Master’s degree thesis

LOG950 Logistics

Production planning and inventory management with capacity limitations at Wonderland AS

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Preface

This master’s thesis research has been the last project of a two-year-long exciting journey as MSc students in Supply Chain Management and Operations Management at Molde University College. It was performed during the winter and spring of 2018.

The research was conducted based on a close collaboration with Wonderland AS. The project gave us an understanding of how theoretical knowledge can be applied in practice. Production planning and inventory control are the central issues in the supply chain management and operations research. We have learned that the application of scientific methods in operations management is a powerful tool for companies to use in order to remain competitive in the marketplace.

We would like to thank former Wonderland AS CEO Jon Daniel Nesje for assigning us to the project in the summer of 2017. We appreciate the great help and time given to us by Factory Manager Håvard Fanum and Data&Calculations Manager Jan Bråten at Wonderland during our work on this thesis. Finally, a big “thank you” to our supervisor, Associate Professor Arild Hoff at Molde University College, for his guidance, dedication and effort he put in helping us throughout this research.

Molde, May 2018

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Summary

In order to gain a competitive advantage in the global marketplace, a company should perform better than their competitors. A top-down approach should be used in order to link a company's strategic goals to its operations. The Norwegian furniture manufacturer Wonderland AS has identified challenges to remain competitive when using a make-to-stock production strategy due to the capital tied up in the finished goods inventory. A need to transform the production process and the inventory management with respect to the capacity limitations has become a reality.

The purpose of the thesis is investigate the current situation and to develop efficient production planning and inventory control tools for the components. This with respect to capacity limitations in order to meet customers' demand in the context of the production strategy transformation.

Literature studies in such areas as supply chain management as production planning, inventory control and capacity utilization were made. The empirical study was based on the information provided by Wonderland. Several meetings and continuous dialog with Wonderland contributed to the effective research development.

Seasonal demand patterns for components were detected and a forecast of the demand was made. Two production sections of components were studied. A customized ABC-grouping and analysis of components were conducted and different production strategies were applied to A, B and C groups with an assessment of the available and required capacity.

The results include an inventory control policy dealing with the seasonal demand pattern, capacity limitations and the service level requirements. The authors came up with suggestions for the capacity adjustments in order to proceed with the production strategy transformation.

Contents

1.0 Introduction

The goal of this chapter is to present the company with its business environment and products, the research problem, the purpose of the thesis and the limitations.

1.1 The Background Issues

The competitive customer landscape pushes for faster lead times, flexibility and better quality combined with lower costs. Internationalization of trade has influenced even small companies to improve their competitiveness in the global marketplace. The capability to adjust to changes in demand balancing between excessive inventory and shortages is the focus of modern manufacturing planning and control systems (Vollmann, et al., 2005).

Sharma (2008) states that a decision making process in business environments become more and more complicated. Large input data requires a systematic approach and scientific methods in both day-to-day and strategic decisions. Operations Research (OR) techniques can be used as a supporting tool in order to enhance the quality of those decisions.

Operations Research tries to secure improvements in social systems through the application of scientific methods. OR studies deal with the three-way relationship between decision makers, beneficiaries and the operations researcher (Churchman, 1970).

The Operations Research methodology according to Bertrand & Fransoo (2002) deals mainly with modeling of real-life problems and has the goal of implementing obtained solutions.

1.2 Presentation of Wonderland AS

Wonderland AS is a furniture producing company, which is located in Åndalsnes, Møre and Romsdal County in the western part of Norway. Figure 1 shows the location of the factory and the head office.

Figure 1. Wonderland’s location (http://www.wonderlandbeds.com/, n.d.).

It has only one factory with 98 employees and an operating income of about 273 million NOK in fiscal year 2016. (Eniro Holding AS, n.d.)

Wonderland started their operations in 1969 as a company called "Westnofa". Since then Wonderland has become "one of Scandinavia's leading manufacturers of beds and mattresses" (Wonderland Beds, n.d.). Westnofa was established by Stokke Fabrikker AS as one of seven factories in Norway, with the aim to reach new markets and purchase competitors (Stokke Industri AS, n.d.). Wonderland was established as a department in Westnofa at this time. (Aandalsnes avis, n.d.) At the beginning, the production of Westnofa was focused on making simple foam for the furniture industry, but in the early 2000’s the company started to concentrate their activities on adjustable beds in order to deliver more customized solutions. Since then Wonderland delivers high quality "personalized beds and mattresses" (Wonderland Beds, n.d.). In 1996 Wonderland expanded the market to reach more than Norwegian customers and opened their first sales office abroad, in Sweden (Wonderland Beds, n.d.).

Wonderland delivers its products to their customers via three business areas: stores and retailers with a network of sales points in Scandinavia and several other countries in Europe, hotels with the requirement for quality solutions and the offshore and marine sector with focus on quality (Eniro Holding AS, n.d.) (Wonderland Beds, n.d.).

Wonderland is a member of the so-called furniture industry cluster in Møre and Romsdal. 83 companies with 3618 employees, both manufacturers and suppliers, were part of this cluster in 2017 (http://www.norwegianrooms.com/). The companies within the cluster are connected through mutual relationships and cooperation. Transparency, trust and the pursuit of an overarching strategy are requirements for membership. The cooperation and loose relationships within the cluster give the individual companies access to new technologies and new procedures. The close cooperation brings together companies that normally compete with each other in the marketplace (Norwegian Rooms AS, n.d.).

Those 83 companies have built a common value chain with about 50% of the furniture market share in Norway. The largest and most profitable furniture manufacturers, such as Ekornes, Stokke, HÅG/RH/RBM Group, Westnofa/Recticel and Wonderland have developed their own concepts of brand building, based on a tailored value chain (Oterhals & Johannessen, 2009).

The furniture manufacturers from Møre and Romsdal reach their customers through a network of retailers, such as Møbelringen, Bohus and Skeidar for the Norwegian domestic market, and a network of independent vendors in the rest of Scandinavia and Europe (Oterhals & Johannessen, 2009). Figure 2 presents the network of retailers.

Figure 2. The network of Wonderland's retailers (http://www.wonderlandbeds.com/, n.d.).

Wonderland offers the following products, presented in Figure 3: continental beds, adjustable beds, box-spring and reversible mattresses. The customers can choose between latex and welun filling, and four different firmness settings: soft, medium, firm and extra firm. The offered bed sizes are: 90x200, 90x210, 105x210, 180x200, 180x210 and 210x210. All beds are available in 19 colors (Wonderland Beds, n.d.). This accounts for 3648 possible combinations.

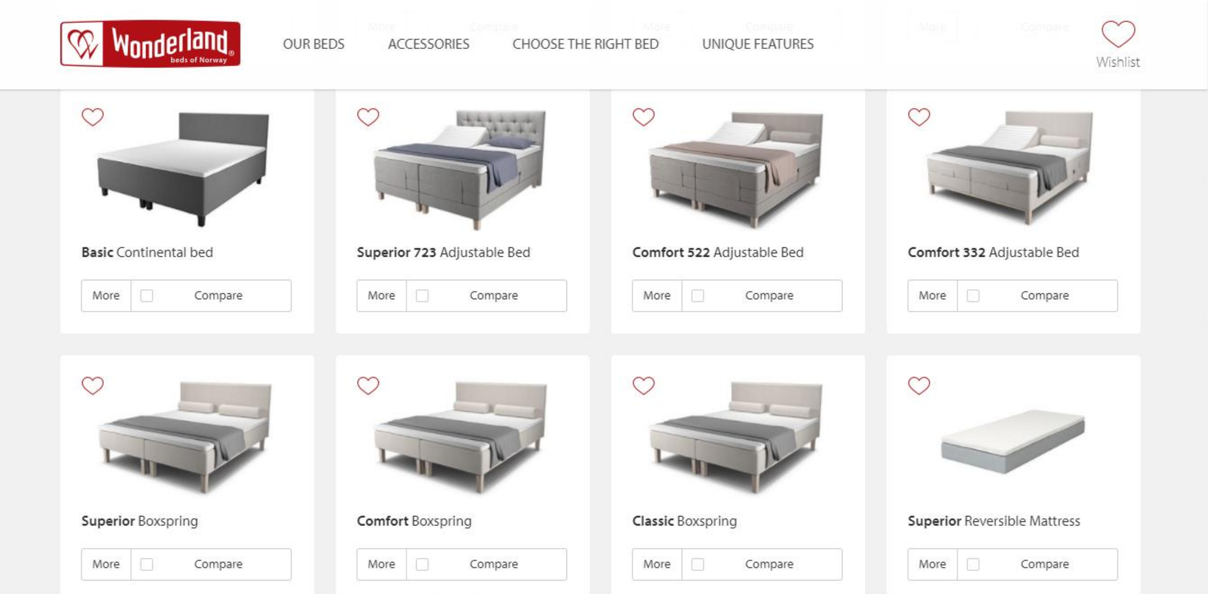


Figure 3. An example of Wonderland’s products (http://www.wonderlandbeds.com/, n.d.).

The following description of the production flow at Wonderland is based on an interview carried out at Wonderland’s head office.

The production area at Wonderland is divided into three major parts. Figure 4 shows the graphical representation of the manufacturing area at the company. The first section is the mold production section (1), the second area is the cutting and runstitching section (2) and the third section is the assembly section (3).

Wonderland wants to focus on the most critical processes for molds and cover production and in consultation with Wonderland it was decided to limit the project to the area of the self-produced components within its production planning and inventory management. Therefore, only the mold production section (1) and the cover production section (2) will be treated in the thesis.

The assembly section at Wonderland consists of three work stations with one worker per each station. Molds from the production area will be moved to the assembly station, then a cover according to the order will be put on. It takes on average five minutes to assemble one end-product resulting in that 12 of them are assembled per hour at one work station. The output of the assemble section equals to 36 end-products per hour or 279 per working day of 7,75 hours duration. A most typical end-product consists of 4 mattresses: 2 on the bottom and 2 main mattresses on the top, but such type of the end-product as a box-spring may consist only of one mattress. In order to make a capacity analysis of the assembly section, sales data for the end-products and their bill of materials is required. The assembly section, according to Wonderland, does not represent a bottleneck in the production process.

In section 1, one machine for the cutting of foam is placed with one supervising worker. Section 2 has space for nine machines/workers. Section 3 has three manual stations with one worker each. The description of the production flow at Wonderland is based on information given to us during our factory visits.

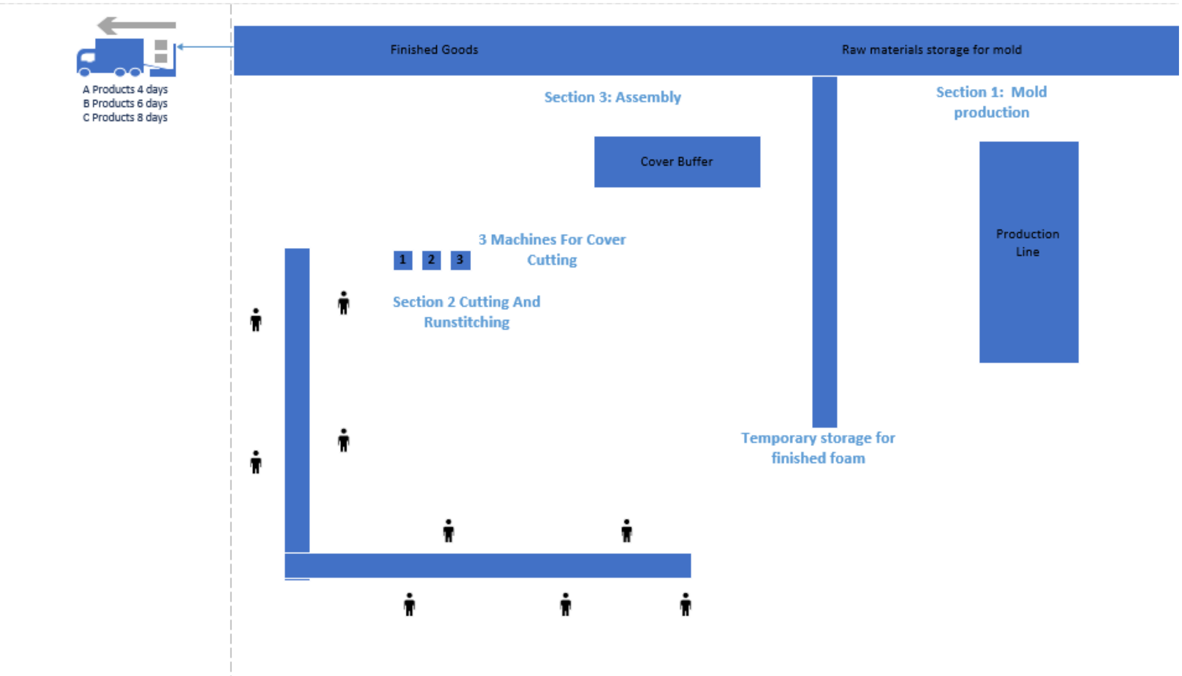


Figure 4. Production flow at Wonderland.

Currently the manufacturing process follows a make-to-stock production strategy. Most of the products are produced based on a historical data forecast, using methods, which rely on subjective assessments. Finished products are moved to the Finished Goods Inventory (FGI) rented storage, which is located just a hundred meters from the production facilities. Storage is about 500 square meters and 5 meters high. Wonderland experiences challenges with the capital tied up in FGI. The need for capital infusions became a reality and a group of new investors entered the company in 2017. The decision for a complete production process transformation was made. Wonderland has the goal of removing FGI storage by the year 2020.

The manufacturing process begins in section 1 with the production of foam and feather boxes or "molds". The finished molds are temporarily stored in a small storage area between sections 1, 2 and 3. This area can be regarded as a subassembly stock. The cutting of fabrics for the cover in section 2 occurs automatically on one of the three machines and in the current solution will not start before the foam is finished in section 1. Wonderland uses carts to move the covers between section 2 and the assembly area. The carts are attached to rails that are fixed above the work area and build as a kind of net over the production area. At the beginning of the cutting and runstitching process, the order is scanned and matched with cut parts needed for this order. The worker attaches the ID-number of the order to the cart containing the needed cut parts of the fabric. It gives them visibility of the status and the location of the order. After the cover is finished, the components are assembled in the assembly section (3).

Wonderland's production is aimed against two sales campaigns per year: in January and in August. The main sales channel is, as mentioned before, the network of retailers on the Norwegian market. The consequence of this sales strategy is a seasonal demand pattern, which causes challenges in adjusting production to the available capacity. The stock is built up during the year in order to be able to deliver the products in sales periods.

The total production of molds has amounted to 97.567 items in 2016 and 88.867 items in 2017. The total production of covers has amounted to 67.881 items in 2016 and 70.206 items in 2017. A full bed can consist of several combinations of molds and covers where a cover can be used on more than one mold. Thus, the total demand for molds are typically larger than the demand for covers.

1.3 Problem definition

Our research project was initiated by Wonderland AS. The company recognized the need for change in its production strategy due to the high level of capital tied in its finished goods inventory. The underlying reason of the current situation is a mismatch between a make-to-stock production approach and fluctuations in customers demand. This thesis is a part of an overall project with which Wonderland wants to transform its inventory control and production strategy by 2020. The focus is to find solutions to respond to the variations in the demand with a high level of service, preventing lost sales and avoiding eventual backorders. Flexibility and responsiveness should be achieved in accordance with the capacity capabilities. The amount of capital tied up in the FGI should be reduced.

1.4 The purpose of this thesis

The main question this thesis tries to answer is: How much potential is there for the Wonderland manufacturing process to be adjusted in a more efficient way? Practical recommendations should be given in the form of specific tools for manufacturing planning and inventory control with respect to capacity requirements.

1.5 Research questions

This thesis consists of the following research questions:

1. How can production planning and inventory control be linked with a new production approach with respect to variations in demand and customer service level requirements?

In order to maintain an appropriate customer service level in connection with a new production concept a customized production planning and inventory control approach will be presented.

2. How can available manpower, machines, storage capacity and a new production strategy be adjusted to each other?

An analysis of available and required capacity will be presented. A production plan that allows meeting demand requirements efficiently will be developed.

1.6 Limitations

The research problem would be much more complex if upstream and downstream material flows would be taken into consideration. The focus will therefore be only on internal production activities, i.e. assuming raw materials to be present. The relationships between Wonderland and its retailers in terms of joint marketing campaigns, which influence the level of the demand, will be out of the scope of this research.

Sales data was collected for 2016 and 2017. Due to the implementation of an ERP system at the end of 2017, data for December 2017 was missing and could not be obtained. After consultation with Wonderland it was decided to use data identical to December 2016 for December 2017. It was considered appropriate due to seasonal demand pattern since December 2016 has similar number of working days due to the Christmas holidays.

1.7 Thesis disposition

Chapter 1 (Introduction) gives the description of the company, the problem definition, the purpose of the thesis, research questions and limitations.

Chapter 2 (Theoretical Framework) gives an overview of the most relevant theoretical issues in supply chain management and operations research.

Chapter 3 (Methodical Framework) gives an overview of the existing research philosophy, research purpose, research method, research approach, research strategy and the research types, the data gathering issues and research quality criteria.

Chapter 4 (Empirical Framework) describes the empirical investigation which has been carried out in the frame of theoretical concepts.

Chapter 5 (Conclusion and Recommendations) includes conclusions and practical recommendations for Wonderland AS.

Chapter 6 (Further research opportunity) will give an indication about area for further research.

2.0 THEORETICAL BACKGROUND

This chapter gives an overview of our most relevant literature topics, which constitutes the framework of this research. Operations strategy, manufacturing planning and control theory, inventory control and production management methods will be introduced.

2.1 The strategy

A company formulates the aims and the way to achieve those objectives in its business strategy. The business strategy includes the market with the aimed customers, investment level, allocation of resources and the functional strategy with the marketing, financial and operations strategy. The operations strategy defines the use of resources to obtain the overall set aim. Production enterprises have to specify how the products will be manufactured (internal processes, needed employees) and distributed, as well as what type and size of inventory is needed (Nahmias, 2009).

The operations strategy is directed towards time horizon, focus, evaluation and consistency (Bozarth & Chapman, 1996).

The first aspect is the time horizon with three time components: short, medium and long term. A time horizon can be defined as time needed for the chosen strategy to show hoped-for effects. Short time changes of the operations strategy (impact on the activity measured in hours or days) can be achieved within the purchasing strategy, the production-, workforce planning and controlling of inventory as well as quality. Medium-term changes (impact on the activity measured in weeks or months) can be achieved via demand forecast, workforce size planning and decision-making on inventory and service level. The long time components are decisions on new facilities and their locations. It is important to emphasize that every aspect in the time horizon decision-making is characterized by risk, possible negative consequences and uncertainty of choices. The focus in the operations strategy is directed on "process technologies, market demands with price, lead time and reliability, product volumes, quality level and manufacturing task". The demand of the market dictates on which products the companies have to focus. The lead-time is crucial for a manufacturer to be able to compete on the market. The key concern of product volumes is to plan the activities within facilities in such a way as to avoid idle time or overutilization of resources. Companies with a production of several different articles should be able to manage the manufacturing task in order to avoid regular setups and changes in the production processes (Nahmias, 2009).

Wonderland formulated the aim to substitute the make-to-stock production strategy by different production strategies depending on demand classes of different products in order to meet customers demand and stay competitive on the market. The goal to reduce the amount of tied-up capital in the Finished Goods Inventory should be achieved by implementing those production strategies. A FGI storage which Wonderland rents now will be replaced by the FGI storage constructed by the year 2020.

Operational planning is responsible for the determining of resource constraints and their availability (Nicholas, 1998). The purpose is to find the best possible production plan for the competing production steps and the production plan within the steps at the same time (King, 1975).

Wonderland has limited capacity in production (machines), storage and workforce. The goal is to utilize available capacity in efficient way in order to meet customers demand and to retain competitive. The outcome of this research should indicate if there is a need of a capacity adjustment.

One of the most important criteria to succeed in the marketplace and to keep or win market share is time to market. The first company on the market is the order winner. The concept of time-based competition (TBC) is closely related to the time-to-market principle (Nahmias, 2009). The main idea of the time-based-competition concept is to reduce the time of crucial processes and thus to reduce the cycle time as well. The implementation of the plan needed for this concept can lead to an enhanced market position, flexibility and lower costs (Bozarth & Chapman, 1996).

It is crucial for Wonderland to meet time requirements due to competition from other companies in the furniture cluster. Wonderland is committed to deliver specific products to the retailers within pre-specified lead times.

As mentioned above, Wonderland is part of the furniture cluster in Møre and Romsdal with close relationships to its competitors. One of the major competitors in the region and on the Norwegian market is Ekornes Beds AS with the SVANE beds brand and a portfolio - of products, which is very similar to Wonderland's. Figure 5 shows the Ekornes product range under the SVANE trademark.

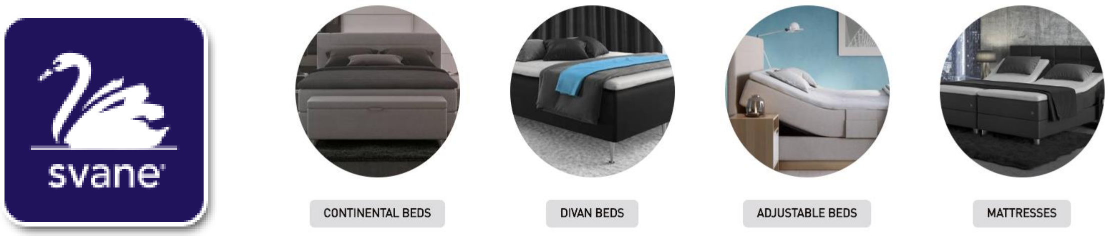


Figure 5. The Ekornes' product range under the SVANE trademark (http://svanebeds.com/us, n.d.).

Both Wonderland and Ekornes belong to the furniture cluster and benefit from it, but they are competitors in the every-day business and fight for the same customers and market share. Ekornes characterizes its own products as innovative and unique (Ekornes ASA, 2018). Ekornes Beds AS employed 79 workers and had an operating income of about 265 million NOK in fiscal year 2016 (Eniro Holding AS, n.d.) (273 million NOK for Wonderland in the same year).

Wonderland itself defines two brands as their main competitors: JENSEN (beds from the Swedish company Hilding Anders) and SVANE – in addition to many foreign private producers.

