R 7.290.645,04
11-Nov-09	R 4.534.095,06	8-Feb-10	R 5.178.029,15	12-Apr-10	R 7.205.595,33
12-Nov-09	R 4.643.640,35	9-Feb-10	R 5.056.286,69	13-Apr-10	R 4.063.172,23
13-Nov-09	R 4.493.942,01	10-Feb-10	R 4.577.872,40	15-Apr-10	R 3.941.191,69
16-Nov-09	R 4.605.460,69	11-Feb-10	R 4.402.697,68	16-Apr-10	R 4.608.227,35
17-Nov-09	R 4.471.329,49	15-Feb-10	R 4.613.929,26	19-Apr-10	R 4.488.240,36
18-Nov-09	R 4.625.919,39	16-Feb-10	R 4.934.278,00	20-Apr-10	R 4.453.772,40
19-Nov-09	R 4.593.004,46	17-Feb-10	R 4.392.246,03	21-Apr-10	R 4.457.317,24
20-Nov-09	R 5.006.580,37	18-Feb-10	R 4.367.814,80	22-Apr-10	R 4.698.215,61
23-Nov-09	R 5.601.696,03	19-Feb-10	R 4.357.872,19	26-Apr-10	R 4.916.583,46
24-Nov-09	R 4.240.217,39	22-Feb-10	R 4.334.310,03	29-Apr-10	R 5.055.466,84
				3-May-10	R 4.981.508,19
Average WIP		**R 4.548.952,36**			

Appendix C – MRP Model for Alnet

Machine Speed	rpm	450
Courses/cm		5,5
Utilisation	%	0,7
Machine Throughput	m/hr	34,4
	m/day	636

Line speed (m/h)	183,9	run inn/m	2,25
	329,7	Line	4,03
	185,5		2,27
	318,6		3,89

Alnet 80%		**wk**								
		44	45	46	47	48	49	50	51	52
Sales forecast		14159	14159	14159	14159	11064	9000	9000	9000	9000
Customer Orders		6000	3500	7000	3500	0	1000	1500	1000	1000
Project Available	15000	13913	15325	10060	8294	9945	12659	14874	17588	17124
Safety stock		10000	10000	10000	10000	10000	10000	10000	10000	10000
Required production		20159	17659	21159	17659	12770	10055	10500	10000	10000
# days production		32	28	33	28	20	16	17	16	16
MPS		19072	19072	15893	15893	12715	12715	12715	12715	9536

Warping Light Green	Beamlength	37000													
Gross Requirements		1429	1429	1429	1429	1429	0	0	1429	1429	1429	1429	1429	0	0
Scheduled Receipts		0	0	0	0	0	0	0	0	0	0	0	0	0	0
Project on-hand															
Machine 1	37000	35571	34142	32713	31284	29855	29855	29855	28426	26997	25568	24139	22710	22710	22710
Machine 11	5000	3571	2142	713	-716	34855	34855	34855	33426	31997	30568	29139	27710	27710	27710
Machine 16	25000	23571	22142	20713	19284	17855	17855	17855	16426	14997	13568	12139	10710	10710	10710
Machine 24	13000	11571	10142	8713	7284	5855	5855	5855	4426	2997	1568	139	-1290	35710	35710
Machine 27	10000	8571	7142	5713	4284	2855	2855	2855	1426	-3	35568	34139	32710	32710	32710
Net requirements		0	0	0	3	0	0	0	0	3	0	0	3	0	0
Floor stock	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Planned order receipts		0	0	0	3	0	0	0	0	3	0	0	3	0	0
Planned order releases		0	0	3	0	0	0	0	3	0	0	3	0	0	0
Safety stock	3														

Warping Black 1	Beamlength	37000													
Gross Requirements		2561	2561	2561	2561	2561	0	0	2561	2561	2561	2561	2561	0	0
Scheduled Receipts		0	0	0	0	0	0	0	0	0	0	0	0	0	0
Project on-hand															
Machine 1	5000	2439	-123	34316	31754	29193	29193	29193	26631	24070	21508	18947	16385	16385	16385
Machine 11	4000	1439	-1123	33316	30754	28193	28193	28193	25631	23070	20508	17947	15385	15385	15385
Machine 16	26000	23439	20877	18316	15754	13193	13193	13193	10631	8070	5508	2947	385	385	385
Machine 24	20000	17439	14877	12316	9754	7193	7193	7193	4631	2070	-492	33947	31385	31385	31385
Machine 27	10000	7439	4877	2316	-246	34193	34193	34193	31631	29070	26508	23947	21385	21385	21385
Net requirements		0	6	0	3	0	0	0	0	0	3	0	0	0	0
Floor stock	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Planned order receipts		0	6	0	3	0	0	0	0	0	3	0	0	0	0
Planned order releases		6	0	3	0	0	0	0	0	3	0	0	0	0	0
Safety stock	3														