Changes in the business strategy should not be excluded. The possible change of the strategy includes qualitative and quantitative objectives that have to be formulated and be clear for the company before the changes start (Eversheim, et al., 1997).

It is crucial for Wonderland to comply with deliverability in order to remain competitive on the market and retain market share. Transformation of the production strategy should strengthen their ability to meet the industry-specific delivery lead times.

2.2 Manufacturing environments

Planning and control in production is based on the management of customer demand. It should be adjusted to the company's strategy, production capacity and its customers' requirements. The base for the manufacturing environments classification is the customer order decoupling point (CODP). The customer order decoupling point in different manufacturing environments is presented in Figure 6 (Vollmann, et al., 2005).

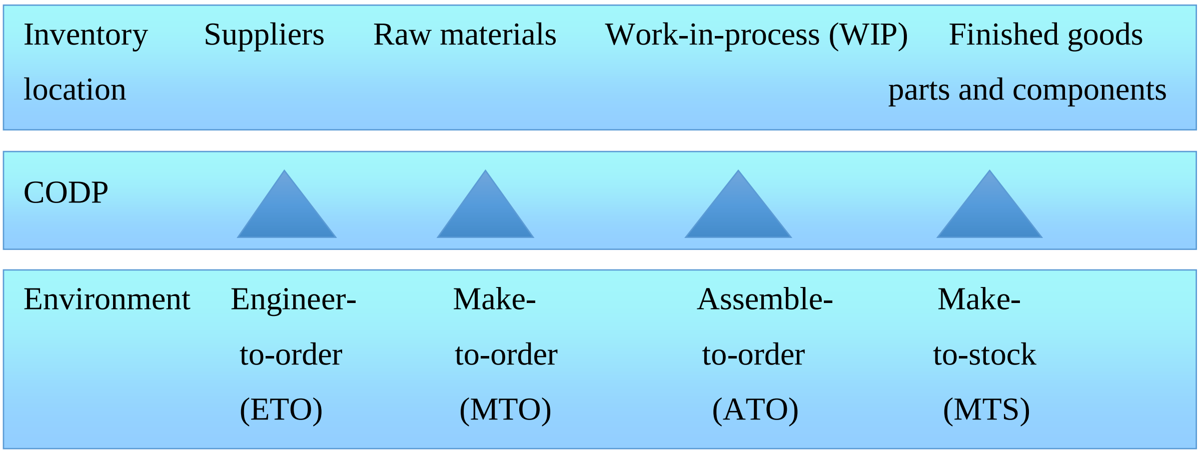


Figure 6. CODP in four production environments

Make-to-stock (MTS), Assemble or finish-to-order (ATO), Make-to-order (MTO) and Engineer-to-order (ETO) are typical production strategies for a production company. Every strategy needs a buffer barrier to deal with the unsure, changing demand. Inventory and capacity are typical buffer barriers in the production. Capacity is achieved by using the concepts of flexible workforce and flexibility of processes. The main idea of inventory with planned safety stock is to secure both the dependent demand as well as the independent demand. The size of inventory and safety stock depends on the company's requirement on service levels and the willingness to tie the capital into it (Bozarth & Chapman, 1996).

2.2.1 The Make-to-Stock (MTS) Environment

The make-to-stock environment (MTS) has the latest CODP (Customer Order Decoupling Point), which shows when the customer order enters the system. In this type of manufacturing environment the production is based on the demand forecast and not on actual demand (Kolisch, 2001). The customers purchase goods from the FGI (Finished Goods Inventory) and whether an item is available or not determines customer service. The most important issue here is to find the balance between FGI levels and customer service levels (Vollmann, et al., 2005). The problem with using an MTS manufacturing strategy is that the amount of finished goods can exceed the actual demand on one product, while on other products with higher demand than predicted, the stock is short. A large stock of finished goods ties up money and space capacity (Cox & Schleier, 2010). The capital tied up in inventories should be monitored (Axsäter, 2000). The money tied up in inventory could be used differently and this is the opportunity cost or the cost of capital.

The inventory holding cost is the sum of the cost of capital and the cost of keeping items on hand: storage, handling, insurance, taxes and shrinkage costs (Krajewski, et al., 2016). The usual form to evaluate the financial situation of a company is the ROI (Return on investment), which "is simply the ratio of the profit realized by a particular operation over the investment made in that operation" and the best way to enhance ROI is to increase the profit or decrease the investment (Nahmias, 2009).

Wonderland realized that it could be an advantage to not only follow the MTS production strategy due to the frequent mismatch with customer's demand resulting in sufficient finished goods obsolescence and over-dimensioned capital investments. In the situation with stochastic demand one should consider the trade-off between the size of FGI and the service level objective. Wonderland recognized the need for different strategies for different groups of products as to decrease capital investments – while ensuring smooth capacity utilization, increasing flexibility and responsiveness.

2.2.2 The Assemble-to-Order (ATO) Environment

Assemble-to-Order (ATO) means that the standard components are used to put together a unique end product. Crucial components, subassemblies and materials need to be on stock and prepared for incoming customer orders, but the final assembly is postponed until the order for a specific item is received by the company (Kolisch, 2001). In an ATO production environment it is advantageous to define the customer orders in terms of different components and options. Companies can gain from moving the CODP from finished products to components. If N_i is the number of alternatives for component i, then the total number of combinations for n components is: $N_1 * N_2 * \ldots * N_n$. (Vollmann, et al., 2005).

Wonderland decided, among other things, to set up a buffer for subassembly inventories in order to move the CODP from FGI for a part of the components.

2.2.3 The Make-to-Order (MTO) Environment

In the make-to-order (MTO) strategy, the manufacturers wait until the customer order is placed (Kolisch R., 2001). In make-to-order environments producers are not as sure about demand than in MTS and ATO environments (Vollmann, et al., 2005).

Production of products with low demand rate or customized products will benefit from moving the CODP from FGI to raw materials inventory. Wonderland assumes that there is a proportion of their products which can follow the MTO production strategy.

2.2.4 The Engineer-to-Order (ETO) / Design-to-Order (DTO) Environments

On the other end of the scale from MTS is the engineer-to-order (ETO) strategy. The supplier has to provide engineering work to be able to deliver the customized order according to the customer's expectation. The final product is often unique (Kolisch, 2001). The term "customized" describes products which require design activities for non-standard customer orders with non-standard requirements (Schönsleben, et al., 2017).

These strategies can be relevant for Wonderland in cases where an offshore customer or hotel orders non-standard products, but it is a rare situation and will not be considered in this research.

2.2.5 Manufacturing environments versus lead time

Customers have some considerations on the acceptable lead times for different categories of products. On the market place with high competition, it may be advantageous to offer availability or short lead time to customers. However, trade-offs between short lead times and investments in capabilities to obtain short lead times must be evaluated.

Short lead times attract customers, but lead to greater probability of tardiness in production. Longer lead times are less difficult to fulfil, but customers may choose competitors. A good lead time policy is to balance these two alternatives (Slotnick & Sobel, 2005).

One of the most important tasks in the operations function is "delivery reliability or on-time delivery (OTD)", otherwise the companies could face lost sales or even total loss of customers and markets. OTD can be seen here as the order qualifier. The delivery of products according to customer wishes and time-expectations is faster than the market competition. To examine if the order fulfilment is possible, companies have to relay on production (work-in progress, capacity issues) and inventory (finished items). The key point of order winning is to be able to synchronize the operations lead time (OLT) with the customers' lead time expectations. OLT can be described as a sum of the process lead time and the backorders. Figure 7 shows the graphical illustration of the OTL concept (Hill & Hill, 2009).

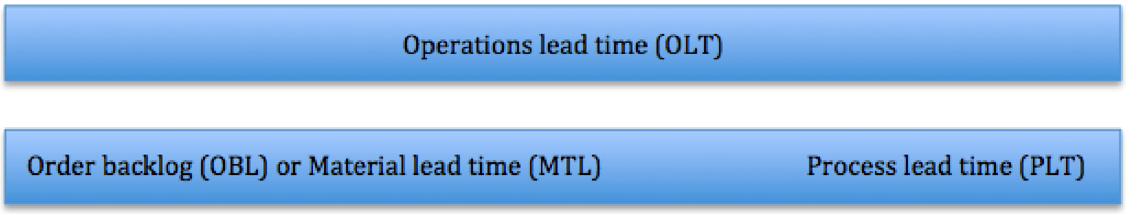


Figure 7. The graphical illustration of the OLT concept (Hill & Hill, 2009).

Companies have to be able to react to different possibilities that can occur between the customers' expected delivery time and the company's operations lead time. When the customers' expected delivery time is shorter, than the operations lead time (as Figure 8 shows) some procedures have to be implemented: adding flexible capacity in form of overtime or extra shift; rescheduling of the production processes: changes in the priorities of jobs, which job should be finished in time and which need to account for backorders; changing the production strategy from MTO to ATO (work-in-progress) or to MTS (inventory of end-products); a more flexible supply chain (Hill & Hill, 2009).

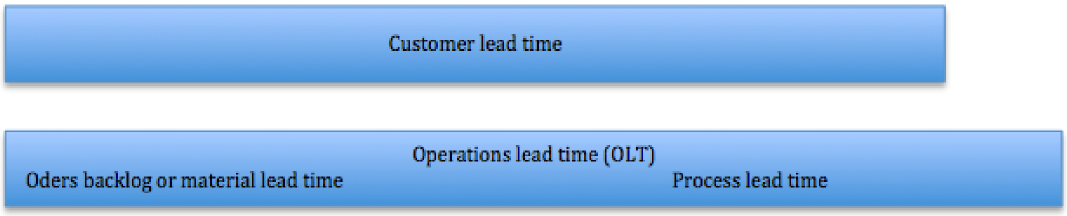


Figure 8. Production situation when customers' expected delivery time is shorter than operations lead time (Hill & Hill, 2009).

The following situation, i.e. when the customer's expected delivery time is longer then the company's operations lead time (Figure 9), can be positive for the company and the production processes doesn't require changes (Hill & Hill, 2009).

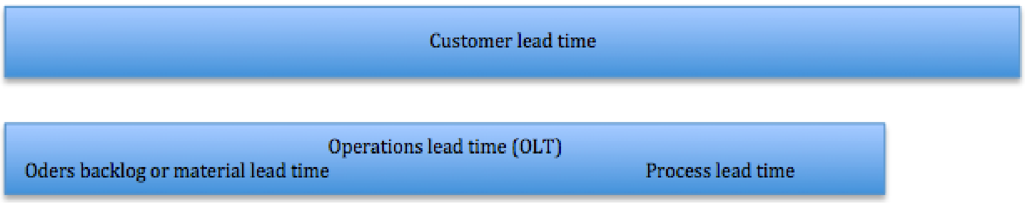


Figure 9. The situation when the customers' expected lead time is longer than the company´s operations lead time (Hill & Hill, 2009).

Specific production strategy affects the operations lead time. The production is aligned against the market or rather the customers. Figure 10 shows different production strategies with the corresponding lead times (Hill & Hill, 2009).

Production strategy	Lead Time
Design to order	Long
Engineer to order	
Make to order	
Assemble to order	
Make to stock	Short

Figure 10. Production strategies with corresponding lead times (Hill & Hill, 2009).

2.2.6 Master scheduling approach for different production strategies

A company is not forced to limit itself to one production strategy. It is possible to use a combination of several strategies. MTO can be used to cover the demand of products with low volumes and high variety. Low demand products should be produced in small batches, and back orders and rescheduling can be used to counteract the demand. The MTS strategy is best to be used for products with high volume and low variety. The demand can be covered through the production in high-volume batches and inventory with finished end products. The ATO strategy can be used for items that are between the description of MTO and MTS products (Hill & Hill, 2009).

Wonderland committed itself in front of retailers to deliver orders for high demand products within four days, orders for medium demand products within six days and orders for low demand products within eight days. Figure 11 shows the three productions strategies and their characteristics (Hill & Hill, 2009).

Strategic variables			Master scheduling approach		
			MTO	ATO	MTS
Markets	Product	Type	Special	→	Standard
		Range	Wide	→	Narrow
	Individual product volume per time unit		Low	→	High
	Delivery	Speed	Difficult	→	Easy
		Reliability	Difficult		Easy
Operations	Process choice		Jobbing or low- volume batch	→	High-volume batch
	Managing volume and mix changes		Backorders	Work-in-progress inventory	Finished products inventory
	Meeting delivery speed requirements		Reschedule orders	Decrease	Eliminate process lead time

Figure 11. The master scheduling approach with production strategies (Hill & Hill, 2009).

2.3 Buffer barriers

"The idealized organization structure for time-based competitors is seen as a fully integrated, value-added delivery system designed to meet customers' needs at a minimum amount of time". The most important aspect of time-based competition is to place the buffer barriers and safety stock in the right place within the production processes. The placing of buffer barriers in the production process is shown in Figure 12. The buffer barrier (extra capacity or standard component safety buffer) is placed between two processes to ensure the production flow. In the best case the buffer barrier is set as late in the production process as possible. The aim is to shield the largest possible amount of process steps from the changes in demand. The production flow can be divided into two parts: downstream and upstream from the barrier. In the upstream part, the focus lies on renewal of the buffer barrier itself and not on customer orders. The customer orders stay in the focus of the downstream part (Bozarth & Chapman, 1996).

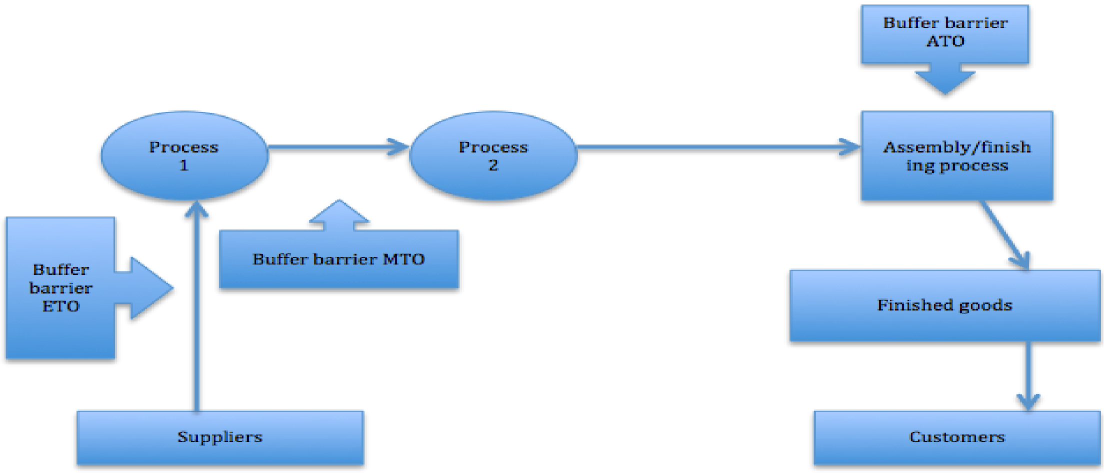


Figure 12. Production environments with buffer barriers (Bozarth & Chapman, 1996).

Wonderland will implement a subassembly buffer with the finite capacity for products with a medium demand rate in order to reduce the time needed to meet customers demand.

2.4 Chase and Level production strategies

A strategy which adopts changes in workforce in order to adjust capacity to demand is called a chase strategy. Another strategy, which deals with a stable work force is called a level strategy (Nahmias, 2009).

Level strategy implies constant production rate output during regular times. Demand variations should be solved by using inventories, overtime or subcontracting, among other things. (Schroeder, 1993).

In the pure chase strategy a variable work force level is used to deal with demand fluctuations. In this case inventories, overtime or subcontracting are not required. A good approach to evaluate decision about using one or the other strategy is to consider costs involved (Schroeder, 1993).

The hybrid strategy is a combination of these two strategies. The goal is to find a balance between costs and benefits (Vollmann, et al., 2005).

Wonderland practices a level strategy solving demand fluctuations by building up inventories in periods with low demand and by the use of overtime production. In some of the high seasons, additional evening shifts were implemented, but Wonderland concluded that this solution was costly due to the 50% higher wage and they will not consider it as an option.

2.5 Forecasting

In the context of operations planning both subjective and objective forecasting methods can be used. Subjective forecasting methods include customer surveys, the Delphi method where a number of experts are given a questionnaire by mail avoiding face-to-face discussion, a jury of executive opinion and sales force composites. Objective forecasting methods are based on past history. Forecasts can be classified according to the time horizon: short-term (days/weeks), intermediate term (week/month) and long-term (month/years) are common types (Nahmias, 2009).

Common practice is to use the normal distribution with μ - the mean and σ - standard deviation for unit time demand modelling. It is important to determine how uncertain a forecast is. Sometimes forecasts can consider manual adjustments when one deals with new products without historical data or influence of sales campaigns (Axsäter, 2000).
Quantitative forecasting and most inventory systems use forecasts based on the pattern of past demand: "time series" – observations taken at regular intervals of time. Forecasts should be reviewed by managers before their adoption. (Waters, 1992).

Chase (2013) argues that a forecast impacts inventory carrying costs and service level.
Previously subjective forecast methods were used by Wonderland which where personal-judgement dominated. In the frame of this thesis, it is more appropriate to use objective forecast methods based on past sales data where the seasonality, the trend and the size of the forecast error can be measured. We assume that the demand during lead time follows normal curve distribution and the forecast error over lead time is normally distributed.

2.5.1 Methods for seasonal series: Winters's Method for Seasonal Problems

Chase (2013) distinguish between three exponential smoothing (ES) methods: single exponential smoothing (SES), Holt's two-parameter and Holt's-Winters' three-parameter methods. He states that for the quantitative forecast models an existing demand pattern can be forecasted in isolation from randomness and devided into elements such as trend and seasonality. A trend represents long-time changes in the observation of the demand level. Seasonality can be related to sales campaigns which take places at the same time every year. The assumption that the sales activities which influenced the past demand will continue in the future is needed. Demand can be represented as a function of the trend plus seasonality plus unexplained error/randomness, where randomness is the difference between the actual demand, the trend and the seasonality. However, trend and seasonality can not provide all the required information.

Wonderland has seasonal variations in demand due to marketing campaigns rolled out by its main retailers together with furniture production companies. It seems reasonable to assume that there exist a seasonal pattern in the demand observations. These campaigns take place in January (January Sale) and August (Autumn Sale) each year due to the fact, that many people start at new jobs, move, buy houses and accordingly need new furniture in connection with Christmas and summer holidays. Sales will obviously continue this pattern in the future. This is the reason to assume that Wonderland will experience the seasonal pattern of demand as well.
When the seasonality is present, other methods are not suitable to apply because they will signalize the unexplaind error, which is related to the seasonality. This is the reason why Winters' method should be used for future demand prediction at Wonderland.

The main objectives of the forecasts are planning and control of inventory and production, investment planning, estimating of sales and/or budget. The estimation of sales for individual products is very crucial information needed for inventory control systems and for production scheduling. This type of information allows for better decision-making regarding order quantity and production/lot size. It is important to point out that the decision-making in such cases is based on a monthly or weekly forecast of future sales. The model for forecasting with a seasonal ratio and linear trend captures both short and long-term changes in future sales. The aspects of the market or the current economic situation, marketing or price strategies are not taken into account (Winters, 1960).

The following equations are needed:

(1) The series

$$S_t = a\,(D_t/C_{t-N}) + (1-a)\,(S_{t-1} + G_{t-1})$$

(2) The trend

$G_t = b\ [S_t – S_{t-1}] + (1 – b)\ G_{t-1}$

(3) The seasonal factors

$C_t = y(D_t/S_t) + (1-y)C_{t-N}$

(4) The forecast, made in period t for any future period t+k

$F_{t,\ t+\tau} = (S_t + \tau\ G_t)\ C_{t + \tau-N}$

Where: a, b and c are smoothing constants within the range between 0.0 and 1.0

N - Number of periods

D_t – Demand in period t

C_t – seasonal factor for the period t of a season

G_t – smoothed value of the slope

S_t - smoothed value of the series

F_t – forecast for demand in period t made in period t-1

$F_{t,\ t+\tau}$ – forecast for demand in period t+τ made in period t

τ – number of periods until forecast applies (Nahmias, 2009).

In some situations it can be beneficial to estimate seasonal factors from the total demand for the whole group of items (Axsäter, 2000).

2.6 Multi-Item Management: ABC analysis

ABC analysis is a method for dividing items into categories so that the most important items receive closer attention (Vollmann, et al., 2005). ABC inventory classification systems are used to streamline management of inventories. ABC classification can be performed using single or multiple criteria, for example demand value or product cost. It can be difficult in practice to implement stock keeping unit (SKU) inventory control methods for large amount of SKUs (Teunter, et al., 2010). According to traditional ABC analysis 20% of the products are responsible for 80% of annual sales, 30% of the products are responsible for 15% of annual sales and the last 50% of products achieve 5% of annual sales. A-products are crucial for the company and the inventory level should be reviewed continuously. The forecast should be also more precise. B-products can rather be controlled periodically and be treated in groups by using less precise methods to estimate the demand (Nahmias, 2009). For C-items a more manual and simple approach can be used in order to minimize efforts devoted to inventory management (Silver , et al., 1998).

Management should review the classification. The classification can be changed. In the end, specific policies should be defined for managing each group (Vollmann, et al., 2005).

The use of ABC-analysis was suggested to Wonderland in the early stage of this project. At the later computational stage it turned out that the ABC-grouping deviated from the traditional approach. Initial ABC-grouping was reviewed by Wonderland and accepted as a basis for the calculation.

2.7 Inventory control

Inventory management takes a central role in the planning and control area, especially in manufacturing (Chapman, 2006). It provides smooth operations and anticipates demand changes. The investment in inventory can exceed 25% of business capital (Vollmann, et al., 2005). Nahmias (2009) argues that companies using scientific inventory control methods gain a competitive advantage on the market.

2.7.1 Independent versus dependent demand inventories

The literature distinguishes between independent and dependent demand inventories. "Sellable" products can be classified as independent inventories and demand for them is independent from the company’s internal processes (Chapman, 2006). Demand for items in production such as raw materials and components are the dependent demand. These kinds of inventories with their positions in the process are shown in Figure 13 (Vollmann, et al., 2005).

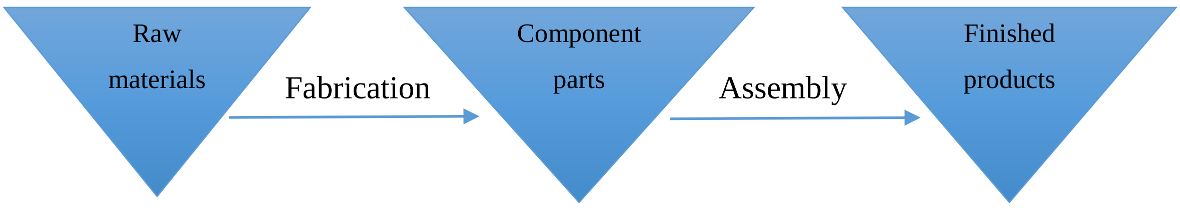


Figure 13. Dependent-demand inventories in the production process 13 (Vollmann, et al., 2005).

2.7.2 Types of inventory

The most common types of inventory depending on their function in the process are as follows: transit stock, cycle stock, safety stock and anticipation stock. Transit stock or pipeline stock is inventory in movement from one activity to another. Cycle stock exists when the rate of replenishment exceeds the demand rate (Chapman, 2006). Safety stock can be defined as an average level of the net stock just before a new replenishment arrives.

Net stock = On-hand stock – Backorders

On-hand stock is the stock that is physically on the shelf. It cannot be negative.

Inventory position = On hand + On order – Backorders – Committed

A positive safety stock provides a buffer against larger-than-average demand during the effective replenishment lead time (Silver , et al., 1998).
Anticipation stock is built up in advance for periods with the demand larger than normal production output, for example seasonal demand or marketing promotions (Chapman, 2006).

2.7.3 Lot sizing

A number of lot-sizing algorithms have been developed for manufacturing and can include: lot for lot (LFL), economic order quantity (EOQ), Silver-Meal heuristic, the part period balancing method and the optimal lot-sizing by dynamic programming, the Wagner-Whitin algorithm – an exact recurements policy (Nahmias, 2009).

A lot for lot policy involves direct translation of net requirements into production quantities (Browne, et al., 1996).

EOQ determines the optimal lot size that minimizes the setup cots and the holding costs:
min [TC = total setup cost + total holding cost], where TC- total costs in a time period.
EOQ lot sizing is based on a number of assumptions such as that the demand rate is constant and deterministic, shortages are not allowed, lead time is assumed to be of zero duration and a very long planning horizon.
EOQ lot-sizing is based on this formula:

$Q = \sqrt{\frac{2KD}{h}}$;

Q –lot size, in units

K – the fixed set-up cost

D – the average demand rate
h – holding cost

The Silver-Meal heuristic is based on defining the average cost per period as a function of the number of periods (Nahmias, 2009).

The part period balancing method equates the cost of set-up with the cost of inventory (Browne, et al., 1996).

Common for the above mentioned methods is that production will take place in some periods and items will be stored until the demand occures. The methods are not appropriate for Wonderland to apply because Wonderland uses mainly a level strategy where the capacity utilization should be balanced over time due to limited storage capacity.

When demand varies with a given probability, different decision rules are applied. An appropriate relocation of buffer or safety stock in order to meet demand fluctations improve the service provided to customers (Silver , et al., 1998).

1. Order-Point, Order-Quantity (s,Q) System: continuous review system. A fixed quantity Q is ordered when the inventory position drops to reorder point s or lower.
2. Order-Point, Order-Up-to-Level (s,S) System: continuous review system. A replenishment is made whenever the inventory position drops to the order point s or lower, like the (s,Q) system. In contrast to the (s,Q) system a variable quantity Q is used, ordering enough to raise the inventory position to the order-up-to-level S.
3. Order-Up-To-Level (R,S) System: periodic review system. Each R unit of time a quantity Q is ordered to raise the inventory position to the level S.
4. (R,s,S) System: is a combination of (s,S) and (R,S) systems. Every R units of time inventory is checked and quantity Q is ordered to raise the inventory position to the level S if the inventory position is below the reorder point s (Silver , et al., 1998).

Silver et al. (1998) suggests the following rules (Table 1) for selecting the form of the inventory policy:

Table 1. Rules of thumb for selecting the form of inventory policy

	Continuous Review	Periodic Review
A items	(s,S)	(R,s,S)
B items	(s,Q)	(R,S)
C items	The simplest strategy should be selected	

2.7.4 Service level

Definition of service refers to the probability of meeting a demand. Probability of no stock out per replenishment cycle refers to the cycle service level or Type 1 service and can be calculated as follows when assuming that the demand in the lead time follows the normal distribution:

Probability {stock out in lead time} = pu>= (k) = 1 - P1

P1 can be defined as the fraction of cycles without an occasion when the on-hand inventory drops below zero.

pu>= (k) – Probability {stock out in a lead time}

k - the safety factor

Safety stock = k * σ lead time,

where σ lead time - the standard deviation of the demand during lead time.

Low service levels imply frequent stock out situations. In order to prevent a stock out situations a safety stock may be established. Long lead time, high demand variability and high service level requires a high safety stock level and vice versa. Frequent replenishments can reduce lead time and better forecasts can reduce demand variability (Silver , et al., 1998).

Focusing on the P1 service level is recommended when stock outs cause similar effects on the production.

That means that, for example, setup costs occur or overtime has to be used, regardless the number of items being short (Nahmias, 2009).

Another service level, which is the fraction of demand that is satisfied directly from the stock on hand is defined as the fill rate or Type 2 service (Silver , Pyke, & Peterson, 1998). The customer service level can be expressed as the extent of investment into inventory in order to fulfil service level criteria. Service level/inventory investment trade-offs should be evaluated (Vollmann, et al., 2005).

The fill rate which corresponds to a given Type 2 service can be calculated in the following way:

$P2 = n(R) / Q$, where

P2 – service level type 2 (proportion of demands satisfied from stock / fill rate)

n(R) – the expected number of stock-outs per cycle when using reorder point R

Q – order quantity/lot size

L(z) – normalized loss function. $n(R) = \sigma L(z)$ (under the standard normal curve for the demand during lead time)

σ – standard deviation of the demand in the lead time (Nahmias, 2009).

2.8 Master Production Schedule

The Master Production Schedule is a specific production plan for the products of a company determining quantities and time. MPS must be updated when new information regarding sales, demand and operations can be obtained. MPS should be aligned to the production environment. MTS companies produce in batches carrying FGI. The MPS unit is a finished product. The ATO firms produce subassemblies, but postpone final assembly until the customer order enters the system. They use buffering tools in order to maximize responsiveness. The MPS unit is a component or subassembly. The production schedule unit in MTO strategy is a particular item, produced after a customer order. Figure 14 shows MPS in a manufacturing planning and control system (Vollmann, et al., 2005).

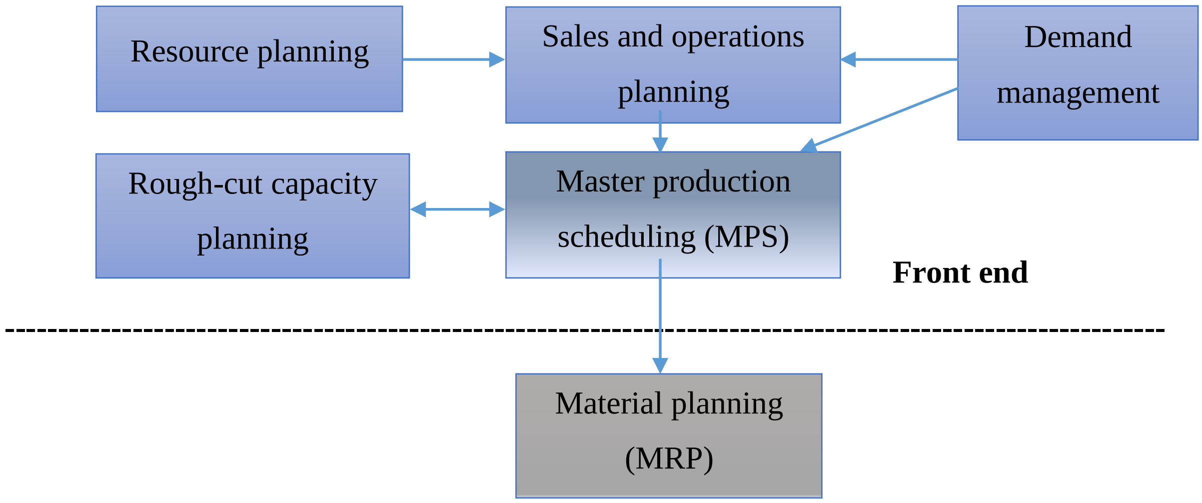


Figure 14. An example of MPS in a manufacturing planning and control system (Vollmann, et al., 2005).

Herrmann (2006) states that MPS requires the following input parameters:
- The specified planning horizon (weeks or months)
- Given resources and products (SKUs)
- Actual customer orders or estimation of demand
- Minimum or standard lot size
- On-hand inventory (initial SKUs inventory at the start of planning horizon)
- Safety stock level (to cover the fluctuation of demand)
- Maximum inventory (maximum capacity)
- Production rate (number of products per one unit time)
- Set-up time (changing the production line from producing one type of products to another type of products)
- Backorders/backlogging (maximum number of orders that can be scheduled for the production in the next periods)
- Capacity (the available capacity, number of hours or days)
- Maximum number of hours of available overtime

The output of MPS can be defined as follows:
- Beginning inventory (the number of items at the start of the time period, for the first period the beginning inventory is equal to the safety stock)
- Ending inventory (the number of items at the of the time period)
- Net requirement (the number of items to be produced).

The production scheduling system can be described as a dynamic net of responsible, connected employees (managers, scheduling planners or salesmen) with the purpose to develop a plan based on shared information of job status, resources and/or status of the different inventory types. The team has the aim to obtain the best possible answer to the following questions: When should the received order be released for production? Which resources should be reserved for which task, prioritising between several jobs? Which production task should be stopped and which resource should be relocated from one job to another? The scheduling plan is needed as an estimation for better organizing within production and will usually not be equal to the production in reality. The necessity for rescheduling of the production plan will occur. The scheduling plan must be updated for infeasibility, order modifications, disruption in the production or supply chain and prioritizing of new orders. The scheduling plan should include feedback control systems to update the actual scheduling plan based on new information. Figure 15 shows a scheduling plan with a feedback control system (Herrmann, 2006).

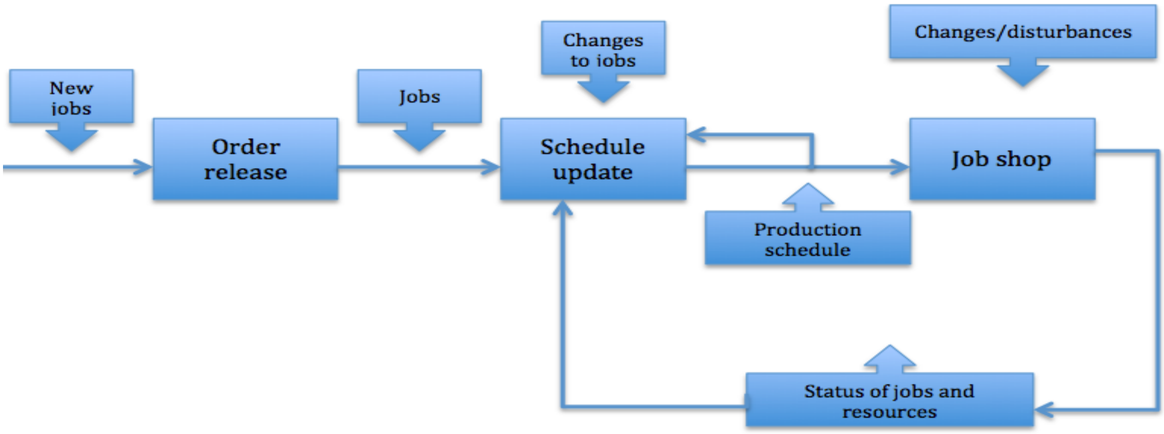


Figure 15. Scheduling plan with feedback control system (Herrmann, 2006).

Further, sample MPS are shown in Figure 16 and Figure 17 (Vollmann, et al., 2005).

Week number	1	2	3	4	5	6	7	8	9	10	11	12
Forecast	5	5	5	5	5	5	15	15	15	15	15	15
Available	25	30	35	40	45	50	45	40	35	30	25	20
MPS	10	10	10	10	10	10	10	10	10	10	10	10
On hand	20											

Figure 16. A Level Production MPS Approach to Seasonal Sales (Vollmann, et al., 2005).

Week number	1	2	3	4	5	6	7	8	9	10	11	12
Forecast	5	5	5	5	5	5	15	15	15	15	15	15
Available	15	10	5	30	25	20	5	20	5	20	5	20
MPS				30				30		30		30
On hand	20											

Figure 17. Lot Sizing in the MPS (Vollmann, et al., 2005).

Typically, a product consists of several components. The bill-of-materials explosion translates MPS for end items into production schedules with time and quantity requirements for components at the lower level. Figure 18 shows the produced components which form the end product delivered by Wonderland.

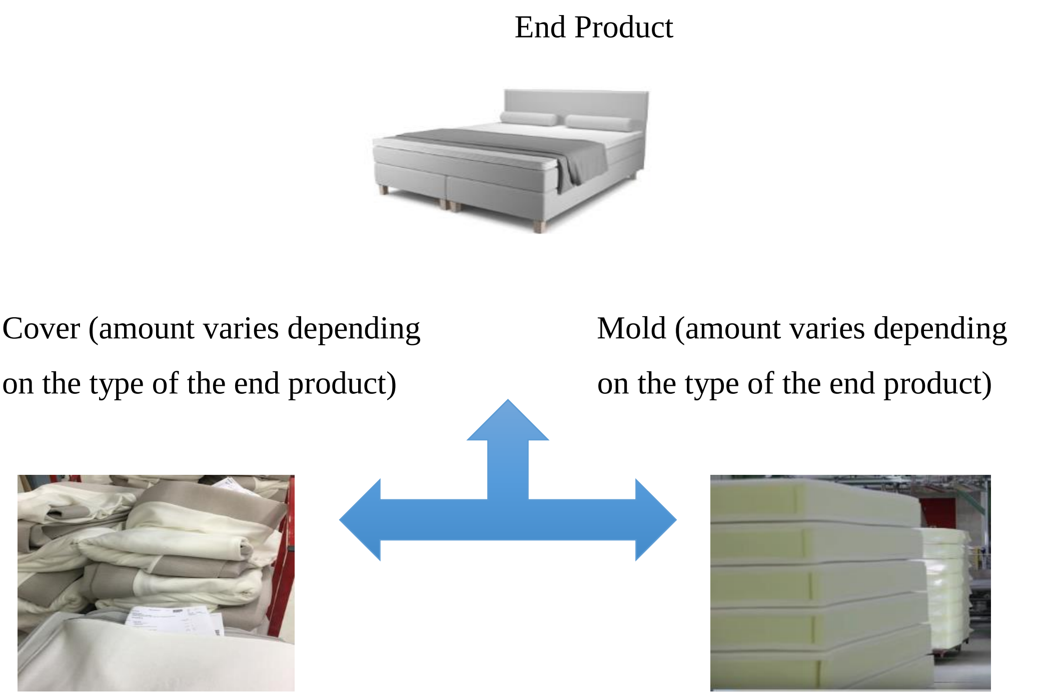


Figure 18. Own produced components forming the end product at Wonderland.

Reduction of operating costs and high productivity can be obtained with the help of production scheduling, especially for production environments with complex production processes, several levels of production and high end-product diversity. The main goals of the production scheduling are the awareness of competing resources and the release of correct jobs to the next production task (Herrmann, 2006).

2.9 Capacity planning

Capacity is "the amount of output that a system is capable of achieving over a specific period of time". On the one hand the companies can use their strategic capacity planning to manage the capacity of crucial resources (workforce size, machines). On the other hand capacity planning influences a company’s competitiveness on the market, inventory levels and the costs. The concept of capacity flexibility can be defined as the capability to quickly maintain changes in the production level. The production level can be decreased or increased on short notice, or the production of one specific product can be changed to the production of another product. The companies can reach this level of capability by using a flexible workforce, processes (low set-up cost) and facilities (Chase, et al., 1998).

The MPS is the primary information basis for rough-cut capacity planning. Rough-cut capacity requirements can be estimated using overall factors (CPOF). Information from

MPS in units and direct labour time per end unit in hours can give an estimate for the required capacity. Required U (capacity) = Amount of product A*Direct labour in hours/unit for product A + …+Amount of product N*Direct labour in hours/unit for product N (Vollmann, et al., 2005).

MPS helps to keep an overview over resources and the state of capacity. The aspect of overtime has to be considered in order to expend the production capacity. Table 2 shows the typical resources control table (Herrmann, 2006).

Table 2. The typical resources control table (Herrmann, 2006).

	Week 1	Week 2	Week 3	Week 4
Regular capacity				
Used capacity				
% Used capacity				
Overtime allowed				

Capacity and due date aspects can be incorporated into MPS. It can be demonstrate by these consistency relations:

1. $P_t = \min(C, Q_{t-1} + R_t)$
2. $Q_t = Q_{t-1} + Rt - Pt$
3. $W_t = Q_{t-1} + R = Q_t + P_t$
4. $L_t = W_t/C$

Where

C – capacity of the work center

R_t - work released to the work center during period t

P_t – production from the work center during period t

Q_t – the queue at the work center

W_t – the work-in-process at the work center

L_t – lead time at work center

T – time periods (Graves, et al., 1993).

2.10 Operations Scheduling

Production conditions often change in practice and some operations must be performed using dispatching rules, which prioritize a job among others in the queue. Lead time can be managed since it depends on priority and capacity. Sequencing and scheduling deals with time phased resource allocation (Graves, et al., 1993).

Scheduling is an important tool for manufacturing operations control. The main goals of scheduling can be specified as meeting due dates, minimize WIP inventory, minimize the average flow time, minimize machine/worker idle time, reduce setup times and minimize production costs. The most common scheduling rules are the following:
The First-Come, First-Served (FCFS) rule means that the jobs are scheduled in the order they come in (Nahmias, 2009). This rule is based on a "fairness" criterion. It is often used in practice, but scores bad on all criteria and is not optimal (Schroeder, 1993).

The Shortest Processing Time (SPT) rule schedules jobs in increasing processing time order. The job with the shortest processing time will be finished quickly resulting in high flow rate and high utilization. It performs best on "number of orders completed" criteria.

The Earliest Due Date (EDD) rule means to complete jobs in order of their due dates. This dispatching rule minimizes maximum tardiness and scores high on the following criteria: number of orders completed, average number of orders waiting in the shop, yearly cost of carrying orders in queue, ratio of holding cost while waiting to holding cost while on machine, percentage of labour and machine capacity utilization.

The Critical ratio (CR) rule is based on calculating a priority index: remaining time until due date / remaining processing time, describing the ratio demand time/supply time. If the ratio is more than 1, there is enough time to complete the job, otherwise the job will be late (Schroeder, 1993).
Lead time reduction is a relevant objective for Wonderland. Application of dispatching rules can reduce lead times and improve production flow. Since different lead times are established for A, B and C products, the EDD rule should be applied in order to prioritize existing and new orders by their due date and reduce maximum tardiness. Every day production should follow the A-B-C sequence. All items in the mold production section have equal processing times, but a combination of the EDD and the SPT rules can be relevant for the runstitching and the assembly sections. Jobs with equal due date should follow the increasing processing time sequence in order to complete a maximum number of orders.

3.0 METHODICAL FRAMEWORK

This chapter gives an overview of the existing research philosophy, research purpose, research method, research approach, research strategy and the research types, depending on outcome. The data gathering issues and quality criteria will be presented at the end of the chapter.

3.1 Research philosophy

Research can be defined as actions undertaken in order to find out things, using a systematic approach based on logical relationships (Saunders, et al., 2012). This thesis is an approach to solving a real world problem. The outcome will depend on the subjective perception of the problem, its limitations and assumptions. Due to that, the philosophy of relativism is adopted in the thesis. It implies that the "reality" is constructed by individuals and should be seen in the context of a mental framework in contrast with realists who argues that the "reality" exists independent of social actors (Meredith, 2001).

3.2 Research purpose

Classification of the research is done according to its purpose: exploratory, descriptive or explanatory. An exploratory study can be initiated when it is necessary to clarify a problem of research. It involves the study of literature and actions connected to the collection of information (Saunders, et al., 2012). It is appropriate to consider exploratory research as the first stage of a research process.

Descriptive studies are a fact-finding investigation (Krishnaswami & Statyaprasad, 2010).
Explanatory studies investigate relationships between variables (Saunders, et al., 2012).
This research is based on a specific production company with a given market position, relationships with suppliers and customers, management context, production facilities and capacity parameters. The production strategy transformation process, initiated by the company, constructs the frame for this research and will be influenced by unique decisions. This thesis has a descriptive study approach in the initial section where the research problem is defined. The second part of the thesis tends to be exploratory due to the search of theoretical and existing methods in order to find a practical solution to the problem.

3.3 Research method

Research methods can be classified as: qualitative, quantitative or multiple. The quantitative method is associated with data collection and analysis (Saunders, et al., 2012). Prognoses of demand based on data from the past, analysis, calculations of safety stock in terms of customer service level, lot-sizing and capacity requirements planning were performed using quantitative methods. The qualitative method gives a subjective assessment of reality (Krishnaswami & Statyaprasad, 2010).

Multiple discussions with the company were conducted via face-to-face meetings, telephone meetings and by e-mail. A significant part of understanding how production flows are organized, approaches for components grouping, explanation of input parameters such as workforce level, overtime usage, production parameters, capacity constraints, limitations and assumptions were achieved by qualitative methods.

A combination of quantitative and qualitative methods was used in this thesis. Multiple methods provide a better approach to business research because they combine strong sides of both methods (Saunders, et al., 2012).

Data gathering is the key point of any research (Bryman & Bell, 2015). Literature distinguishes between primary and secondary data. Primary data is data that has been obtained directly by the researcher for a particular research project from an original source (Currie, 2005). Secondary data is all kinds of information that comes from literature studies (Sontakki, 2009).

The primary data in form of the sales history for two years – 2016 and 2017 – was collected. It gave a basis for analysis of the demand for all products sold on a daily basis. Required information about inventory, production and capacity parameters were obtained through meetings and e-mail exchanges with Wonderland.