Warping Black 2	Beamlength	37000													
Gross Requirements		1441	1441	1441	1441	1441	0	0	1441	1441	1441	1441	1441	0	0
Scheduled Receipts		0	0	0	0	0	0	0	0	0	0	0	0	0	0
Project on-hand															
Machine 1	5000	3559	2118	676	-765	34794	34794	34794	33353	31911	30470	29029	27588	27588	27588
Machine 11	4000	2559	1118	-324	35235	33794	33794	33794	32353	30911	29470	28029	26588	26588	26588
Machine 16	26000	24559	23118	21676	20235	18794	18794	18794	17353	15911	14470	13029	11588	11588	11588
Machine 24	20000	18559	17118	15676	14235	12794	12794	12794	11353	9911	8470	7029	5588	5588	5588
Machine 27	10000	8559	7118	5676	4235	2794	2794	2794	1353	-89	35470	34029	32588	32588	32588
Net requirements		0	0	3	3	0	0	0	0	3	0	0	0	0	0
Floor stock	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Planned order receipts		0	0	3	3	0	0	0	0	3	0	0	0	0	0
Planned order releases		0	3	3	0	0	0	0	3	0	0	0	0	0	0
Safety stock	3														

Dark Gr Tape	Beamlength	27000													
Gross Requirements		2476	2476	2476	2476	2476	0	0	2476	2476	2476	2476	2476	0	0
Scheduled Receipts		0	0	0	0	0	0	0	0	0	0	0	0	0	0
Project on-hand															
Machine 1	5000	2524	49	-2427	22097	19621	19621	19621	17146	14670	12194	9718	7243	7243	7243
Machine 11	4000	1524	-951	23573	21097	18621	18621	18621	16146	13670	11194	8718	6243	6243	6243
Machine 16	26000	23524	21049	18573	16097	13621	13621	13621	11146	8670	6194	3718	1243	1243	1243
Machine 24	20000	17524	15049	12573	10097	7621	7621	7621	5146	2670	194	-2282	22243	22243	22243
Machine 27	10000	7524	5049	2573	97	-2379	24621	24621	22146	19670	17194	14718	12243	12243	12243
Net requirements		0	3	3	0	3	0	0	0	0	0	3	0	0	0
Floor stock	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Planned order receipts		0	3	3	0	3	0	0	0	0	0	3	0	0	0
Planned order releases		3	3	0	3	0	0	0	0	0	3	0	0	0	0
Safety stock	3														

Extrusion Mono															
Gross Requirements	Light Green	0	0	750	0	0	0	0	750	0	0	750	0	0	0
Scheduled Receipts		0	0	0	0	0	0	0	0	1250	0	0	0	0	0
Floor stock	8000	8000	8000	7250	7250	7250	7250	7250	7000	8250	8250	7500	7500	7500	7500
Planned order receipts		0	0	0	0	0	0	0	500	0	0	0	0	0	0
Planned order releases		0	0	0	0	0	0	500	0	0	0	0	0	0	0
Safety stock	7000														

Extrusion Mono															
Gross Requirements	Black	1500	750	1500	0	0	0	0	750	750	0	0	0	0	0
Scheduled Receipts		0	0	0	0	0	0	0	0	0	0	0	0	0	0
Floor stock	6000	4500	3750	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500
Planned order receipts		0	0	1250	0	0	0	0	750	750	0	0	0	0	0
Planned order releases		0	1250	0	0	0	0	750	750	0	0	0	0	0	0
Safety stock	3500														

Extrusion Tape															
Gross Requirements	Dark Green	435	435	0	435	0	0	0	0	0	435	0	0	0	0
Scheduled Receipts		1305	0	0	0	0	0	0	0	0	0	0	0	0	0
Floor stock	2000	2870	2435	2435	2000	2000	2000	2000	2000	2000	1565	1565	1565	1565	1565
Planned order receipts		0	0	0	0	0	0	0	0	0	0	0	0	0	0
Planned order releases		0	0	0	0	0	0	0	0	0	0	0	0	0	0
Safety stock	1500														

Appendix D – MRP Manual

This is the model that is more like a theoretical example but can be used quiet easily. It is for the Alnet 80 Premium. I programmed it for the use of full beams. But the beam length can be adapted when you decide to use the simultaneous run out schedule.

Every Friday a measurement of all the beam lengths on the machines must be taken. In order to make the planning for the next week. When there is known how many meters on the beams are left we can forecast when the beams will be empty in the week we are making the plan for. Using this forecast we can set up a production plan for Premium 80%.

In the first rows of the model the machine speed, utilization and courses/cm. These numbers will influence the usage. And thereby influence the forecast.

The yellow line with "scheduled receipts" corresponds with your planned beams. The net requirements will be calculated based on the knitting needs. When there is floor stock it will be subtracted from this and the safety stock will be taken into consideration. If there is a shortage according to the plan a planned order receipt will be developed. Because it is needed on for example Wednesday in knitting it should be produced at last on Tuesday by warping. So therefore "planned order release" is always one day before.

The planner has to fill in manually the yellow line to plan a production batch. Important is to create combined batches, to avoid set up times. So when there is a planned order receipt on Wednesday and Friday it is better to combine these and make one bigger batch on Wednesday. If the planned line is filled in the demand in "planned order receipt" and "planned order release" will disappear. This is because your stock will be filled up with your scheduled receipts.

Based on the needs of warping and stretching the number of available kilograms in the RMS can be reviewed. If needed a batch of a certain quality of mono or tape can be set up. The model will give you an overview when a shortage of material will occur. It only doesn't take into account that a batch size has to be at least "x" kilograms or doffs.

The model will prevent that machines have to wait on materials because it gives insight in the specific needs of every single machine. It is important that the beam lines are running at a constant rate because otherwise the forecast of the material usage will be wrong. I tested this a few times and now I got a reliable average for this quality. I hope you will enjoy the model!