Secondary data such as books and scientific articles covering relevant theoretical information were provided by the library of Molde University College and the library at the Humboldt University (Grimm-Zentrum) in Berlin.

3.4 Research approach

To come to a conclusion in research, one has to go through three steps: deduction, induction and abduction. Deduction is an approach mostly used in natural science. The researcher moves from a theory to test observations against it. Induction is an approach that starts from collecting data and then developing a theory. Abduction begins from observations and a conceptual framework based on the data will be developed. This theory will then be applied to the phenomena. The researcher moves back and forth from data to theory and from theory to data (Saunders, et al., 2012). Operations management research can be deductive which is driven by an idealized model (axiomatic) and also inductive, which is driven by data (empirical) (Bertrand & Fransoo, 2002).

This research started with an analysis of available data and the formulation of the research question. The relevant theoretical framework was found. Theoretical concepts, methods, models and approaches were applied to existing and generated data. This implies that the abductive approach was utilized.

3.5 Research strategy

Research strategy can be described as a plan, combining different steps in order to answer a research question. We can classify research depending on strategy as: Experiment, Survey, Archival Research, Case Study, Ethnography, Action Research, Grounded Theory and Narrative Inquiry (Saunders, et al., 2012). Experimental research is designed to assess the effects of particular variables on phenomena by keeping the other variables controlled (Krishnaswami & Statyaprasad, 2010). Experiments test a formulated hypothesis rather than to answer an open research question. Experiments are often conducted in laboratories and not in the common business environment (Saunders, et al., 2012).

A survey is a method of research involving collection of data directly from a sample at a particular time (Krishnaswami & Statyaprasad, 2010). Surveys are a popular strategy in business research, which is often associated with a questionnaire or structured interview (Saunders, et al., 2012).

Archival research uses administrative records and documents as a main data source. A case study explores the object, phenomena or processes within its context. It is used in exploratory or explanatory studies and uses both data collection methods (Saunders, et al., 2012). Case studies answer the who, why and how questions in business research. This type of research strategy gives the researcher the possibility to concentrate on specific instances. The initial stage of the master thesis followed a case study approach where we investigated processes within the company.

Ethnography is a type of field observation, which has as its purpose the study of the culture of a society. It is not widely used in business and management (Remenyi, et al., 1998).
Action Research is designed to find solutions to real organisational problems through collaboration. The purpose of Action Research is to produce practical outcomes and to promote change within the company (Saunders, et al., 2012). The cooperation of a company's project members is crucial for this strategy to be successful. Action Research should produce new knowledge that can be implemented and verified in practice (Remenyi, et al., 1998).

The grounded theory refers to the development of theoretical explanations of social processes and interactions. It can be used to investigate business topics as business and management as about people and their behaviour. Narrative inquiry is a qualitative research strategy, which explains an event or a number of connected events (Saunders, et al., 2012).

The purpose of this research is to examine the production environment at Wonderland AS and to develop practical results and suggestions for future transformational processes in respect to the production planning, inventory control and capacity utilization. This leads to the study being action research.

The literature distinguishes between pure research and applied research. Pure research is known as basic or fundamental research without any intention to apply it in practice. The purpose of applied research is to find solutions to a practical problem. It is the main purpose, but it may contribute to the development of theoretical knowledge (Krishnaswami & Statyaprasad, 2010). Our investigation has a goal of solving a real-life problem and it fits into the category of applied research.

3.6 The quality of the research design

Research design quality can be defined by the degree of acceptance by a critical audience (Remenyi, et al., 1998).

3.6.1 Reliability

Reliability determines the consistency of the data gathering and analysis methods (Saunders, et al., 2012). Reliability answers the question of whether the results of research can be repeated. Stability, internal reliability and inter-rater reliability are three factors to consider when deciding whether results are reliable or not. Stability means insignificant variation in measurements over time. Internal reliability refers to consistency of the collected data. Inter-rater reliability deals with the issue of subjective data processing. (Bryman & Bell, 2015).

The authors were concerned about the reliability of data collected at the beginning of the process. To ensure consistency of information, they used two personal sources involved in the project. When it comes to subjectivity of data grouping and the measurement of key input parameters, the authors obtained regular feedback from the company in order to get to an agreement on data interpretation. Wonderland made corrections during the project progression.

3.6.2 Validity

Validity refers to whether the measure reflects the research question. Validity examines integrity of the research findings (Bryman & Bell, 2015). One can distinguish between construct validity, internal validity and external validity. Construct validity is achieved to a sufficient extent when the research measures what it actually is supposed to measure. Internal validity exists when a causal relationship between variables can be observed. External validity answers the question whether there is a generalisation of the research results (Saunders, et al., 2012).

The authors had a number of meetings with Wonderland at the beginning of the project in order to ensure the understanding of the research question. The focus, premises and limitations were discussed in detail. The fact that this research is company-specific can lead to challenges for the generalisation of results. At the same time parts of the conceptual framework - especially production strategy transformation in relation to ABC-grouping, inventory management and capacity utilization - can be applied to other fields.

4.0 EMPIRICAL FRAMEWORK

This chapter presents the empirical investigation, analysis and developed practical solutions based on the theoretical framework.

4.1 General considerations

Wonderland delivered two different sales data sets for two main components, which are not equal to the final products sales data. The processing of the received sales data required two different approaches: one for the covers and one for the molds. In the production process several different characteristics of those components have to be taken into account. For the cover production the colours are the key characteristic, but in the mold production, the information about firmness has to be considered. Based on those requirements data processing and data analysis were done separately.

Wonderland sets the number of working days in 2018 - where the production will take place – to 224.

Wonderland uses their own defined UBIT number as an ID-number to be able to identify their different products. Each UBIT number describes one unique product. The number also describes all characteristics of the product. Wonderland has four types of mold firmness, which are presented by two first digits after a hyphen: 00, 02, 04 and 08. The two last digits after the hyphen represent different colours of the cover. An example is presented in Figure 19 below.

UBITNO	MMITDS
1302021-0022	COMF WE RA 90x210
1302021-0044	COMF WE RA 90x210
1302021-0045	COMF WE RA 90x210
1302021-0060	COMF WE RA 90x210
1302021-0061	COMF WE RA 90x210
1302021-0245	COMF WE RA 90x210
1302021-0420	COMF WE RA 90x210
1302021-0422	COMF WE RA 90x210
1302021-0444	COMF WE RA 90x210
1302021-0445	COMF WE RA 90x210
1302021-0460	COMF WE RA 90x210
1302021-0820	COMF WE RA 90x210
1302021-0821	COMF WE RA 90x210
1302021-0846	COMF WE RA 90x210

Figure 19. Code-representation of the firmness and the colour characteristics of the items.

It is important to mention that the employees at Wonderland are assigned to only one production section. The workforce from the assembly section or the mold production section can not be reassigned to the runstitching section or vice versa. The runstitching operations requires sewing skills while the mold production section, for example, requires driving fork lift skills.

4.2 A mold production section

Figure 20 gives a visual representation of the mold production line at Wonderland.

Figure 20. The mold production line at Wonderland

The mold is produced on a single machine (section 1) that will be treated as an independent workstation. It takes 50 seconds or 0.0139 hours per mold of pure processing time (nominal production rate). The maximum output is 460 molds per regular working shift of a 7.75 hours duration. The output respectively is 59.36 ~ 60 molds per hour or 0.0167 hour per mold (actual production rate). Active production time can be calculated as follows: 460 molds * 0.0139 molds/hour = 6.39 hours. Idle time can be estimated to 7.75 hours – 6.39 hours = 1.36 hour. Wonderland itself estimates idle time to 1.4 hours and set up time for each change from one product to another to 5 minutes or 0.083 hours. Given that the mold production line is operated by 4 persons with wage costs of 280 NOK per hour per person, the set up cost can be estimated to 93 NOK.

The A-products will follow the MTS production strategy and will be produced and kept in the finished goods inventory (FGI) storage which will be constructed in the transformation phase with a capacity of 500 square meters and a height of 14 meters giving it 7000 m3. The available capacity will be sufficiently large to store more than 1000 mattresses.

The B-products will follow the ATO production strategy and will be premanufactured and stored in a subassembly buffer in palettes which are the product carrier for the molds, placed in the production area with a capacity for 550 molds. There will be a subassembly buffer for the covers which are supposed to match the B-mold placed in the cover production area. The description of the cover subassembly buffer will be presented in the cover section chapter.

The C-products will follow the MTO production strategy and will be produced only after receiving a customer order.

Wonderland sets up a target lead time of 4 days for the A-products, 6 days for the B-products and 8 days for the C-products.

Holding cost consists of the capital cost and operating costs involved in storing inventory (Nahmias, 2009). Wonderland estimates capital cost at 4.5% and operating costs at 19.9% thereby the internal interest rate amounts to 24.4% of the unit cost. The unit cost of mold is 685 NOK which gives us 167 NOK in inventory carrying cost per unit per year or 167 NOK.

The analysis is based on obtained sales data for mattresses on a daily basis for two years: 2016 and 2017. Data for 2017 accounts for 898 articles (items). As it was mentioned before the total number of all possible combinations is 3648, but most rare combinations give little contribution to the sales volume. Figure 21 shows some of the sales data for 2017 with daily sales observations.

A	B	AV	AW	AX	AY	AZ	BA	BB	BC	BD	BE	BF	BG	B
UBITNO	MMITDS	20170306	20170307	20170308	20170309	20170310	20170313	20170314	20170315	20170316	20170317	20170320	20170321	20170:
5000026-0400	INNL STANDARD WE 105x210									1	2			
5002006-0400	INNL COMFORT WE 80x200		1	4	2				3			1		
5002020-0800	INNL COMFORT WE 90x200	3	2	3										
5003001-0800	INNL EXCLUSIVE LA 75x200								1	1				
5003006-0000	INNL EXCLUSIVE LA 80x200	2	2	4	3	3	2	1	2	4		1	2	
5003006-0800	INNL EXCLUSIVE LA 80x200	3								2				
5003020-0000	INNL EXCLUSIVE LA 90x200	19			16	9	31	26	25	12	14	4	1	
5003020-0400	INNL EXCLUSIVE LA 90x200	23	4	2	24	26	33	42	34	21	26	8	8	
5003021-0000	INNL EXCLUSIVE LA 90x210	2	2	11	1	1	2		3	4		2	2	
5003026-0000	INNL EXCLUSIVE LA 105x210	1		6							2	1	1	
5003026-0400	INNL EXCLUSIVE LA 105x210	1		2	1	1	1				3		1	
5005020-0800	INNL COMF LATEX 90x200				1	1				3	3			
5005021-0400	INNL COMF LATEX 90x210				2	2				1				
5504001-0044	CO/EX WE KONT BENK 75x200			2	4	8	4	4	2					
5504020-0043	CO/EX WE KONT BENK 90x200										2			
5504020-0045	CO/EX WE KONT BENK 90x200	10	10	10	12	8	14	16	2					
5504020-0046	CO/EX WE KONT BENK 90x200						6	2		4	2			
5504020-0060	CO/EX WE KONT BENK 90x200	2		2	4			2	2	2	4			

Figure 21. Example of the sales data for 2017 on a daily basis.

Each article (unit) describes size, type of the mold, its firmness, quality of the springs, top mattress material (latex or welun) and the colour. For the mold production stage articles can be grouped based on the firmness characteristic. The colour characteristic can be held outside until the next stage in the production process. The grouping of articles on the basis of their firmness results in less number of units, namely 4 in this case and is presented in the Figure 22 below (compare with 14 items in the Figure 19).

UBIT_FIRMN	MMITDS
1302021-04	COMF WE RA 90x210
1302021-00	COMF WE RA 90x210
1302021-08	COMF WE RA 90x210
1302021-02	COMF WE RA 90x210

Figure 22. Grouping on the basis of firmness characteristic

The grouping resulted in total 311 articles for different mold types based on the firmness characteristic.

The demand has a seasonal pattern repeating over the year with the peaks in January and August due to the sales campaigns rolled out by major retailers on the domestic market.

Winters's method, a type of triple exponential smoothing for seasonal problems, was applied in order to make a forecast for 2018. It defines the intercept, the trend and the seasonal factor, which indicates the relative value of each period compared to the average value of the whole period (a year) (Nahmias, 2009).

The seasonal demand pattern for one SKU with a declining trend is shown in Figure 23.

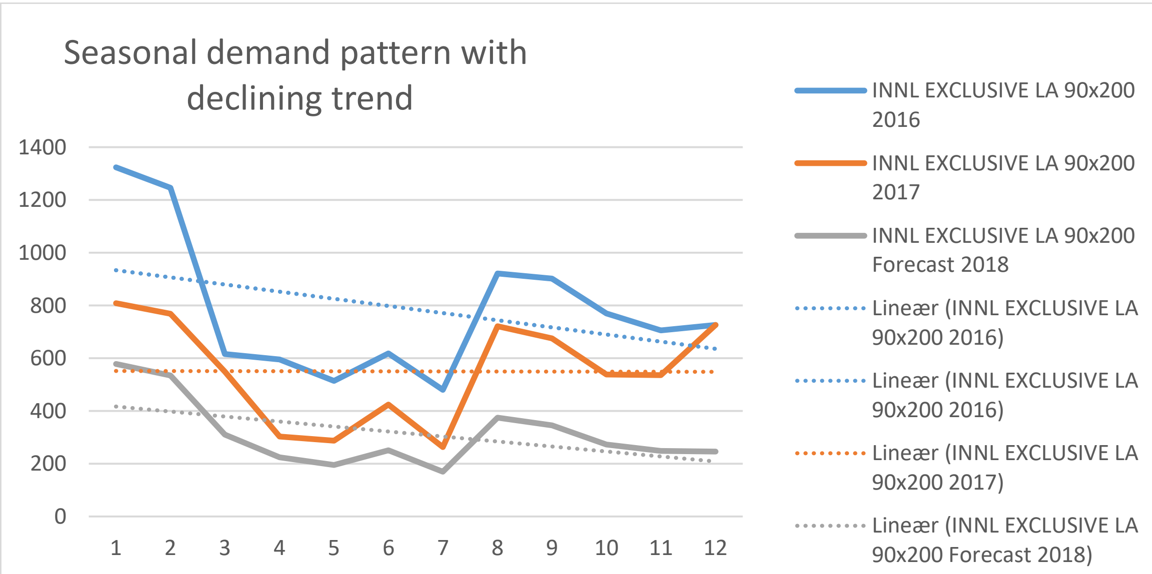


Figure 23. Example of the seasonal demand pattern with declining trend

Chase (2013) states that seasonal variation is a component of the time series around the trend, which is repetitive and predictable. Figure 23 shows repetitive seasonal variations around the trend.

As it is difficult to find optimal smoothing constants, historical data for 2016 and 2017 was weighted equally resulting in the declining trend for the 2018 forecast. One of the drawbacks of the Winters' method according to Chase (2013) is that it adjusts slowly to changes in demand. The method furthermore cannot model such explanatory factors as social-economic situations, competitors' activities, prices, sales and the nature of the business environment. For example, the downfall of the oil prices, which started in the year 2014, influenced the Norwegian economy, which is to a large extent associated with the oil industry. It could have had an impact for Wonderland regarding their sales in the area of the offshore and marine sector and due to customers' solvency in general. It takes time to react to those disruptions and make adjustments, but the demand observations for 2017 show that Wonderland managed to reverse the trend. Monitoring of the competitors' activities and pricing strategies is an important step for the successful demand management.

Differences between the 2018 forecast and actual demand can be treated as a random component of the forecast. Adjustments to the actual demand level can be made with the help of the inventory control policy and capacity regulation.

When it comes to the A-items, 4 of 10 items have an increasing trend and 6 of 10 items have a declining trend and the 2018 forecast for the whole A-group accounts for 90% of the 2017 sales volume.

For the B-items the forecast for 2018 shows that 9 of 66 items ended up with a negative demand due to the declining trend. After consultation with Wonderland some manual adjustments were made: the average demand for each item was multiplied by a normed seasonal factor for the corresponding month. There are both items with increasing and declining trends in the B-group with 3% forecasted demand increase in 2018 in comparison with the 2017 sales.

The C-group consists of 235 SKU in total. The forecast for the group was made based on the sum of the demands for all items. The results of the demand forecast for the C-products shows a 33% increase compared to the 2017 sales data. With 88867 items sold in 2017 and the forecast for 2018 counting for 84964 items Wonderland can expect a 4,4% reduction in sales.

It is notable that it's expected that a reduction in sales for A-products – or "runners" as Wonderland names them – will take place, while the demand for more specialized types, namely B and C products, will increase. Wonderland should look closer at the customers' preferences and map underlying reasons for the issue. Product positioning and customer segmentation can be reviewed. Wonderland works continuously on the development of new product designs and quality improvements based on its extensive knowledge and new innovations. This makes us assume that having a focus on customers' needs will maintain its competitive advantage and result in a brand strengthening and increase of market share.

After the demand forecast had been completed, ABC-grouping was conducted.
Different production strategies will be applied to A, B and C groups and as it was mentioned before,
A items will follow make-to-stock (MTS) production strategy with an announced to the customer lead time equalling to 4 days
B items will follow assemble-to-order (ATO) production strategy with an announced to the customer lead time equalling to 6 days
C items will follow make-to-order (MTO) production strategy with an announced to the customer lead time equalling to 8 days

The mold production line at Wonderland has a finite capacity. All three families of items, A, B and C, will share the available production capacity.

Inventory control involves multiple items. A small number of items accounts for a large part of sales volume (Nahmias, 2009). Axsäter (2000) states that the items can be grouped in different ways depending on the specific requirements of the company.

After a discussion with Wonderland, a decision to apply ABC-analysis to stock keeping units (SKU) based on the total annual demand volume was made. Three items which should belong to the B-group due to the demand forecast volume, were moved to the C-group because of their size which will not fit into the pallets in the subassembly buffer.

The ABC-classification deviates from the classical ABC-division and contains an adjustment to the Wonderland specific situation.

The results of the ABC-classification, which were verified and agreed by Wonderland, based on the forecast data for 2018 for the mold are presented in Table 3 and Figure 24.

Table 3. The ABC-classification for mold items at Wonderland

Groupe	Number of SKU items in the groupe	Yearly demand forecast for 2018, items	Proportion of the total demand volume, %
A	10	47 185	55,50
B	66	31 133	36,70
C	235	6 646	7,50
Total	**311**	**84 964**	**100**

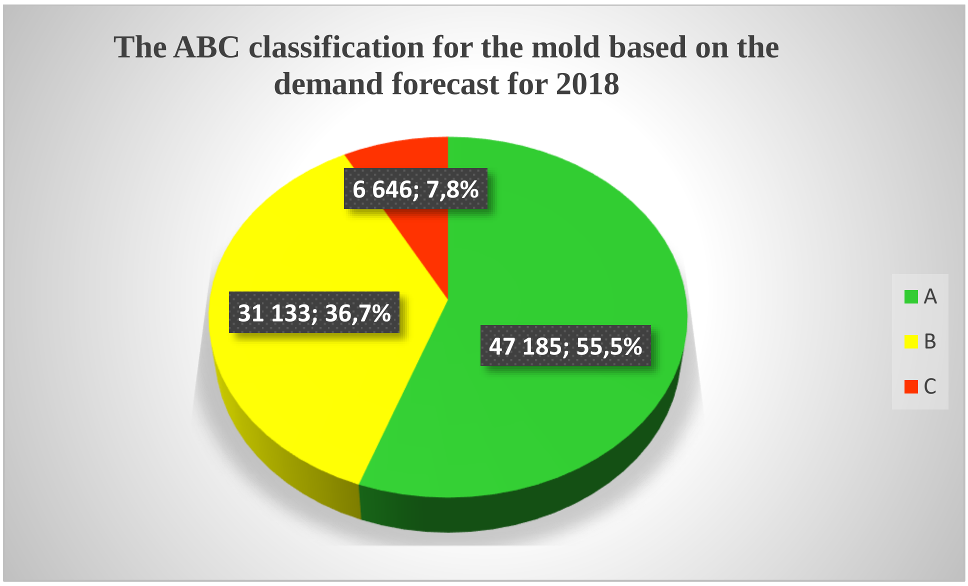


Figure 24. The ABC classification for the mold

4.2.1 A-items

The A-group of the mold will follow the MTS production strategy, it accounts for 55.5% of the total forecasted sales in 2018 and has the shortest customers lead time equal to 4 days. Wonderland intents to have a high focus on this group.

4.2.1.1 Lot-sizing

Production planning has a goal to determine production quantities, expected inventory levels and required resources in the time period during the planning horizon (Graves, et al., 1993).

Lot sizing is as important as different aspects in production planning. The complexity of multi item lot sizing problems is significantly higher than for single item problems. One deals with capacitated lot sizing problem (CLSP) when the capacity constraints are involved. CLSP is NP-hard and different heuristics can be applied (Karimia, et al., 2003). Smaller lot sizes can smooth the production load and diminish the queues in production, but extensive setups may reduce available capacity and increase the queues. A reasonable balance should be found. (Axsäter, 2000).

Nahmias (2009) suggests rotation cycle policy for the case of n products on a single production machine and that the optimal cycle time can be obtained by the following formula:

$$T = \sqrt{\frac{2\sum_{j=1}^{n} Kj}{\sum_{j=1}^{n} HjDj}}$$

T - cycle time

n – number of products, j=1…n

K_j – set up cost for product j

D_j – demand rate for product j

P_j – production rate for product j for the finite production rate model

$H_j = h_j (1- D_j/P_j)$– Modified holding cost for the finite production rate model

h_j – holding unit cost for product j per unit time, $hj= v_j*r$

v_j – unit cost for product j

r – internal interest rate per annum

Optimal cycle time for the A-products is equal to T = 0,0158 or to 3,5 days taking into consideration 224 working days per year. After a discussion with Wonderland the following benefits of planning for production of smaller lot sizes for all items on a daily basis were agreed to: smooth capacity utilization, flexibility in adjustments to meet the actual demand, better production flow with respect to the cover production section and the assembly of finished mattresses. Analysis of the relevant costs, e.g. set up costs and cyclic inventory costs for the cycle time equal to 1 day and 3,5 days is presented in Table 4 below.

Table 4. Relevant costs for the optimal and chosen cycle times

	T = 1 day	T = 3,5 days
Set up cost	206 667	58 861
Cyclic inventory cost	35 489	124 607
Total	242 156	183 468

The difference is equal to 58 688 NOK which represents costs related to the more practical solution. The cycle time for the mold production is set to one day according to the arguments for practical reasons from Wonderland.
We assume that the variation and the demand follows a normal curve distribution.

Due to differences between the demand rate in peak months (high season, HS) and low demand rate months (low season, LS), we will distinguish these periods in our calculations. Standard deviation of demand during lead time is calculated based on the historical data from 2016 and 2017. Lot size sets equal to the average demand during lead time, e.g. one day which is calculated based on the demand forecast for 2018. The high season includes January, February, August and September and accounts for a total of 85 working days, the low season includes March, April, May, June, July, October, November and December accounting for 139 working days.

The results for the calculated lot size and the standard deviation of the demand during lead time for the A-items are presented in the Table 5 below.
The specific production quantity will be decided on a day-to-day basis based on the actual demand.

Table 5. The calculated lot size and the standard deviation of the demand during lead time for A-items.

Number	UBIT_FIRMNESS	MMITDS	Average demand per day_HS	Average demand per day_LS	Standard deviation of the demand during lead time_HS	Standard deviation of the demand during lead time_LS
1	5504020-00	CO/EX WE KONT BENK 90x200	59	42	18	16
2	5000020-04	INNL STANDARD WE 90x200	33	25	12	11
3	5155001	INNL BENK BASIC POC WE 75x200	26	20	18	9
4	5000001-04	INNL STANDARD WE 75x200	25	19	10	6
5	5504001-00	CO/EX WE KONT BENK 75x200	23	15	6	7
6	5003020-04	INNL EXCLUSIVE LA 90x200	22	14	25	18
7	5155020	INNL BENK BASIC POC WE 90x200	21	16	17	8
8	5000020-00	INNL STANDARD WE 90x200	16	15	14	11
9	5000001-00	INNL STANDARD WE 75x200	15	12	12	5
10	5003020-00	INNL EXCLUSIVE LA 90x200	11	7	16	12

4.2.1.2 Service level

Axsäter (2000) argues that it is quite difficult to obtain low inventory costs and a smooth capacity utilization. He suggests to solve the deterministic problem of lot sizing first and as a second step, apply decision rules for stochastic demand.

The probability of not stocking out in the lead time can be specified as Service level type 1. This type of service level measure is appropriate to use when the consequence of not meeting demand is the same independent of amount of items (Nahmias, 2009). The cost of not meeting the demand is a fixed value B1 (Silver , et al., 1998).

It seems appropriate to apply Service level type 1 since the stock out situation results in extra set ups and interruptions of the production process. It is common to assume that shortage costs of not meeting the demand are usually higher compared to holding costs (Waters, 1992).
As a protection against the variations in demand safety stock may be established (Axsäter, 2000).

Wonderland realises that safety stock implies additional investments but it will obtain protection in cases when the demand higher than expected. Stock out situation can have the following costs: excessive setups, costs associated with rush order, document handling of production order release, scheduling and control. (Chapman, 2006). Variability in the arrival process of backlog orders can lead to queues and increase lead time (Graves, et al., 1993).

Use of overtime can be necessary in order to achieve the planned production lead time requirements. Changes in the production plan can lead to nervousness or instability of the production process (Vollmann, et al., 2005).

Based on the above mentioned impacts estimation of the stock out cost (penalty) at Wonderland may be as follows:

Set up cost: extra setup cost of 93 NOK.
Document handling: total 10 minutes including order handling in sales, mold production, cover production and assembly departments. With an average wage cost of 280 NOK the price for document handling is equal to 280*10/60 = 47 NOK.
Nervousness cost: Related costs can be estimated at 400 NOK.
Overtime cost: Products must be assembled and moved to FGI, that means that the overtime cost should include costs in all departments. Average daily lot size per A-item is

around 20 molds. Overtime requirement is about 0.75 hour with 4 workers involved * 420 NOK/hour (50% more than regular time) = 1260 NOK. The estimation of the B1 penalty for the A-group for both seasons is presented in the Table 6 below.

Table 6. The estimation of the stock out penalty B1 for two seasons A-items.

Cost elements	High season	Low season
Extra set up cost	93	93
Document handling cost	47	47
Instability cost	400	400
Overtime cost	1260	0
Total B1 penalty	**1800**	**540**

Silver, et al., (1998) presents an approach using expected total relevant costs (ETRC), which is the function of the k-parameter (safety factor). In order to find an optimal value of the k-parameter for the given lot size, following formula can be used:

$$k = \sqrt{2 \ln \frac{D * B1}{\sqrt{2\pi} * Q * v * r * \sigma \text{ lead time}}}$$

For the given lot size it is sufficient to analyse safety stock and stock out costs.

Safety stock cost = $\sigma_{\text{lead time}} * v * r * k$

Stock out cost = $D * B1 * P_{u>=}(k) / Q$, where

$\sigma_{\text{lead time}}$ – the standard deviation of the demand during lead time

v – unit cost

r – internal interest rate

k – safety factor

D – demand rate

B1 – stock out occasion penalty

Pu >= (k) - Probability {stock out in a lead time}

Q – calculated lot size

Figures 25 and 26 show the optimal value of the k-parameter, P1 service level and total relevant cost for the A-items during two seasons.

UBIT_FIRMNESS	MMITDS	Lot size	$\sigma_{lead\ time}$	Demand	Unit cost	Setup cost	B1	r	k	Safety stock cost	pu>=(k) = 1 - P1	Stock out cost	Total relevant cost	P1
5504020-00	CO/EX WE KONT BENK 90x200	42	16	5 779	685	93	540	0,16	2,37	4 230	0,008894	661	4 891	99,11
5000020-04	INNL STANDARD WE 90x200	25	11	3 408	685	93	540	0,16	2,52	3 091	0,005868	432	3 523	99,41
5155001	INNL BENK BASIC POC WE 75x200	20	9	2 824	685	93	540	0,16	2,61	2 621	0,004527	345	2 966	99,55
5000001-04	INNL STANDARD WE 75x200	19	6	2 675	685	93	540	0,16	2,76	1 848	0,002890	220	2 067	99,71
5504001-00	CO/EX WE KONT BENK 75x200	15	7	2 150	685	93	540	0,16	2,71	2 117	0,003364	260	2 377	99,66
5003020-04	INNL EXCLUSIVE LA 90x200	14	18	1 923	685	93	540	0,16	2,32	4 656	0,010170	754	5 411	98,98
5155020	INNL BENK BASIC POC WE 90x200	16	8	2 252	685	93	540	0,16	2,66	2 369	0,003907	297	2 666	99,61
5000020-00	INNL STANDARD WE 90x200	15	11	2 146	685	93	540	0,16	2,54	3 115	0,005543	428	3 543	99,45
5000001-00	INNL STANDARD WE 75x200	12	5	1 674	685	93	540	0,16	2,83	1 574	0,002327	175	1 750	99,77
5003020-00	INNL EXCLUSIVE LA 90x200	7	12	1 024	685	93	540	0,16	2,51	3 363	0,006037	477	3 840	99,40
										28 984		4 050	**33 034**	

Figure 25. The optimal value of the k-parameter, P1 service level and total relevant cost for the A-items during the low season.

UBIT_FIRMNESS	MMITDS	Lot size	$\sigma_{lead\ time}$	Demand	Unit cost	Setup cost	B1	r	k	Safety stock cost	pu>=(k) = 1 - P1	Stock out cost	Total relevant cost	P1
5504020-00	CO/EX WE KONT BENK 90x200	59	18	4 988	685	93	1800	0,08	2,87	2 873	0,002052	312	3 185	99,79
5000020-04	INNL STANDARD WE 90x200	33	12	2 844	685	93	1800	0,08	3,01	2 012	0,001306	203	2 214	99,87
5155001	INNL BENK BASIC POC WE 75x200	26	18	2 251	685	93	1800	0,08	2,87	2 881	0,002052	320	3 201	99,79
5000001-04	INNL STANDARD WE 75x200	25	10	2 116	685	93	1800	0,08	3,06	1 707	0,001107	169	1 875	99,89
5504001-00	CO/EX WE KONT BENK 75x200	23	6	1 959	685	93	1800	0,08	3,23	1 079	0,000619	95	1 174	99,94
5003020-04	INNL EXCLUSIVE LA 90x200	22	25	1 834	685	93	1800	0,08	2,74	3 820	0,003072	461	4 281	99,69
5155020	INNL BENK BASIC POC WE 90x200	21	17	1 775	685	93	1800	0,08	2,89	2 732	0,001926	293	3 025	99,81
5000020-00	INNL STANDARD WE 90x200	16	14	1 356	685	93	1800	0,08	2,95	2 302	0,001589	242	2 545	99,84
5000001-00	INNL STANDARD WE 75x200	15	12	1 265	685	93	1800	0,08	3,00	2 007	0,001350	205	2 212	99,87
5003020-00	INNL EXCLUSIVE LA 90x200	11	16	941	685	93	1800	0,08	2,91	2 594	0,001807	278	2 872	99,82
										24 006		2 578	**26 584**	

Figure 26. The optimal value of the k-parameter, P1 service level and total relevant cost for the A-items during the high season.

It can be easy to understand and implement for Wonderland a common service level for both A- and B-items. One of the objectives of the strategy transformation was to reduce amount of the capital tired up in finished goods. Since there is a direct relationship between the k-parameter and the safety stock value, it can be recommended to use lower than optimal service level for Wonderland.

The analysis of the ETRC for different service levels (99%, 98% and 97%) for the low and high seasons are presented in Figure 27 and Figure 28. Internal interest rate r is calculated based on a 8 month duration for the low season and 4 month duration for the high season.

									99 %			98 %			97 %	
UBIT_FIRMNESS	MMITDS	Lot size	$\sigma_{lead\ time}$	Demand	Unit cost	Setup cost	B1	r	Safety stock cost	Stockout cost	Sum	Safety stock cost	Stock out cost	Sum	Safety stock cost	Stock out cost	Sum
5504020-00	CO/EX WE KONT BENK 90x200	42	16	5 779	685	93	540	0,16	4 155	743	4 898	3 656	1 486	5 142	3 352	2 229	5 581
5000020-04	INNL STANDARD WE 90x200	25	11	3 408	685	93	540	0,16	2 856	736	3 593	2 513	1 472	3 985	2 305	2 208	4 513
5155001	INNL BENK BASIC POC WE 75x200	20	9	2 824	685	93	540	0,16	2 337	762	3 100	2 056	1 525	3 581	1 886	2 287	4 173
5000001-04	INNL STANDARD WE 75x200	19	6	2 675	685	93	540	0,16	1 558	760	2 318	1 371	1 521	2 891	1 257	2 281	3 538
5504001-00	CO/EX WE KONT BENK 75x200	15	7	2 150	685	93	540	0,16	1 818	774	2 592	1 599	1 548	3 147	1 467	2 322	3 789
5003020-04	INNL EXCLUSIVE LA 90x200	14	18	1 923	685	93	540	0,16	4 674	742	5 416	4 112	1 483	5 596	3 771	2 225	5 997
5155020	INNL BENK BASIC POC WE 90x200	16	8	2 252	685	93	540	0,16	2 077	760	2 837	1 828	1 520	3 348	1 676	2 280	3 956
5000020-00	INNL STANDARD WE 90x200	15	11	2 146	685	93	540	0,16	2 856	773	3 629	2 513	1 545	4 058	2 305	2 318	4 622
5000001-00	INNL STANDARD WE 75x200	12	5	1 674	685	93	540	0,16	1 298	753	2 052	1 142	1 507	2 649	1 048	2 260	3 308
5003020-00	INNL EXCLUSIVE LA 90x200	7	12	1 024	685	93	540	0,16	3 116	790	3 906	2 742	1 580	4 322	2 514	2 370	4 884
									26 747	7 593	**34 340**	23 533	15 187	**38 719**	21 581	22 780	**44 361**

Figure 27. The results of analysis of the ETRC for different service levels for the low season.

This shows that the service level for the low demand months corresponding to 99% gives the lowest sum of the total safety stock and stock out costs equalling to 34 340 NOK.

									99 %			98 %			97 %	
UBIT_FIRMNESS	MMITDS	Lot size	$\sigma_{lead\ time}$	Demand	Unit cost	Setup cost	B1	r	Safety stock cost	Stockout cost	Sum	Safety stock cost	Stock out cost	Sum	Safety stock cost	Stock out cost	Sum
5504020-00	CO/EX WE KONT BENK 90x200	59	18	4 988	685	93	1800	0,08	2 336	1 522	3 857	2 055	3 044	5 099	1 885	4 565	6 450
5000020-04	INNL STANDARD WE 90x200	33	12	2 844	685	93	1800	0,08	1 557	1 551	3 108	1 370	3 103	4 473	1 256	4 654	5 910
5155001	INNL BENK BASIC POC WE 75x200	26	18	2 251	685	93	1800	0,08	2 336	1 558	3 894	2 055	3 117	5 172	1 885	4 675	6 560
5000001-04	INNL STANDARD WE 75x200	25	10	2 116	685	93	1800	0,08	1 298	1 524	2 821	1 142	3 047	4 189	1 047	4 571	5 618
5504001-00	CO/EX WE KONT BENK 75x200	23	6	1 959	685	93	1800	0,08	779	1 533	2 312	685	3 066	3 751	628	4 599	5 228
5003020-04	INNL EXCLUSIVE LA 90x200	22	25	1 834	685	93	1800	0,08	3 244	1 501	4 745	2 854	3 001	5 855	2 617	4 502	7 119
5155020	INNL BENK BASIC POC WE 90x200	21	17	1 775	685	93	1800	0,08	2 206	1 522	3 728	1 941	3 044	4 984	1 780	4 565	6 345
5000020-00	INNL STANDARD WE 90x200	16	14	1 356	685	93	1800	0,08	1 817	1 526	3 342	1 598	3 051	4 649	1 466	4 577	6 042
5000001-00	INNL STANDARD WE 75x200	15	12	1 265	685	93	1800	0,08	1 557	1 519	3 076	1 370	3 037	4 407	1 256	4 556	5 812
5003020-00	INNL EXCLUSIVE LA 90x200	11	16	941	685	93	1800	0,08	2 076	1 540	3 616	1 827	3 080	4 906	1 675	4 619	6 295
									19 204	15 294	**34 499**	16 896	30 589	**47 485**	15 495	45 883	**61 378**

Figure 28. The results of analysis of the ETRC for different service levels for the high season.

The lowest sum of the total safety stock and stock out costs equalling to 34 499 NOK corresponds to the 99% service level for the high demand months. Due to high volume of A-products contributing with 55.5% of the total forecasted demand value and four days lead time to customers it seems reasonable to maintain a service level equal to 99% which is lower than optimal, but it gives reasonable safety stock level.

Different inventory control methods can be applied to different groups of items (Axsäter, 2000). Due to daily production at Wonderland, a periodic review inventory policy with the review interval of one day will provide a possibility for adjustment of production capacity to the demand variations resulting in smooth capacity utilization.

The value for the control parameter S and the safety stock for periodic (R,S) system can be calculated as follows:

Safety stock = safety factor (k) * Standard deviation of the demand during lead time;

S (order up-to-level) = Safety stock + Calculated lot size.

Implementation of the periodic review (R,S) policy with the review interval equal to one day means that Wonderland will produce a flexible quantity of each of the 10 A-items in order to raise the inventory position to the level S.

Values for the calculated lot size, safety stock and S-level for the high and low seasons for the A-group are presented in the Table 7 below. Aggregate daily production of the A-items will amount to 251 items in the high season and to 185 items in the low season.

Table 7. The calculated lot size, safety stock and S-parameter for both seasons' A-items

Number	UBIT_FIRMNESS	MMITDS	Calculated lot size_HS	Calculated lot size_LS	Safety stock_HS	Safety stock_LS	S_HS	S_LS
1	5504020-00	CO/EX WE KONT BENK 90x200	59	42	42	37	101	79
2	5000020-04	INNL STANDARD WE 90x200	33	25	28	26	61	51
3	5155001	INNL BENK BASIC POC WE 75x200	26	20	42	21	68	41
4	5000001-04	INNL STANDARD WE 75x200	25	19	23	14	48	33
5	5504001-00	CO/EX WE KONT BENK 75x200	23	15	14	16	37	31
6	5003020-04	INNL EXCLUSIVE LA 90x200	22	14	58	42	80	56
7	5155020	INNL BENK BASIC POC WE 90x200	21	16	40	19	61	35
8	5000020-00	INNL STANDARD WE 90x200	16	15	33	26	49	41
9	5000001-00	INNL STANDARD WE 75x200	15	12	28	12	43	24
10	5003020-00	INNL EXCLUSIVE LA 90x200	11	7	37	28	48	35

4.2.1.3 Capacity

With the total safety stock value equalling to 241 A-items in the low season and 345 items in the high season and respective daily production of 185 and 251 items, given 426 items during the low season and of 596 A-items in the high season there will be enough space capacity in the FGI storage. It is worth clarifying that since finished products may consist of different number of mattresses, the capacity is calculated on the basis of a single mattress.

There will be no production during three weeks in July due to summer holidays, but the sales department will process orders and will ship available goods (e-mail from 08.02.2018). We make the assumption that some of the July demand will be met by production during 6 working days in July, while the remaining demand will be met in August with the help of prolonged customers lead time.

4.2.2 B-items

The B-group of molds will follow the ATO production strategy. It accounts for 36.7% of the total forecasted sales in 2018 and a customers lead time equalling to 6 days.

4.2.2.1 Lot-sizing

Initially, Wonderland informed us that they consider 85 items belonging to the B-category. After sales data was grouped and analysed the authors suggested to assign only 69 items to the B-group due to their total sales volume per annum. 3 of those 69 items had dimensions which would not fit into the pallets in the subassembly buffer and they were assigned to the C-group. The B-group consists of 66 items, which will be premanufactured and stored in the subassembly buffer with a max capacity of 550 molds. Wonderland states that in order to smooth both production line capacity utilization and the utilization of the space in the subassembly buffer, production of the B-items should follow a production cycle equal to one day. Table 8 shows values for the calculated lot size and the standard deviation of the demand during lead time for the B-group for both seasons.

Analysis of the average demand during lead time shows that mainly 28 of total 66 items have a calculated lot size greater than one. It is appropriate to move those items with lot size equal to one or lower to the C-group with low demand items following the make-to-order production strategy. The production plan for the remaining 28 items in the B-group will contribute to a daily production with 123 items in the high season and 101 items will be produced daily during the eight months with a low demand rate.

Table 8. The calculated lot size and the standard deviation of the demand during lead time for the B-group for both seasons.

Number	UBIT_FIRMNESS	MMITDS	Average demand per day_HS	Average demand per day_LS	Standard deviation of the demand during lead time_HS	Standard deviation of the demand during lead time_LS
1	5003001-04	INNL EXCLUSIVE LA 75x200	14	8	5	3
2	5506520-00	KONT BENK 900 90x200	13	11	9	7
3	5002020-04	INNL COMFORT WE 90x200	10	11	12	12
4	5003001-00	INNL EXCLUSIVE LA 75x200	8	5	3	3
5	5002001-04	INNL COMFORT WE 75x200	6	4	2	2
6	5005020-04	INNL COMF LATEX 90x200	5	5	9	5
7	5504006-00	CO/EX WE KONT BENK 80x200	5	4	2	2
8	5504021-00	CO/EX WE KONT BENK 90x210	5	3	2	2
9	5002020-00	INNL COMFORT WE 90x200	5	5	7	8
10	5005020-00	INNL COMF LATEX 90x200	4	4	6	4
11	5000006-04	INNL STANDARD WE 80x200	4	3	2	3
12	5003021-04	INNL EXCLUSIVE LA 90x210	4	3	2	1
13	5003020-08	INNL EXCLUSIVE LA 90x200	3	2	3	3
14	5000040-00	INNL STANDARD WE 120x200	3	2	2	2
15	5000040-04	INNL STANDARD WE 120x200	3	2	2	2
16	5002001-00	INNL COMFORT WE 75x200	3	3	1	2
17	5506506-00	KONT BENK 900 80x200	3	4	2	4
18	5000020-08	INNL STANDARD WE 90x200	3	2	3	3
19	5000006-00	INNL STANDARD WE 80x200	3	2	1	1
20	5003520-04	INNL EXCLUSIVE WE 90x200	3	3	3	2
21	5003006-04	INNL EXCLUSIVE LA 80x200	2	3	2	5
22	5003006-00	INNL EXCLUSIVE LA 80x200	2	2	2	4
23	5504026-00	CO/EX WE KONT BENK 105x210	2	2	1	1
24	5000021-04	INNL STANDARD WE 90x210	2	2	1	1
25	5002020-08	INNL COMFORT WE 90x200	2	1	3	1
26	5003021-00	INNL EXCLUSIVE LA 90x210	2	2	1	1
27	5003026-04	INNL EXCLUSIVE LA 105x210	2	1	1	1
28	5155006	INNL BENK BASIC POC WE 80x200	2	2	1	1
29	5155040	INNL BENK BASIC POC WE 120x200	1	1	1	0
30	5005020-08	INNL COMF LATEX 90x200	1	0	2	2
31	5000091	INNL ST WE SPESIAL 70-90	1	1	1	1
32	5506521-00	KONT BENK 900 90x210	1	1	1	1
33	1302020-04	COMF WE RA 90x200	1	1	1	1
34	5155021	INNL BENK BASIC POC WE 90x210	1	1	1	1
35	5000021-00	INNL STANDARD WE 90x210	1	1	1	1
36	5002001-08	INNL COMFORT WE 75x200	1	1	1	1
37	5002006-04	INNL COMFORT WE 80x200	1	1	2	1
38	5507020-00	KONT BENK 1000 90x200	1	2	1	2
39	5003020-02	INNL EXCLUSIVE LA 90x200	1	1	2	1
40	5003026-00	INNL EXCLUSIVE LA 105x210	1	1	1	1
41	5506526-00	KONT BENK 900 105x210	1	1	1	1
42	5003001-08	INNL EXCLUSIVE LA 75x200	1	1	1	1
43	1402020-04	COMF LA RA 90x200	1	0	1	1
44	5000026-04	INNL STANDARD WE 105x210	1	1	1	1
45	5504040-00	CO/EX WE KONT BENK 120x200	1	1	1	0
46	5000000-04	INNL STANDARD WE 75x190	1	0	1	0
47	5005021-04	INNL COMF LATEX 90x210	1	1	1	0
48	2602020-04	SUPERIOR RAMME 90x200	1	1	0	1
49	5003021-08	INNL EXCLUSIVE LA 90x210	1	1	0	0
50	5003006-08	INNL EXCLUSIVE LA 80x200	1	1	0	1
51	5000025-00	INNL STANDARD WE 105x200	1	0	1	0
52	1302020-00	COMF WE RA 90x200	1	0	0	0
53	5000000-00	INNL STANDARD WE 75x190	1	0	1	1
54	1402020-00	COMF LA RA 90x200	1	1	1	1
55	4402020-00	CLASSIC WE RA 90x200	1	0	0	0
56	4352020-04	ST RA 90x200	0	2	1	4
57	5003220-04	INNL EXCLUSIVE LA 90x200 SR	0	3	0	3
58	5003220-00	INNL EXCLUSIVE LA 90x200 SR	0	2	0	3
59	5002006-00	INNL COMFORT WE 80x200	0	0	1	1
60	5005001-04	INNL COMF LATEX 75x200	0	0	2	1
61	5005006-04	INNL COMF LATEX 80x200	0	0	1	1
62	5002021-04	INNL COMFORT WE 90x210	0	0	1	0
63	5003526-04	INNL EXCLUSIVE WE 105x210	0	1	1	2
64	5000025-04	INNL STANDARD WE 105x200	0	0	0	0
65	5005006-00	INNL COMF LATEX 80x200	0	1	1	1
66	5000092	INNL ST WE SPESIAL 91-120	0	0	1	0

4.2.2.2 Service level

Service level P1 will be applied to the B-group as well, however the stock out cost element associated with nervousness is reduced to 100 NOK. The reduction is related to the lower impact of instability of the production process due to a longer agreed customer lead time of six days compared to four days for the A-items.

Calculations of the B1 penalty for the high season should include overtime cost which can be approximated in the following way: average daily lot size for items in the B-group is around 4 molds. Overtime requirement is about 0.15 hours with 2 workers involved * 420 NOK/hour (50% more than regular time) = 126 NOK. The estimation of the B1 penalty for the B-group for both seasons is presented in Table 9 below.

Table 9. The estimation of the stock out penalty B1 for two seasonal B-items.

Cost elements	High season	Low season
Extra set up cost	93	93
Document handling cost	47	47
Instability cost	100	100
Overtime cost	126	0
Total B1 penalty	**366**	**240**

The ETRC approach is applied for different service levels, lower than optimal, for the low season B-items and the results are presented in the Figure 29 below. Expected total relevant costs equals to 31777 NOK for the given 99% service level.

										99 %			98 %			97 %	
Number	UBIT_FIRMNESS	MMITDS	Lot size	$\sigma_{lead\ time}$	Demand	Unit cost	Setup cost	B1	r	Safety stock cost	Stock out cost	Sum	Safety stock cost	Stock out cost	Sum	Safety stock cost	Stock out cost	Sum
1	5003001-04	INNL EXCLUSIVE LA 75x200	8	3	1 136	685	93	240	0,163	779	341	1 120	685	682	1 367	629	1 022	1 651
2	5506520-00	KONT BENK 900 90x200	11	7	1 496	685	93	240	0,163	1 818	326	2 144	1 599	653	2 252	1 467	979	2 446
3	5002020-04	INNL COMFORT WE 90x200	11	12	1 477	685	93	240	0,163	3 116	322	3 438	2 742	645	3 386	2 514	967	3 481
4	5003001-00	INNL EXCLUSIVE LA 75x200	5	3	636	685	93	240	0,163	779	305	1 084	685	611	1 296	629	916	1 544
5	5002001-04	INNL COMFORT WE 75x200	4	2	572	685	93	240	0,163	519	343	863	457	686	1 143	419	1 030	1 449
6	5005020-04	INNL COMF LATEX 90x200	5	5	745	685	93	240	0,163	1 298	358	1 656	1 142	715	1 858	1 048	1 073	2 120
7	5504006-00	CO/EX WE KONT BENK 80x200	4	2	577	685	93	240	0,163	519	346	866	457	692	1 149	419	1 039	1 458
8	5504021-00	CO/EX WE KONT BENK 90x210	3	2	443	685	93	240	0,163	519	354	874	457	709	1 166	419	1 063	1 482
9	5002020-00	INNL COMFORT WE 90x200	5	8	760	685	93	240	0,163	2 077	365	2 442	1 828	730	2 557	1 676	1 094	2 771
10	5005020-00	INNL COMF LATEX 90x200	4	4	560	685	93	240	0,163	1 039	336	1 375	914	672	1 586	838	1 008	1 846
11	5000006-04	INNL STANDARD WE 80x200	3	3	468	685	93	240	0,163	779	374	1 153	685	749	1 434	629	1 123	1 752
12	5003021-04	INNL EXCLUSIVE LA 90x210	3	1	354	685	93	240	0,163	260	283	543	228	566	795	210	850	1 059
13	5003020-08	INNL EXCLUSIVE LA 90x200	2	3	330	685	93	240	0,163	779	396	1 175	685	792	1 477	629	1 188	1 817
14	5000040-00	INNL STANDARD WE 120x200	2	2	325	685	93	240	0,163	519	390	909	457	780	1 237	419	1 170	1 589
15	5000040-04	INNL STANDARD WE 120x200	2	2	334	685	93	240	0,163	519	401	920	457	802	1 259	419	1 202	1 621
16	5002001-00	INNL COMFORT WE 75x200	3	2	364	685	93	240	0,163	519	291	811	457	582	1 039	419	874	1 293
17	5506506-00	KONT BENK 900 80x200	4	4	522	685	93	240	0,163	1 039	313	1 352	914	626	1 540	838	940	1 778
18	5000020-08	INNL STANDARD WE 90x200	2	3	313	685	93	240	0,163	779	376	1 155	685	751	1 437	629	1 127	1 755
19	5000006-00	INNL STANDARD WE 80x200	2	1	327	685	93	240	0,163	260	392	652	228	785	1 013	210	1 177	1 387
20	5003520-04	INNL EXCLUSIVE WE 90x200	3	2	352	685	93	240	0,163	519	282	801	457	563	1 020	419	845	1 264
21	5003006-04	INNL EXCLUSIVE LA 80x200	3	5	349	685	93	240	0,163	1 298	279	1 578	1 142	558	1 701	1 048	838	1 885
22	5003006-00	INNL EXCLUSIVE LA 80x200	2	4	220	685	93	240	0,163	1 039	264	1 303	914	528	1 442	838	792	1 630
23	5504026-00	CO/EX WE KONT BENK 105x210	2	1	271	685	93	240	0,163	260	325	585	228	650	879	210	976	1 185
24	5000021-04	INNL STANDARD WE 90x210	2	1	211	685	93	240	0,163	260	253	513	228	506	735	210	760	969
25	5002020-08	INNL COMFORT WE 90x200	1	1	191	685	93	240	0,163	260	458	718	228	917	1 145	210	1 375	1 585
26	5003021-00	INNL EXCLUSIVE LA 90x210	2	1	220	685	93	240	0,163	260	264	524	228	528	756	210	792	1 002
27	5003026-04	INNL EXCLUSIVE LA 105x210	1	1	186	685	93	240	0,163	260	446	706	228	893	1 121	210	1 339	1 549
28	5155006	INNL BENK BASIC POC WE 80x200	2	1	216	685	93	240	0,163	260	259	519	228	518	747	210	778	987
										22 332	9 445	**31 777**	19 649	18 890	**38 538**	18 019	28 335	**46 354**

Figure 29. The results of analysis of the ETRC for different service levels for the low season B-items.

For the high season B-items, expected total relevant costs equals to 20697 NOK for the given 99% service level. The results are presented in the Figure 30 below.

										99 %			98 %			97 %		
Number	UBIT_FIRMNESS	MMITDS	Lot size	$\sigma_{\text{lead time}}$	Demand	Unit cost	Setup cost	B1	r	Safety stock cost	Stock out cost	Sum	Safety stock cost	Stock out cost	Sum	Safety stock cost	Stock out cost	Sum
1	5003001-04	INNL EXCLUSIVE LA 75x200	14	5	1 194	685	93	366	0,081	649	312	961	571	624	1 195	523	936	1 460
2	5506520-00	KONT BENK 900 90x200	13	9	1 066	685	93	366	0,081	1 168	300	1 468	1 027	600	1 628	942	900	1 843
3	5002020-04	INNL COMFORT WE 90x200	10	12	888	685	93	366	0,081	1 557	325	1 882	1 370	650	2 020	1 256	975	2 231
4	5003001-00	INNL EXCLUSIVE LA 75x200	8	3	685	685	93	366	0,081	389	313	703	342	627	969	314	940	1 254
5	5002001-04	INNL COMFORT WE 75x200	6	2	520	685	93	366	0,081	260	317	577	228	634	863	209	952	1 161
6	5005020-04	INNL COMF LATEX 90x200	5	9	460	685	93	366	0,081	1 168	337	1 505	1 027	673	1 701	942	1 010	1 952
7	5504006-00	CO/EX WE KONT BENK 80x200	5	2	414	685	93	366	0,081	260	303	563	228	606	834	209	909	1 119
8	5504021-00	CO/EX WE KONT BENK 90x210	5	2	415	685	93	366	0,081	260	304	563	228	608	836	209	911	1 121
9	5002020-00	INNL COMFORT WE 90x200	5	7	423	685	93	366	0,081	908	310	1 218	799	619	1 418	733	929	1 662
10	5005020-00	INNL COMF LATEX 90x200	4	6	362	685	93	366	0,081	779	331	1 110	685	662	1 347	628	994	1 622
11	5000006-04	INNL STANDARD WE 80x200	4	2	299	685	93	366	0,081	260	274	533	228	547	776	209	821	1 030
12	5003021-04	INNL EXCLUSIVE LA 90x210	4	2	336	685	93	366	0,081	260	307	567	228	615	843	209	922	1 132
13	5003020-08	INNL EXCLUSIVE LA 90x200	3	3	286	685	93	366	0,081	389	349	738	342	698	1 040	314	1 047	1 361
14	5000040-00	INNL STANDARD WE 120x200	3	2	283	685	93	366	0,081	260	345	605	228	691	919	209	1 036	1 245
15	5000040-04	INNL STANDARD WE 120x200	3	2	290	685	93	366	0,081	260	354	614	228	709	937	209	1 063	1 272
16	5002001-00	INNL COMFORT WE 75x200	3	1	275	685	93	366	0,081	130	336	465	114	671	785	105	1 007	1 111
17	5506506-00	KONT BENK 900 80x200	3	2	291	685	93	366	0,081	260	355	615	228	710	938	209	1 065	1 274
18	5000020-08	INNL STANDARD WE 90x200	3	3	262	685	93	366	0,081	389	320	709	342	639	982	314	959	1 273
19	5000006-00	INNL STANDARD WE 80x200	3	1	216	685	93	366	0,081	130	264	393	114	527	641	105	791	895
20	5003520-04	INNL EXCLUSIVE WE 90x200	3	3	250	685	93	366	0,081	389	305	694	342	610	952	314	915	1 229
21	5003006-04	INNL EXCLUSIVE LA 80x200	2	2	192	685	93	366	0,081	260	351	611	228	703	931	209	1 054	1 264
22	5003006-00	INNL EXCLUSIVE LA 80x200	2	2	216	685	93	366	0,081	260	395	655	228	791	1 019	209	1 186	1 395
23	5504026-00	CO/EX WE KONT BENK 105x210	2	1	198	685	93	366	0,081	130	362	492	114	725	839	105	1 087	1 192
24	5000021-04	INNL STANDARD WE 90x210	2	1	181	685	93	366	0,081	130	331	461	114	662	776	105	993	1 097
25	5002020-08	INNL COMFORT WE 90x200	2	3	162	685	93	366	0,081	389	296	686	342	593	935	314	889	1 203
26	5003021-00	INNL EXCLUSIVE LA 90x210	2	1	186	685	93	366	0,081	130	340	470	114	681	795	105	1 021	1 126
27	5003026-04	INNL EXCLUSIVE LA 105x210	2	1	165	685	93	366	0,081	130	302	432	114	604	718	105	906	1 011
28	5155006	INNL BENK BASIC POC WE 80x200	2	1	153	685	93	366	0,081	130	280	410	114	560	674	105	840	945
										11 678	9 019	**20 697**	10 275	18 038	**28 313**	9 423	27 058	**36 480**

Figure 30. The results of analysis of the ETRC for different service levels for the high season B-items.

Table 10. The calculated lot size, safety stock and S-parameter for both seasons B-items.

Number	UBIT_FIRMNESS	MMITDS	Calculated lot size_HS	Calculated lot size_LS	Safety stock_HS	Safety stock_LS	S_HS	S_LS
1	5003001-04	INNL EXCLUSIVE LA 75x200	14	8	12	7	26	15
2	5506520-00	KONT BENK 900 90x200	13	11	21	16	34	27
3	5002020-04	INNL COMFORT WE 90x200	10	11	28	28	38	39
4	5003001-00	INNL EXCLUSIVE LA 75x200	8	5	7	7	15	12
5	5002001-04	INNL COMFORT WE 75x200	6	4	5	5	11	9
6	5005020-04	INNL COMF LATEX 90x200	5	5	21	12	26	17
7	5504006-00	CO/EX WE KONT BENK 80x200	5	4	5	5	10	9
8	5504021-00	CO/EX WE KONT BENK 90x210	5	3	5	5	10	8
9	5002020-00	INNL COMFORT WE 90x200	5	5	16	19	21	24
10	5005020-00	INNL COMF LATEX 90x200	4	4	14	9	18	13
11	5000006-04	INNL STANDARD WE 80x200	4	3	5	7	9	10
12	5003021-04	INNL EXCLUSIVE LA 90x210	4	3	5	2	9	5
13	5003020-08	INNL EXCLUSIVE LA 90x200	3	2	7	7	10	9
14	5000040-00	INNL STANDARD WE 120x200	3	2	5	5	8	7
15	5000040-04	INNL STANDARD WE 120x200	3	2	5	5	8	7
16	5002001-00	INNL COMFORT WE 75x200	3	3	2	5	5	8
17	5506506-00	KONT BENK 900 80x200	3	4	5	9	8	13
18	5000020-08	INNL STANDARD WE 90x200	3	2	7	7	10	9
19	5000006-00	INNL STANDARD WE 80x200	3	2	2	2	5	4
20	5003520-04	INNL EXCLUSIVE WE 90x200	3	3	7	5	10	8
21	5003006-04	INNL EXCLUSIVE LA 80x200	2	3	5	12	7	15
22	5003006-00	INNL EXCLUSIVE LA 80x200	2	2	5	9	7	11
23	5504026-00	CO/EX WE KONT BENK 105x210	2	2	2	2	4	4
24	5000021-04	INNL STANDARD WE 90x210	2	2	2	2	4	4
25	5002020-08	INNL COMFORT WE 90x200	2	1	7	2	9	3
26	5003021-00	INNL EXCLUSIVE LA 90x210	2	2	2	2	4	4
27	5003026-04	INNL EXCLUSIVE LA 105x210	2	1	2	2	4	3
28	5155006	INNL BENK BASIC POC WE 80x200	2	2	2	2	4	4

Applying an (R,S) inventory policy for the B-group with the review interval equal to one day, the following calculated lot sizes, safety stock levels and the S-parameter (order up-to-level) values are obtained and presented in Table 10 above.

4.2.2.3 Capacity

With the daily production of 123 and 101 B-items and the safety stock of 211 and 200 items in the high and the low seasons respectively, the expected number of the B-items in the subassembly buffer equals to 334 and 301. There is an excess capacity in the buffer equal to 550 – 333 = 217 items in the high season and 550 – 301 = 249 items in the low season. In case of a rush order which can delay withdrawal of components from the subassembly buffer, capacity for a 1.7 and a 2.5 days production volume (during high and low seasons respectively) is available.

We make the assumption that a part of the July demand for the B-items will be met during 6 working days in July. In order to satisfy the remaining demand, the extension of the announced lead time is required.

4.2.3 C-items

38 items were moved from the B-group to the C-group resulting in total 273 items and the total forecasted amount of molds equal to 13156 which corresponds to 15.5% of the total forecasted amount for all types of molds. The C-group will follow the make-to-order production strategy and Table 11 shows the approximation for daily production quantities.

Table 11. Daily production quantities for the C-group.

C-group	jan.18	feb.18	mar.18	apr.18	mai.18	jun.18	jul.18	aug.18	sep.18	okt.18	nov.18	des.18
Demand	1430	1102	990	1251	1027	1391	702	1404	1234	945	1126	554
Number of working days	22	20	17	19	17	21	6	23	20	23	22	14
Production per day, units	65	55	58	66	60	66	117	61	62	41	51	40

The C-items do not fully follow the seasonal pattern in comparison with the A- and B-items if we look at the demand forecast in isolation. Seasonal segregation however will remain for all three groups of items in total.

We make the assumption that some of C-items will be produced during the six working days in July. Some of the customers will wait more than three weeks and those C-items will be produced in August. A longer lead time will be required in order to meet the rest of the demand.

Average demand per day for the high season equals to 61. When the production follows the MTS production strategy, finished goods are stored at the FGI and the actual demand can be met from the FGI during periods with no production. The outcome of the MTO approach for the C-products during periods with no production should be tested. The estimation of the average daily production for the low season of the C-items equals to 57.

The FGI storage capacity may be reduced by 61 (57 in the low season) items per day if they need to be stored a short period of time before they will be shipped to customers.

4.2.4 Production plan for the mold section

All three groups of mold share their production capacity at the mold production line. A daily production plan for two seasons with a capacity assessment is presented in Table 12.

It is worth clarifying that actual amounts of all three groups of items which will be produced on daily basis will be decided using the (R,S) inventory policy.

The daily production plan will allow Wonderland to asses and adjust available capacity.

Table 12. Daily production plan for the mold section

Number	Group	Number in the group	UBIT_FIRMNESS	MMITDS	Calculated lot size_HS	Calculated lot size_LS
1	A	1	5504020-00	CO/EX WE KONT BENK 90x200	59	42
2	A	2	5000020-04	INNL STANDARD WE 90x200	33	25
3	A	3	5155001	INNL BENK BASIC POC WE 75x200	26	20
4	A	4	5000001-04	INNL STANDARD WE 75x200	25	19
5	A	5	5504001-00	CO/EX WE KONT BENK 75x200	23	15
6	A	6	5003020-04	INNL EXCLUSIVE LA 90x200	22	14
7	A	7	5155020	INNL BENK BASIC POC WE 90x200	21	16
8	A	8	5000020-00	INNL STANDARD WE 90x200	16	15
9	A	9	5000001-00	INNL STANDARD WE 75x200	15	12
10	A	10	5003020-00	INNL EXCLUSIVE LA 90x200	11	7
11	B	1	5003001-04	INNL EXCLUSIVE LA 75x200	14	8
12	B	2	5506520-00	KONT BENK 900 90x200	13	11
13	B	3	5002020-04	INNL COMFORT WE 90x200	10	11
14	B	4	5003001-00	INNL EXCLUSIVE LA 75x200	8	5
15	B	5	5002001-04	INNL COMFORT WE 75x200	6	4
16	B	6	5005020-04	INNL COMF LATEX 90x200	5	5
17	B	7	5504006-00	CO/EX WE KONT BENK 80x200	5	4
18	B	8	5504021-00	CO/EX WE KONT BENK 90x210	5	3
19	B	9	5002020-00	INNL COMFORT WE 90x200	5	5
20	B	10	5005020-00	INNL COMF LATEX 90x200	4	4
21	B	11	5000006-04	INNL STANDARD WE 80x200	4	3
22	B	12	5003021-04	INNL EXCLUSIVE LA 90x210	4	3
23	B	13	5003020-08	INNL EXCLUSIVE LA 90x200	3	2
24	B	14	5000040-00	INNL STANDARD WE 120x200	3	2
25	B	15	5000040-04	INNL STANDARD WE 120x200	3	2
26	B	16	5002001-00	INNL COMFORT WE 75x200	3	3
27	B	17	5506506-00	KONT BENK 900 80x200	3	4
28	B	18	5000020-08	INNL STANDARD WE 90x200	3	2
29	B	19	5000006-00	INNL STANDARD WE 80x200	3	2
30	B	20	5003520-04	INNL EXCLUSIVE WE 90x200	3	3
31	B	21	5003006-04	INNL EXCLUSIVE LA 80x200	2	3
32	B	22	5003006-00	INNL EXCLUSIVE LA 80x200	2	2
33	B	23	5504026-00	CO/EX WE KONT BENK 105x210	2	2
34	B	24	5000021-04	INNL STANDARD WE 90x210	2	2
35	B	25	5002020-08	INNL COMFORT WE 90x200	2	1
36	B	26	5003021-00	INNL EXCLUSIVE LA 90x210	2	2
37	B	27	5003026-04	INNL EXCLUSIVE LA 105x210	2	1
38	B	28	5155006	INNL BENK BASIC POC WE 80x200	2	2
39	C	some of 273 different items			61	57
				Production	435	343
				Capacity	460	460
				Utilization, %	95	75
				Spare capacity, %	5	25
				Spare capacity in amount of molds	25	117
				Spare capacity in hours	0,42	1,95

4.3 A cover production section

First the cover data from 2016 and 2017 was structured. The data obtained from Wonderland contained about 2.000 types of items. Wonderland also buys some products additionally to their own production to be more competitive in the market. The analysis was made only for products that are being produced by Wonderland at their facilities in Åndalsnes. Purchased products were removed from the list and are not considered in the calculations.

The analysis of the cover was only made in consideration of the colours and the size. For the products with the same first seven digits before the hyphen the two first digits after the hyphen (describing the firmness) were removed. The aim was to find the actual types of covers with consideration of the colours that have to be produced. It is important to say that only a small part of the list could be summarized. This shows the large product diversification and large variations of the products with consideration of firmness, colours and size that Wonderland offers its customers. Table 13 shows an example of the analysis.

Table 13. An example of the cover analysis

UBITO	UBITO after analysis	The Name
1302001-00**44**	1302001-**44**	COMF WE RA 75x200
1302001-04**44**	1302001-**44**	
1302001-08**44**	1302001-**44**	
1458120-00**45**	1458120-**45**	TREKK H19 VB 90x200
1458155-00**71**	1458155-**71**	TREKK H19 VB 180x200

Due to the implementation of an ERP system at the end of 2017, data for December 2017 is missing and cannot be obtained. Estimation of the missing data for December 2017 is based, according to Wonderland´s decision, on the sales data from December 2016 with an increase of 5%. Wonderland selected December 2016 as basis for the missing data in December 2017 because of the similar market and production situation. Also the customer behavior in the Christmas period is comparable – as is the amount of working days before the holidays.

To get an overview of the products and to understand their significance for the production, an ABC analysis of sold items from 2017 was carried out and can be presented as follows in Table 14.

Table 14. ABC analysis of sold items in 2017

Group	Number of SKU items in the group	Annual demand for 2017	Percentage proportion of annual demand
A	10	13.793	21 %
B	74	26.850	42 %
C	1.358	23.941	37 %
Total	1.442	64.584	100%

It is important to emphasize that the A products of the cover analysis correspond to the most preferred cover colors. The A cover items can be used for A, B and C mold products.

Additionally, the number of items in each group and the range of annual sales were determined. This classification gives more information about A, B and C items. Especially, the information about the items in the B and C groups can be used later to obtain better production and inventory utilization. The classification of the A, B and C products can be seen in Table 15-17.

Table 15. A- Products with the sales range per year

Product	Range for sales items per year	Number of items in the range	Total
A	3021-833	10	13.793

Table 16. B- Products with the sales range per year

Product	Range for sales items per year	Number of items in the range	Total
B	868-189	74	26.850

Table 17. C- Products with the sales range per year

Product	Range for sales items per year	Number of items in the range	Total
C	187-101	41	5496
	99-51	86	6151
	50-20	211	6751
	19-10	200	2746
	9-2	641	2618
	1	179	179
Total		1.358	23.941

Furthermore Winters´s method for seasonal problems was used to obtain a forecast of sales data for 2018. It is important to mention that at least two full seasonal sets of data are needed for initializing method.

The results of Winters´s method for the monthly forecast for 2018 is presented in the Table 18.

Table 18. The results of the Winters´s method

J	F	M	A	M	J	J	A	S	O	N	D	Total
8554	6519	4930	4072	3793	4793	3253	6913	6662	5397	5427	5044	65.357

The forecast data was also analysed to understand the structure of the forecast and the importance of the groups. The results can be seen in Table 19.

Table 19. The ABC structure of the forecast for 2018

Group	Number of items in the group	Annual demand based on forecast for 2017	Percentage proportion of annual demand
A	10	13.744	21 %
B	77	27.090	41 %
C	1.355	24.523	38 %
Total	1.442	65.357	100%

The ABC analysis is based on information from Wonderland and was made after several consultations with Wonderland. Further calculation and analysis may come to different conclusions or recommendations. The graphical interpretation of the ABC analysis is represented in Figure 31.

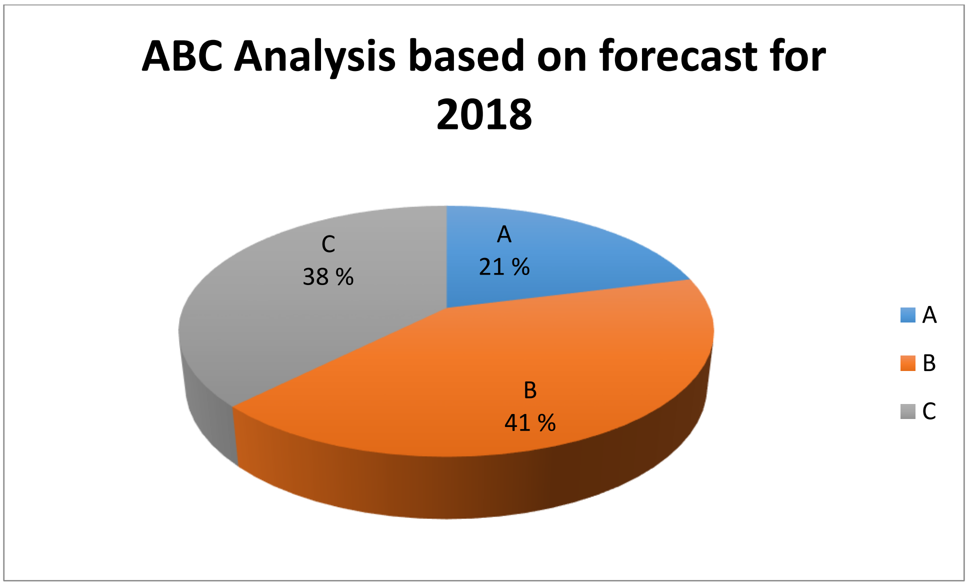


Figure 31. The graphical interpretation of the ABC analysis for 2018

The implementation of Winters´ method resulted in negative prognoses for 65 products for one or several months in 2018. After consultation with Wonderland, the negative value of the forecast can be attributed to a negative trend in 2016 and 2017. According to Wonderland, the negative trend for 65 products is only temporary and will change in 2018.

For our further calculation the average value for 2017 was multiplied by normed seasonal factors, based on Wonderland´s wish to ignore the negative trend for 65 products.

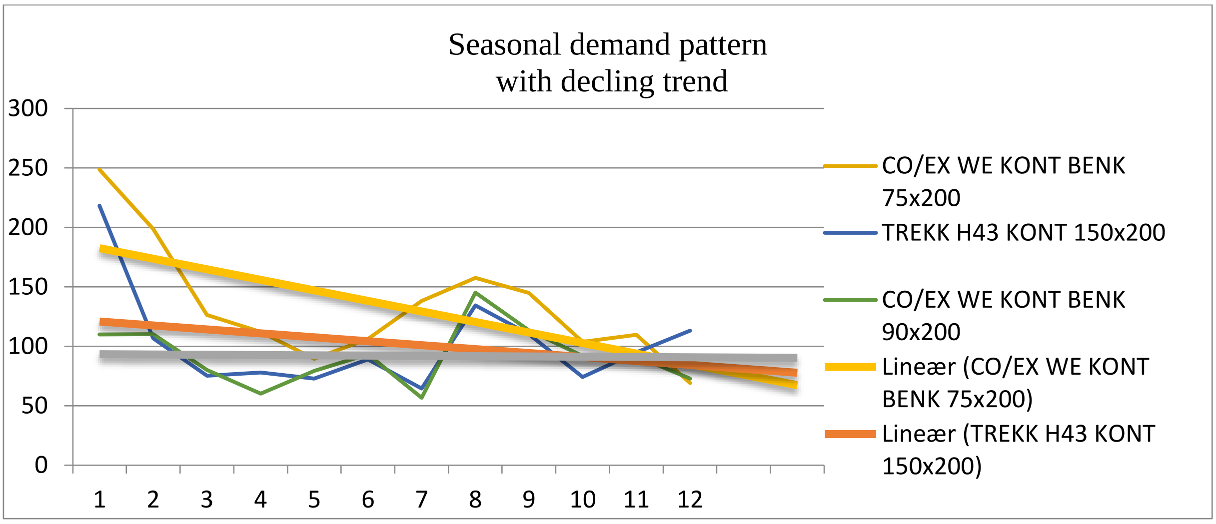


Figure 32. Example of the seasonal demand pattern with declining trend.

Wonderland decided that A, B and C products should be produced matching the production strategy of the mold. A products should go directly to the assembly station and then to the warehouse. The B cover products should, as the B mold products, have a safety stock. C products should be produced according to the ATO strategy. The cover production and the size of the buffer should match requirements of the mold production. Wonderland already adjusted this to the new situation and decided that 150 active carts should be used for storage of covers in the production line and 55 inactive carts should be used as a buffer for B products.

4.3.1 Available capacity in the cover production

After consultation with Wonderland the calculation was made only for the runstitching station and the buffer. The capacity of the cutting machines preceding the runstitching section was not analysed further since it is sufficient to meet the necessary demand. The runstitching section can be described as a bottleneck in the production line and the best possible utilization of the resources in this section can ensure smooth production and decrease costs and disruptions in the whole production process.

Our first step was the calculation of the maximum capacity.

9 employees are currently working at the runstitching station. There are 224 working days in 2018 at 7.75 working hours per day. 7.75 working hours are the effective work time per day per one employee (legal break is excluded). The time needed for one employee to complete one cover is 15 min.

Production time/nominal production rate for one cover is 15 min.
1 employee: 7.75 * 4 = 31 covers per day per one employee
9 employees: 9 * 31 = 279 covers per day
224 * 279 = 62,496 covers per year

Total production time per day:
1 employee = 7.75 Hours= 465 min
9 employees: 9 * 465 = 4185 min = 69.75 Hours
4185 * 224 = 937,440 min per year = 15,624 Hours
15 min = 0.25 hours per one cover
Production rate 1 cover / 15 min = 0.06666

After several consultations with Wonderland, no setup cost for the cover production line was included in the further calculations. The size of setup costs is of secondary importance and does not have a large share in the total cost structure. From a practical standpoint, to avoid stresses in production (also with respect to workforce), the items will still be produced based on a predefined lot size. The lot size can also be used to achieve better handling of raw materials (fabric rolls) in the production process.

The calculation of the maximal available capacity for the cover production line looks is presented in Table 20 below.

Table 20. The maximal available capacity in the cover production line

2018	Working days per month in 2018	Max capacity per month in 2018 in runstiching section, units per month	Per day	Carts needed per day by max capacity: 279/4
January	22	6138	279	70
February	20	5580	279	70
March	17	4743	279	70
April	19	5301	279	70
Mai	17	4743	279	70
June	21	5859	279	70
July	6	1674	279	70
August	23	6417	279	70
September	20	5580	279	70
October	23	6417	279	70
November	22	6138	279	70
December	14	3906	279	70
Total working days in 2018 / max capacity 2018	**224**	**62496**		

In the production area, carts are used to transport and to store the covers. Wonderland already made the decision to use 150 active carts with a capacity of 4 covers each in the cover production, which results in space for 150*4=600 covers. Figure 33 shows the parts of the production area by Wonderland.

Figure 33. The production area by Wonderland.

The number of carts needed for the forecast can be seen in Table 21.

Table 21. The number of carts needed in the cover production based on forecast for 2018

2018	Working days per month in 2018	Forecast of demand for 2018	Production per day	Carts needed per day based on forecast for 2018
January	22	8554	389	98
February	20	6519	326	82
March	17	4930	290	73
April	19	4072	215	54
Mai	17	3793	224	56
June	21	4793	229	58
July	6	3253	543	136
August	23	6913	301	76
September	20	6662	334	84
October	23	5397	235	59
November	22	5427	247	62
December	14	5044	361	91
Total working days in 2018 / max capacity 2018	**224**	**65357**		

The comparison between the maximum capacity in 2018 and the forecast for 2018 are shown in Table 22 below. The analysis of the forecast demand and the available capacity shows that Wonderland does not have enough capacity to satisfy the demand within the normally available capacity. Wonderland solved the capacity problem with overtime in the last 2 years. Wonderland used the MTS strategy in the last 2 years, but this strategy could not prevent overtime. The high demand period required additional production capacity in the form of overtime of the production for the C products. Wonderland has limited access to seasonal workers to increase the production capacity. The runstitching section needs workers with certain skills and the access to this group is limited by the facility location.

Table 22. The comparison between the maximum capacity and forecast in 2018

2018	Forecast of demand for 2018	Max capacity per month in 2018 in runstitching section, units per month	Difference between forecast and max capacity	Carts needed per day based on forecast for 2018	Carts needed by max capacity
January	**8554**	**6138**	**-2416**	98	70
February	**6519**	**5580**	**-939**	82	70
March	**4930**	**4743**	**-187**	73	70
April	4072	5301	1229	54	70
Mai	3793	4743	950	56	70
June	4793	5859	1066	58	70
July	**3253**	**1674**	**-1579**	136	70
August	**6913**	**6417**	**-496**	76	70
September	**6662**	**5580**	**-1082**	84	70
October	5397	6417	1020	59	70
November	5427	6138	711	62	70
December	**5044**	**3906**	**-1138**	91	70
Max capacity 2018	**65357**	**62496**			

The analysis of the data shows that the forecasts for the months of January, February, March, July, August, September and December exceed the maximum capacity. The production problem can be solved by overtime. The allowed overtime is 9 workers with a maximum of 4 hours per day, which delivers 36 hours per day. One employee works 7.75 hours per day, 4 hours overtime mean ≈ 52% more production time per day per employee. The following example in table 23 show the overtime solution for 2018.

Table 23. An example for the overtime solution for 2018

2018	**Difference between forecast and max capacity**	**Number of items to produced per day Difference / working day in month**	**Total overtime needed in hours per day**	**Total overtime allowed 9 workers * 4 hours**
January	**-2416**	**110**	**27.25**	**36**
February	**-939**	**47**	**11.75**	**36**
March	**-187**	**11**	**2.75**	**36**
April	1229	0	0	36
Mai	950	0	0	36
June	1066	0	0	36
July	**-1576**	**263**	**65.75**	**36**
August	**-496**	**22**	**5.5**	**36**
September	**-1082**	**54**	**13.5**	**36**
October	1020	0	0	36

November	711	0	0	36
December	**-1138**	**81**	**20.25**	**36**

The resources control table 24 shows the state of capacity and the overtime needed in the production to satisfy the demand.

Table 24. The resources control table

	J	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Regular capacity	6138	5580	4743	5301	4743	5859	1674	6417	5580	6417	6138	3906
Used capacity	8554	6519	4930	4072	3793	4793	3253	6913	6662	5397	5427	5044
% Used capacity	**139.36**	**116.82**	**103.94**	76.81	79.97	81.80	**194.32**	**107.72**	**119.39**	84,1	88.41	**129.13**
Overtime allowed	52%	52%	52%	52%	52%	52%	52%	52%	52%	52%	52%	52%

4.3.2 Lot size

As mentioned before, there are no setup costs in the runstitching section. But at the same time, the runstitching section is the bottleneck in the cover production. Its capacity constitutes the production rate for covers. Possible disruptions in the runstitching section can have a huge impact on Wonderland. The lot sizes for each product will be considered from one day to the next day. This approach gives Wonderland the opportunity to react to the actual demand and the lot sizes of the particular products can be defined based on demand for the next days. The advantage of this production policy is a short lead time, which causes less inventory/safety stock, flexibility in the use of resources and better reaction to changes in the demand. Additionally the need for overtime can also be determined.

The delivery time for A (4 days), B (6 days) and for C (8 days) products can also be an advantage. The available capacity can first be used to produce A and B items.
The cutting section will only deliver what can be processed in the runstitching section. The throughput of the runstitching section is decisive in the cover production line.

It may occur that additionally to the normal daily production, rush orders and the replenishment for the Safety Stock (S) have to be added. In this case, the lot size of all items cannot exceed the available capacity even with the consideration of overtime. As mentioned above, A and B products should be prioritized, as well as rush orders. The C products should be produce when the capacity is sufficient.

Wonderland already decided to have 150 active carts in the cover production line and 55 inactive carts in the buffer only for B products (safety stock for B products). 55 inactive carts in the cover buffer build the safety stock for B products and also give the upper bound for the buffer capacity. Figure 34 shows the cover buffer by Wonderland.

Figure 34. The cover buffer in the cover production area

Due to seasonal demand patterns caused by two sales campaigns per year, two separately calculations of the lot size and safety stock have been performed: one for months with high demand (January, February, August and September) and one for months with low demand (the remaining months). In the year 2018, there are 85 working days in the high demand period and 139 days in the low demand period. The distinction between the working days in high and low period was adapted to Wonderland's working days (224 working days in 2018).

Based on this, the lot size for A, B and C products was calculated.

It is important to emphasize that the Q_j values must be considered as an average lot-size factor and have to be adjusted according to the actual daily demand.

$Q_j = \frac{D_{ij}}{t_i}$, where:

Q_j - Lot size for product j

D_{ij} - Average demand rate for product j in the period i

i - Period 1 high demand, period 2 low demand

t_i - Average working days t period i, i = high, low

There are 224 working days in 2018: 85 working days in the high demand period (4 months) and 139 working days in the low demand period (8 months).

This gives us the following results, which are presented in table 25 for the A covers in the high demand period:

Table 25. Average lot-size for A products in the high demand period

UBITO		D_{ij} - Average demand in high demand season based on forecast	Average Lot size $Q_j = \frac{D_{ij}}{t_i}$
5504020-45	CO/EX WE KONT BENK 90x200	301	14
5504020-42	CO/EX WE KONT BENK 90x200	338	16
1458120-45	TREKK H19 VB 90x200	204	10
5504001-45	CO/EX WE KONT BENK 75x200	188	9
4808346-45	TREKK H43 KONT 150x200	142	7
5504020-74	CO/EX WE KONT BENK 90x200	120	6
4808342-45	TREKK H43 KONT 140x200	93	4
5506520-61	KONT BENK 900 90x200	87	4
5504020-71	CO/EX WE KONT BENK 90x200	96	5
5504020-61	CO/EX WE KONT BENK 90x200	159	7
Total			**82**

Daily capacity is 279 covers per day. 82 covers of A products constitute ≈ 29.39 % of the daily capacity. 21 carts are needed to store the A products (82/4=20.5 ≈ 21 carts).

Lot size in a low demand period can be seen in Table 26 below.

Table 26. Average lot-size for A products in the low demand period

UBITO		D_{ij} - Average demand in low demand season based on forecast	Lot size $Q_j = \frac{D_{ij}}{t_i}$
5504020-45	CO/EX WE KONT BENK 90x200	153	9
5504020-42	CO/EX WE KONT BENK 90x200	61	4
1458120-45	TREKK H19 VB 90x200	123	7
5504001-45	CO/EX WE KONT BENK 75x200	107	6
4808346-45	TREKK H43 KONT 150x200	83	5
5504020-74	CO/EX WE KONT BENK 90x200	78	4
4808342-45	TREKK H43 KONT 140x200	81	5
5506520-61	KONT BENK 900 90x200	71	4
5504020-71	CO/EX WE KONT BENK 90x200	65	4
5504020-61	CO/EX WE KONT BENK 90x200	32	2
Total			**50**

Daily capacity is 279 covers per day. 50 covers of A products constitutes ≈ 17.92% of the daily capacity. 13 carts are needed to store the A products (50/4=12.5 ≈ 13 carts).

This gives us the following results for the B covers in the high demand period. It contains 77 products. Table 27 shows the range of the average lot size in the high demand period.

Table 27. Average lot-size for B products in the high demand period

Average Lot size per day =7 items	**Average Lot size per day =5 items**	**Average Lot size per day = 4items**	**Average Lot size per day =3 items**	**Average Lot size per day =2 items**	**Average Lot size per day =1 items**	**Average Lot size per day =0 items**	**Total**
1	4	4	7	20	37	4	77
7	20	16	21	40	37	0	141

Daily capacity is 279 covers per day. 141 covers of B products are ≈ 50.53% of the daily capacity. 36 carts are needed to store the B products (141/4=35.75 ≈ 36 carts).

The analysis of the average lot size per day in the high demand period shows that 4 items will not be produced due to low average demand in the high demand period. Those items were removed from the B group and moved to the C group for both periods: with high demand and with low demand. This solution gives more flexibility in the production in high demand periods and decreases the safety stock costs. The C products will be produced according to the MTO strategy. The change within the B group with the new number of 73 items will not cause changes in the daily capacity used for B products and can be illustrated as follows in Table 28.

Table 28. New number of products in B group

Average Lot size per day =7 items	**Average Lot size per day =5 items**	**Average Lot size per day = 4items**	**Average Lot size per day =3 items**	**Average Lot size per day =2 items**	**Average Lot size per day =1 items**	**Total**
1	4	4	7	20	37	73
7	20	16	21	40	37	141

Daily capacity is 279 covers per day. 141 covers of B products are ≈ 50.53% of the daily capacity. 36 carts are needed to store the B products (141/4=35.75 ≈ 36 carts).

This gives the following results for the B covers in the low demand period: It now contains 73 products. Table 29 shows the range of the average lot size in the low demand period.

Table 29. Average lot-size for B products in the low demand period

Average Lot size per day =4 items	**Average Lot size per day =3 items**	**Average Lot size per day = 2items**	**Average Lot size per day =1 items**	**Total**
1	7	17	48	73
4	21	34	48	107

Daily capacity is 279 covers per day. 107 covers of B products constitute ≈ 38.35% of the daily capacity. 27 carts are needed to store the B products (107/4=26.75 ≈ 27 carts).
Based on the calculation of A and B products the following conclusion for C products in the high demand period can be made. Table 30 shows the share of A,B and C in the daily production in the high demand period.

Table 30. ABC Products and the share of daily production in the high demand period

	Production per day	% Production per day	Carts per day
A	82	≈ 29.32%	21
B	141	≈ 50.53%	36
C	**56**	**≈ 20.07%**	**14**
Total	279	≈ 100%	71

According to the calculation above the number of carts needed for the maximum capacity per day is 70. The result gives 71 carts. This difference can be explained by rounding errors.
The conclusion for C products in the low demand period based on respectively calculations for A and B products can be presented thusly:

Table 31. ABC Products and the share of daily production in the low demand period

	Production per day	% Production per day	Carts per day
A	50	≈ 17.92%	13
B	107	≈ 38.35%	27
C	**122**	**≈ 43.72%**	**31**
Total	279	≈ 100%	71

Table 31 shows the share of A, B and C in the daily production in the low demand period.

4.3.3 Safety stock and service level

As mentioned above Wonderland plans to have a B buffer of 55 carts. It has to be examined if the buffer has enough space to contain the Safety Stock for all 73 items of B products. The service level has to be calculated in consideration of the capacity and the number of items that should be moved to the daily production.

The assumption was made that the demand during lead time follows normal curve distribution. The P1 service level was chosen for Wonderland. P1 states the probability of not stocking out in the lead time. The P1 service level is used in situations with similar consequences of stock outs (Nahmias, 2009)

In case of stock outs, Wonderland has to face similar consequences for cover as for mold production. The products have to be produced as rush orders within available capacity. The use of overtime cannot be excluded. The overtime depends to some extent on the number of products that have to be produced to cover the actual demand. The time needed for one employee to complete one cover is 15 min.

However, it can be assumed that when the overtime is decided, it will be longer than 15 min with one employees. According to this decision, a calculated lot size can be produced with the aim to cover not only the particular stock out but also cover future needs.

The corresponding k values, the safety stock levels and order-up levels were determined. Further, based on the daily production policy several calculations were made to find the standard deviation during the lead time equal to one day.

δ_l - standard deviation of demand during the lead time
δ_w - standard deviation of demand for a week
LT - lead time in days (equal to 5 days/one production week)

$\delta_l = \delta_w * \sqrt{LT}$ (Chapman, 2006)

Based on the daily production policy the lead time periods with high and low demand can be calculated as follows:

The following calculation resulted in the value of safety stock:

SS= $k * \delta_l$, where

k - statistical k from the normal distribution- value corresponding to the chosen service level

δ_l - standard deviation of demand during the lead time (Chapman, 2006)

The order up-to level-principle is a part of a periodic review policy.

The safety stock will be replenished with the interval of one day. The inventory level will be known for example only at the end of the working day. Q_j has to be presumed as an average value. In practice, the actual stochastic demand will determine the value of Q_j.

The order up-to level values can be calculated thusly:

$S_j = SS_j + Q_j$

The B buffer contains 55 carts, which gives us 55*4=220 covers in the buffer. The safety stock and the service level for covers have to be coordinate with the safety stock and the service level for molds. Since the A and B mold items have a 99 % service level, the cover service level has to be adjusted to the mold service level.

The safety stock calculation gives the following results for periods with high demand and can be seen in Table 32.

Table 32. Safety Stock in the high demand period

	Safety Stock for all items in B group	Max capacity of the buffer
99% service level	**386**	220
98% service level	**344**	220
97% service level	**315**	220
96% service level	**288**	220
95% service level	**277**	220
94% service level	**257**	220
93% service level	**247**	220
92% service level	**233**	220
91% service level	**225**	220
90% service level	213	220

The result of the calculations shows that all 73 items in the period with high demand can be included in the Safety Stock with a 90% service level. To be able to match the service level in the mold production the 99 % service level has to be achieved. The cover service level and the mold service level have to match each other. The cover in the B group can be used for the mold in A or B group. The mismatch will cause delays in the delivery or other forms of stresses in the cover production (rush orders).

The solution can be to increase the number of charts to 97 (386/4 cover per carts) or decrease the number of products in the B group.

The B group contains 37 items with an average lot size per day equal to 1. All 37 items with the demand in the high period within the range from 53 to 125 and with an average lot size equal to 1 were removed from the group to test the impact on the safety stock and the service level.

Average lot size for 36 items in the B group in the high demand period. Table 33 shows the range of the average lot size in the high demand period.

Table 33. Average lot size in the high demand period for 36 items in B group

Average Lot size per day =7 items	**Average Lot size per day =5 items**	**Average Lot size per day = 4items**	**Average Lot size per day =3 items**	**Average Lot size per day =2 items**	**Total/**
1	4	4	7	20	36
7	20	16	21	40	104

Daily capacity is 279 covers per day. 104 covers of B products gives us ≈ 37.27% of the daily capacity. 26 carts are needed to store the B products (104/4=26 carts).

The safety stock for 36 items of the B group during the high demand period can be seen in Table 34.

Table 34. Safety Stock in the high demand period for 36 items

	Safety Stock for all items in B group	Max capacity of the buffer
99% service level	**204**	**220**
98% service level	186	220
97% service level	171	220
96% service level	155	220
95% service level	146	220
94% service level	140	220
93% service level	133	220
92% service level	124	220
91% service level	120	220
90% service level	115	220

The result of the calculations shows that all 36 items in the period with high demand can be included in the Safety Stock with a 99% service level and lower.

Based on the calculation of A and B products the following conclusion for C products in the high demand period can be made. Table 35 shows the share of A,B and C in the daily production in the high demand.

Table 35. ABC Products and the share of daily production in the high demand period

	Production per day	% Production per day	Carts per day
A	82	≈ 29.32%	21
B	104	≈ 37.27%	26
C	**93**	**≈ 33.33%**	**24**
Total	279	≈ 100%	71

Average lot size for 36 items in the B group in the low demand period was also determined:

Table 36. Average lot isze for 36 items in B group in the low demand period

Average Lot size per day =4 items	**Average Lot size per day =3 items**	**Average Lot size per day = 2items**	**Average Lot size per day =1 items**	**Total**
1	7	16	12	36
4	21	32	12	69

Daily capacity is 279 covers per day. 69 covers of B products constitute ≈ 24.73% of the daily capacity. 18 carts are needed to store the B products (69/4≈18).

The safety stock for 36 items of the B group during the low demand period is presented in Table 37.

Table 37. Safety Stock in the low demand period for 36 items

	Safety Stock for all items in B group	Max capacity of the buffer
99% service level	**159**	**220**
98% service level	137	220
97% service level	125	220
96% service level	118	220
95% service level	113	220
94% service level	105	220
93% service level	101	220
92% service level	93	220
91% service level	90	220
90% service level	86	220

The result of the calculations shows that all 36 items in the period with high demand can be included in the Safety Stock with a 99% service level and lower.

The conclusion for C products in the low demand period based on respectively calculations for A and B products is presented in Table 38:

Table 38. ABC Products and the share of daily production in the low demand period

	Production per day	% Production per day	Carts per day
A	50	≈ 17.92%	13
B	69	≈ 24.73%	18
C	**160**	**≈ 57.34%**	**40**
Total	279	≈ 100%	71

The up-to-level values for 36 items in the high and low demand period with the service level of 99% are presented in Table 39.

Table 39. The up-to-level values in the high and low demand period

Cover	High demand period			Low demand period		
	Average Lot size	Safety Stock	S=SS+Q	Average Lot size	Safety Stock	S=SS+Q
CO/EX WE KONT BENK 90x200	7	5	12	2	5	7
CO/EX WE KONT BENK 90x200	5	12	17	3	10	13
CO/EX WE KONT BENK 75x200	5	10	15	3	4	7
TREKK H19 VB 180x200	4	8	12	3	7	10
TREKK H21 VB 180x200	4	6	10	4	5	9
COVER 332 90x200 SHADOW 45	5	8	13	3	6	9
TREKK H20 VB 180x200	3	6	9	3	3	6
TREKK H21 VB 180x200	5	9	14	2	3	5
TREKK H21 VB 180x200	4	14	18	2	6	8
TREKK H43 KONT 180x200	4	13	17	3	7	10
TREKK H19 VB 75x200	3	5	8	3	3	6
TREKK H19 VB 80x200	3	3	6	2	5	7
TREKK H19 VB 150x200	3	4	7	2	4	6
TREKK H43 KONT 150x200	3	1	4	2	7	9
TREKK KONT ST 180x200	2	8	10	2	6	8
TREKK H21 VB 180x200	3	2	5	2	3	5
TREKK H21 VB 90x200	2	2	4	2	4	6
TREKK H19 VB 75x200	3	6	9	2	6	8
TREKK KONT ST 180x200	2	8	10	2	6	8
TREKK H43 KONT 150x200	2	7	9	2	4	6
TREKK H19 VB 90x200	2	4	6	2	3	5
TREKK H21 VB 180x200	2	2	4	2	2	4
TREKK H21 VB 150x200	2	3	5	1	2	3

TREKK H21 VB 180x200	2	5	7	1	3	4
TREKK H27 RA 90x200	2	7	9	2	6	8
TREKK H19 VB 90x200	2	8	10	1	9	10
TREKK H19 VB 120x200	2	2	4	2	2	4
TREKK H19 VB SPESIAL 70-90	2	1	3	1	2	3
CO/EX WE KONT BENK 90x200	2	5	7	1	3	4
COVER 332 80x200 SHADOW 45	2	3	5	1	3	4
CO/EX WE KONT BENK 90x200	2	4	6	1	4	5
TREKK H43 KONT 180x200	2	7	9	1	3	4
KONT BENK 900 90x200	2	6	8	1	4	5
CO/EX WE KONT BENK 90x200	2	2	4	1	3	4
TREKK H27 RA 120x200	2	5	7	1	4	5
CO/EX WE KONT BENK 75x200	2	3	5	1	2	3

5.0 CONCLUSION AND RECOMMENDATIONS

This chapter gives a summary of our empirical investigation, answers the research question and gives practical recommendations to Wonderland.

5.1 Conclusion of the thesis

Wonderland, an important Norwegian manufacturer of sleeping beds, faced challenges due to capital tied up in its finished goods inventories. The make-to-stock production strategy needed to be replaced. The main focus of this master thesis was to find a solution to adjust production planning and inventory control to a new production strategy with respect to the demand variations and capacity limitations.

The research was a part of a larger internal project with the goal of completing the transformation by the year 2020. The thesis is based on the sales data for two types of components: molds and covers. A customized production planning and inventory control approach with capacity assessment was presented. Due to the demand seasonality, the Winters method was chosen for forecasting of the demand level in 2018.

The importance of the ABC-analysis cannot be overstated. It forms the basis for the differentiation of the production strategies for the A-, B- and C-components. The ABC-grouping deviates from the classical approach and maintains Wonderland's specific requirements. Along with the project progression, a new ABC-grouping was considered for both components. As the result of analysis an optimal service level equal to 99% should be applied for the mold in order to minimize total relevant costs and protect against variations in the demand. The customer service level should be coordinated with the cover components. A periodic review inventory policy (R,S) with review intervals equal to one day has been considered for the high and for the low seasons with specific value for the calculated lot size and the S-level. The capacity assessment shows that some capacity adjustment is required.

In the mold section the machine capacity and the storage capacity for both finished goods and the subassembly buffer is sufficient to meet a new differentiated production strategy consisting of three different strategies depending on the ABC-classification. Manpower capacity can be adjusted for two seasons: increasing of regular working time in the high season and decreasing of regular working time in the low season.

In the cover section, the limited storage capacity determines the service level and the number of items in the B group. The cover production rate per month depends, amongst other things, on the number of working days per month. The workforce capacity has to be adjusted not only for periods with high and low demand, but also for months with less working days due to holidays or Christmas.

For both the mold- and cover production sections the same forecasting method - Winters's seasonal problems, was applied. Its result was a declining trend. The issue was discussed with Wonderland and they state that the negative trend was temporary and will change in 2019. ABC-classification was performed using the same grouping basis for both sections since both cover and mold A-, B- and C-items will follow differentiated production strategy. Common P1 service level equal to 99% was chosen for the cover- and the mold items. A production planning approach based on the cycle time equal to one day was developed for both production sections giving the base for the inventory management policy, e.g. a periodic review policy (R,S) with the review interval equal to one day. The analysis of the calculated safety stock levels for the B-components in both production sections - based on the 99% service level - defined the capacity requirements for the subassembly buffers.

5.2 Recommendations

The authors recommend using statistical tools to make better forecasts for the component demand. This forecast can still contain unexplainable errors and randomness, but it will provide explicit measures for managing seasonal factors contributing to a better resource management.

Wonderland should consider implementation of the MPS in order to incorporate customers' orders into daily production plan based on the forecast. This will contribute to efficient inventory control and capacity planning.

5.2.1 Component: mold

A new ABC-grouping with reduction of the B-group and increasing of the C-group is presented in Table 40 below.

Table 40. A new ABC-grouping for the mold.

Group	Number of SKU items in the group	Yearly demand forecast for 2018, items	Proportion of the total demand volume, %
A	10	47 185	55,50
B	28	24 623	29,00
C	273	13 156	15,50
Total	**311**	**84 964**	**100**

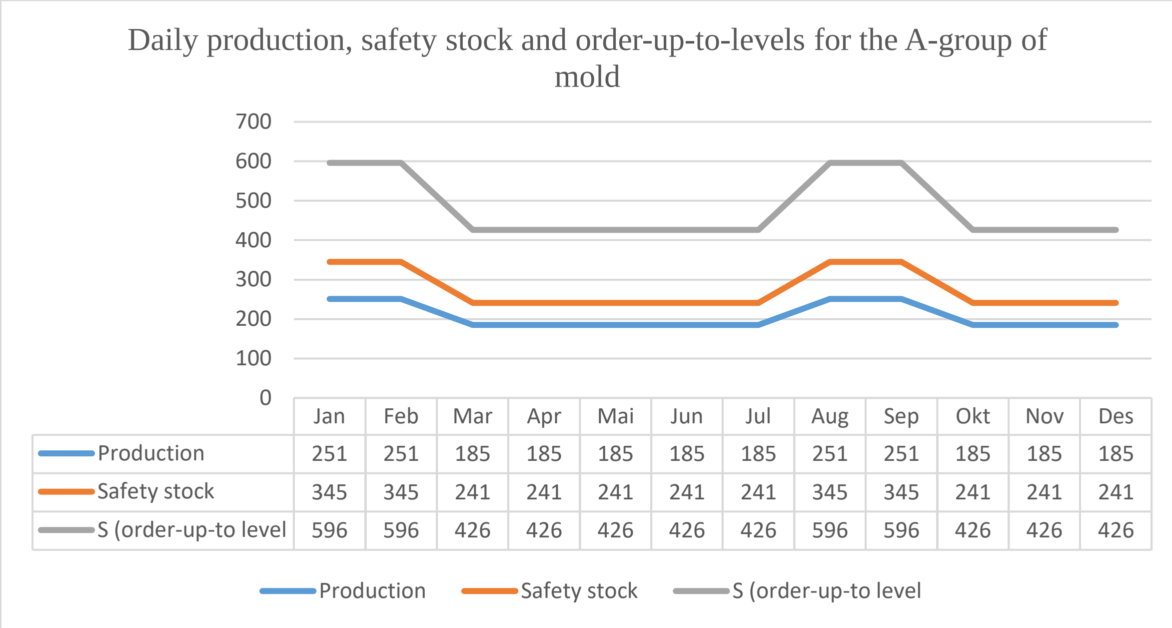
The A-components will follow the MTS production strategy with a 4 days delivery time. The B-components will follow the ATO production strategy with a 6 days delivery time. The B-components will follow the MTO production strategy with a 8 days delivery time.

Production planning and inventory control should be differentiated into two seasons. The high season includes January, February, August and September. The low season includes March, April, May, June, July, October, November and December.

According to the results of the ETRC approach application, a given service level equal to 99%, which is lower than optimal, should be adopted. Safety stock levels should be calculated based on a corresponding safety factor k equal to 2.33.

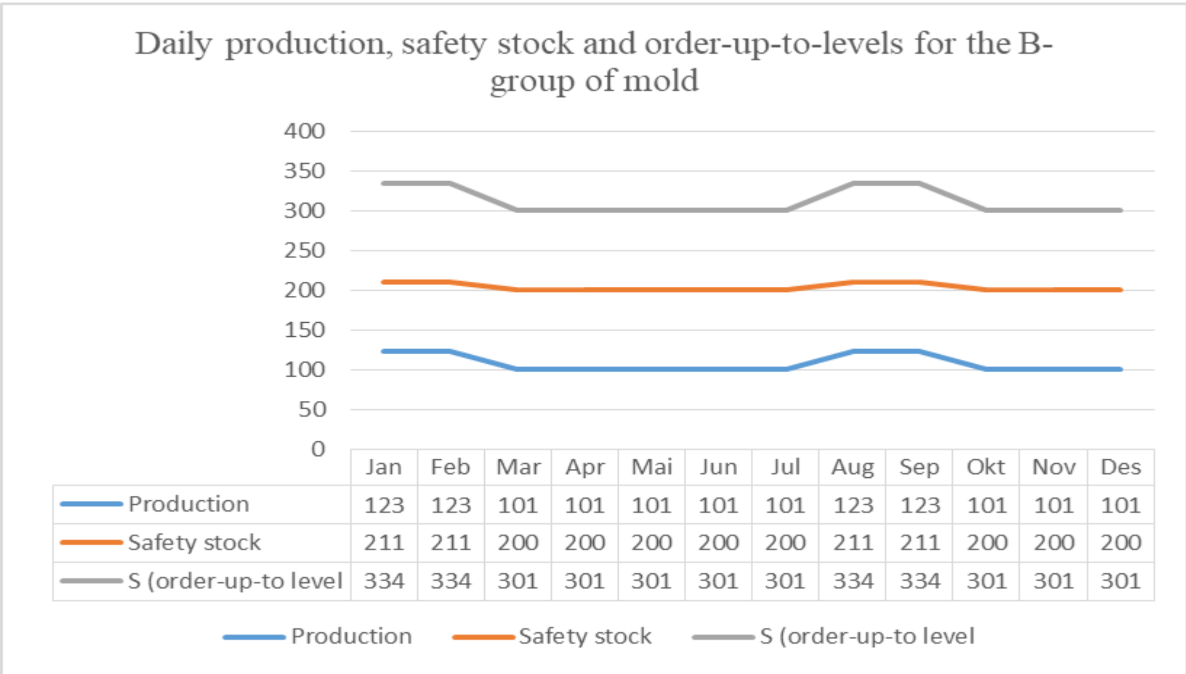
A periodic review (R,S) policy with safety stock levels and S-parameter with an review interval equal to one day based on the forecast for 2018 was developed.

Production plans for the A and B groups are presented in Figure 35 and Figure 36.



	Jan	Feb	Mar	Apr	Mai	Jun	Jul	Aug	Sep	Okt	Nov	Des
Production	251	251	185	185	185	185	185	251	251	185	185	185
Safety stock	345	345	241	241	241	241	241	345	345	241	241	241
S (order-up-to level	596	596	426	426	426	426	426	596	596	426	426	426

Figure 35. Daily production, safety stock and S-level for the A-group of mold.



	Jan	Feb	Mar	Apr	Mai	Jun	Jul	Aug	Sep	Okt	Nov	Des
Production	123	123	101	101	101	101	101	123	123	101	101	101
Safety stock	211	211	200	200	200	200	200	211	211	200	200	200
S (order-up-to level	334	334	301	301	301	301	301	334	334	301	301	301

Figure 36. Daily production, safety stock and S-level for the B-group of mold.

Specific daily production quantities will be decided out of the inventory position in order to rise it to the S-level.

Longer delivery times for C-items during periods with high production load in order to smooth capacity utilization should be considered.

Our analysis of the machine capacity utilization shows that the nominal production rate is equal to 0.0139 hour per mold while actual production rate is equal to 0.0167 hour per mold giving a capacity utilization rate equal to 83%. The mold production line is operated by 4 persons currently. We recommend to measure the duration of the operations involved in the production process in order to find improvement opportunities as to increase capacity utilization as well as reduce relevant costs.

The amount of mattresses which can be placed in the FGI per one day during the high season can be estimated to 780 (production of the A, B and C items + safety stock A items) The authors will present results to Wonderland for evaluation of the trade-offs between investments into the storage space capacity and the possible advantages it could bring.

Spare capacity of the subassembly buffer for the B-products is equal to 1.7 and 2.5 days accordingly for the low and the high seasons. It seems reasonable to retain spare capacity due to the delays for the assembly of the B-items which can be caused by "rush-order" disruptions.

Analysis of the manpower capacity utilization for the mold production line shows that the expected spare capacity is equal to 0.42 hour or 25 minutes during the high season and almost 2 hours during the low season. Introduction of flexible working time may result in better manpower capacity utilization. For example, an extension of regular working time by one hour from 7.75 to 8.75 hours during the high season and a reduction of regular working time by one hour from 7.75 to 6.75 hours during the low season could be tested. This arrangement may increase the manpower capacity buffer during the high season and reduce idle time during the low season.

Wonderland should remember that in the early phase, the building of the safety stock will result in a higher production load. It will settle down after the achievement of the required safety stock level. It is therefore recommended to implement a step-by-step establishment of the safety stock.

The authors recommend an implementation of the EDD and the SPT dispatching rules in order to reduce lead times. The EDD rule should have a priority when Wonderland will sequence orders, while SPT rule should decide which order should be fulfilled first for orders with identical due date.

Changes should be introduced gradually and both old and new systems should be operated in parallel (Axsäter, 2000). The authors suggest that Wonderland monitors the transformational progression carefully and makes adjustments based on the current situation.

5.2.2 Component: cover

Table 41 shows a new ABC structure with reduction of the B- group and increasing in the C-group

Table 41. The new ABC structure

Group	Number of items in the group	Annual demand based on forecast for 2017	Percentage proportion of annual demand
A	10	13 744	21%
B	36	18 396	28%
C	1 396	33 217	51%
Total	1 442	65 357	100%

It is recommended that Wonderland should differentiate its production planning between high (January, February, August and September) and low (March, April, May, June, July, October, November and December) demand periods.

The items should be produced according to a planned average lot size to achieve smooth production processes. The actual lot size Q_j should be determined from day to day based on actual demand. The inventory position should also be determined on a daily basis and the S (order up to level) values should be considered in the production planning.
Workforce utilization and safety stock capacity utilization will be different in high and low

demand periods. The service level should be coordinated with the 99% service level for mold. Further, the reduction in the B group to 36 items is recommended. The production and inventory policy should be aligned according to the ABC structure. The A products have to be prioritized in the production (MTS production strategy, 4 days delivery time).
The EDD rules can also be used to reduce the lead time for A products when the A products have to produced as rush order. B products should be produced to a defined safety stock level (ATO production strategy, 6 days delivery time). C products should be produced according to the MTO strategy (8 days delivery time). Production plan for B group is presented in Figure 37 below. In case of C group, longer delivery time in high demand period should be considered in order to smooth production capacity.

	Jan	Feb	Mar	Apr	Mai	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Production	104	104	69	69	69	69	69	104	104	69	69	69
Safety Stock	204	204	159	159	159	159	159	204	204	159	159	159
S(order-up-to-level)	308	308	228	228	228	228	228	308	308	228	228	228

Figure 37. Daily production, safety stock and S-level for the B-group of cover.

To improve capacity, Wonderland could consider an increase of the workforce in the runstitching section (invest in the vocational education of new employees) or introduce flexible working times to be able to react to the stochastic demand. As in mold production the extension and shortening of the working times (from 6.75 to 8.75 working hour per day) can also be tested in the cover production.

It is recommended that Wonderland continuously enforces its own ABC analysis.
The newly implemented ERP system can be used here to deliver more accurate information. It is also important that the constantly changing sales data is continuously updated. The implementation of the new production and inventory policy by the year 2020 has to be based on the sales data for 2019.

6.0 Further research opportunity

The focus of this master thesis lies in the aligning of the components stock to new and differentiated production strategies. Future research regarding finished goods could be beneficial.

For example, an ABC-analysis can be applied to the end products in order to evaluate a need of holding a stock of raw materials for the least popular products. Considering longer delivery times to customers for these products may release the capital tied up in raw materials and lead to a better capacity utilization.

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